REFRESHER COURSE

Anaesthetic Concerns of Laparoscopic Surgery

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Introduction and background

Laparoscopic surgery is one of the key diagnostic and therapeutic tools in the current surgical era.[1] It is a principle technique for minimally invasive surgery, and has been used in procedures ranging across various surgical subspecialities.[2] Recent technological advances have enabled major progress and extension of the technique from gynaecologic surgery to major general surgical procedures. The greatest clinical advantages are probably in the area of abdominal general surgery, which is the main focus of this article.[3] Since the first laparoscopic cholecystectomy performed in the late 1980`s, the technique has developed as the treatment of choice for patients with gallstone disease. It has also been applied to various thoracic, upper and lower abdominal procedures including fundoplication, vagotomy, hemicolectomy, herniorrhaphy, nephrectomy, pelvic lymph node dissection, bariatric surgery, hysterectomy and oesophagectomy, to name a few.[4]

Surgical requirements

During laparoscopic abdominal surgery, the surgical site is accessed by trocars and cannulae inserted through puncture wounds in the anterior abdominal wall. An endovideo camera displays the surgical site, allowing viewing for the surgeon and assistants. Specially designed laparoscopic instruments such as electrocautery and laser are available to facilitate dissection and haemostasis. The creation of a pneumoperitoneum, by insufflation of gas into the peritoneal cavity, separates the abdominal wall from the viscera, improving visual and physical access. Modern high-flow insufflators can deliver gas at flows of 4 to 6 1.min $^{-1}$. These insufflators allow for precise adjustment of the insufflation pressure. An intra-abdominal pressure (IAP) of around 15 mmHg is adequate for most procedures.

The gas most commonly used for abdominal insufflation is carbon dioxide (CO_2), which does not support combustion, reduces the duration of postoperative abdominal discomfort caused by residual pneumoperitoneum, and minimises the adverse effects of gas introduced extraperitoneally due to its high blood solubility (Ostwald solubility coefficient in human whole blood at 37°C being 0.49). The disadvantages of CO_2 include peritoneal irritation and hypercarbia from systemic gas absorption. Air, oxygen and nitrous oxide have also been used, however, they support combustion which may cause an explosion with the use of diathermy or laser inside the peritoneal cavity.[4]

Conduct of anaesthesia

Anaesthetic management of patients undergoing laparoscopic surgery must accommodate surgical requirements and allow for physiological alterations during surgery. The possibility of procedures being converted to open laparotomy needs to be considered. Laparascopic surgery is most routinely performed under general anaesthesia with a cuffed endotracheal tube and positive pressure ventilation, which allows control of minute ventilation and P_aCO_2. The use of the laryngeal mask airway (LMA) in laparoscopic abdominal surgery remains controversial because of the increased risk of aspiration and problems encountered with ventilation due to higher airway pressures required during pneumoperitoneum.[6] The ProSeal^R LMA is more effective in both obese and non-obese patients, when compared to the Classic LMA, for positive pressure ventilation.[8]

Standard monitors (electrocardiogram, noninvasive blood pressure, pulse oximetry, end tidal CO_2, airway pressures, body temperature and peripheral nerve stimulation) are adequate for most procedures in healthy patients. However, for patients with compromised cardiopulmonary function, an arterial cannula is recommended for haemodynamic monitoring and blood gas sampling.

Access to the patient is often limited by positioning and machinery close to the patient. Therefore, monitoring equipment, intravenous access and injection ports must be secured beforehand.

The procedure is facilitated by proper decompression of the gastrointestinal tract (bowel preparation preoperatively, placement of an oro- or naso-gastric tube and urinary catheter intraoperatively), establishment of adequate muscle relaxation (facilitating placement of laparascopic ports, induction of the pneumoperitoneum and prevention of sudden patient movement that can lead to accidental injuries), and appropriate patient positioning so as to produce gravitational displacement of the abdominal viscera away from the surgical site.[2,4]

Local or regional techniques, as the sole form of anaesthesia, have not been advocated for laparoscopic abdominal procedures, except for short gynaecological procedures. A high block (T2-T4 level) is required to abolish the discomfort of surgical stimulation, which may cause myocardial depression, thus aggravating the effects of the pneumoperitoneum.[5] Additional disadvantages include increased work of breathing, patient positioning, and diaphragmatic irritation, which may not be alleviated by epidural anaesthesia alone in an awake patient.[7]

Recovery from anaesthesia should be rapid with minimal residual effects. It is important to remember that life threatening hypoxia and hypercapnia might still occur due to the residual effects of the pneumoperitoneum causing atelactasis and an additional CO_2 load. These complications can be prevented by lung recruitment prior to reversal of neuromuscular blockade as well as hyperventilation prior to extubation.[8]

Absolute contraindications to laparoscopic abdominal surgery include pre-existing raised intracranial pressure, severe uncorrected hypovolaemia, patients with known right-to-left cardiac shunts or patent foramen ovale, and closed angle glaucoma. Relative contraindications consist of severe ischaemic heart disease, valvular disease, significant renal dysfunction, or end-stage respiratory disease. In these cases, the risk to the individual patient must be weighed against the potential advantages of laparoscopic techniques.[6] Patients presenting for emergency laparoscopic procedures (e.g. appendicectomy, repair of perforated peptic ulcer) should be resuscitated before coming to theatre.

Laparoscopic surgery offers major benefits to the patient. These include reduced pain due to smaller surgical incisions, shorter recovery times after major surgery, earlier enteral feeding (decreased incidence of postoperative ileus), reduced wound infection, and reduced morbidity. These factors all contribute to shorter in-patient stay, and possibly same-day discharge for certain procedures, resulting in a reduction in overall medical cost. Patient groups in which the laparoscopic approach offers the most benefit include obese patients for bariatric surgery and those with significant respiratory disease (less postoperative deterioration in respiratory function).[6]

Despite these benefits, laparoscopy can result in patho-physiological alterations that can complicate the anaesthetic management.[7] A review of potential intraoperative problems is essential for the optimal anaesthetic care of patients undergoing laparoscopic surgery.

Pathophysiologic alterations during laparoscopic surgery

Cardiovascular Effects

Hemodynamic disturbances during laparascopy are primarily due to the creation of the pneumoperitoneum. Normal IAP is 0 to 5 mmHg. Increases in IAP above 10 mmHg are clinically significant, and above 15 mmHg can result in an abdominal compartment syndrome, which affects multiple organ systems.

Pneumoperitoneum causes an increase in systemic vascular resistance (SVR) while causing a decrease in cardiac output (CO). These effects are proportional to the increase in IAP.[2]

The mechanisms responsible for the increase in SVR include mechanical compression of the abdominal organs and vessels, as well as activation of neurohumoral factors (catecholamines, vasopressin, renin-angiotensin system). The decrease in CO is due to decreased venous return from compression of the inferior vena cava (IAP exceeding 20 mmHg), increased resistance in the venous circulation, and possible hypovolemia. CO typically decreases between 10 and 30%.[2]

Healthy patients appear to tolerate these hemodynamic effects well; however, patients with pre-existing cardiac disease or intravascular volume depletion may be at increased risk for further cardiac compromise. To minimize these effects, the lowest insufflation pressure required to achieve adequate surgical exposure should be used. Ideally, insufflation pressure should be less than 15 mmHg. Decreases in venous return and CO may be attenuated by appropriate intravenous fluid loading prior to the induction of pneumoperitoneum.[2]

Furthermore, dysrhythmias (particularly bradyarrhythmias or asystole) can occur during insertion of laparoscopic ports or during insufflation of the abdomen. Stretching of the peritoneum can precipitate a sudden increase in vagal tone. Administration of anticholinergic medications may be necessary. If the arrhythmia persists or results in hemodynamic compromise, prompt interruption of surgery and release of the pneumoperitoneum is indicated.[2]

Pulmonary Effects

Pneumoperitoneum causes an upward displacement of the diaphragm, resulting in reduction of lung volumes, particularly the functional residual capacity (FRC). Pulmonary compliance is reduced (by up to 50%) and airway resistance is increased, with an increased risk of barotrauma during positive pressure ventilation. Limited diaphragmatic mobility also promotes atelectasis and ventilation-perfusion mismatch (V/Q mismatch), with resultant hypercarbia and hypoxaemia.[4] Institution of positive end-expiratory pressure (PEEP) can moderate the decreases in FRC by stenting alveoli open at end expiration.[2] Displacement of the endotracheal tube tip and endobronchial intubation may occur.[4] The increase in IAP also predisposes to regurgitation of gastric contents and pulmonary aspiration.[2]

The most important factor responsible for hypercarbia during laparoscopic procedures is peritoneal absorption of CO_2. The degree of hypercarbia depends on CO_2 insufflation pressure. Hypercarbia can cause haemodynamic changes through sympathoadrenal stimulation manifesting as tachycardia, arrhythmias, low SVR, and may provoke myocardial ischaemia.[4] In routine cases it is easily managed by increasing alveolar ventilation by 10-25%. In cases where the degree of hypercarbia becomes uncontrollable with hyperventilation alone, the pneumoperitoneum should be temporarily released to allow for CO_2 elimination.[2]

Splanchnic Effects

Blood flow to the kidney and liver is significantly compromised with increasing IAP, which is an important consideration in patients with pre-existing disease. The renal effects are significant, being recognized as an independent cause of acute kidney injury. An IAP of 20 mm Hg will reduce GFR by approximately 25%. The mechanisms for this are postulated to be the combined effect of reduced renal afferent flow due to impaired cardiac output and reduced efferent flow due to raised renal venous pressure.

There is also a reduction in mesenteric and gastrointestinal mucosal blood flow by up to 40%, with progressive tissue acidosis developing, as the IAP rises.[6]

Neurological Effects

An elevated IAP causes an increase in intra-cerebral pressure (ICP) by limiting cerebral venous drainage, which may lead to cerebral oedema. This contributes to the temporary neurological dysfunction that patients often experience on emergence from prolonged laparoscopic procedures, particularly those requiring steep Trendelenburg (head-down) positioning.[6]

Patient Positioning

Patient positioning is determined by the view that the surgeon is trying to optimize, but often involves the extremes of the Trendelenburg or reverse Trendelenburg (head-up) position. Prolonged steep Trendelenburg position increases the risks of cerebral oedema, upper airway oedema (which may present with stridor after the operation), worsened FRC and V/Q mismatch, and endobronchial movement of the endotracheal tube. The reverse Trendelenburg position results in reduced venous return, leading to hypotension with possible myocardial and cerebral ischaemia. Venous stasis and reverse Trendelenburg positioning increases the risk of deep venous thrombosis.[8] Extreme positions can also place the patient at risk of movement on the table.[6]

Another complication of prolonged surgery in the steep Trendelenburg position is the onset of "well leg compartment syndrome" caused by the combination of impaired arterial perfusion to the lower limbs, compression of venous vessels and reduced femoral venous drainage due to the pneumo-peritoneum. This can lead to rhabdomyolysis and acute renal failure, contributing to increased morbidity and mortality.[6]

Extreme positioning also increases the risk of nerve compression and injury resulting, most often, in neuropraxia. Despite this being transitory, it does require a neurological examination, rehabilitation and postoperative care. In order to prevent nerve injuries, special care of the areas where nerves pass close beneath the skin (e.g. elbow, knee, feet, face) needs to be taken.[10]

Complications of laparoscopic surgery

Venous Gas Embolism

Venous gas embolism is a potentially fatal complication of pneumoperitoneum (mortality of nearly 30%).[2] CO_2 can enter the circulation when needles or trocars directly puncture a blood vessel, or the tension pneumoperitoneum may force gas into an injured vessel. The consequences depend on the rate and amount of gas introduced. A large volume of CO_2 entering the circulation over a short period of time can result in a mechanical "air lock" in the vena cava or right ventricle, increasing right heart afterload leading to acute right heart failure with arrhythmias, myocardial ischaemia, hypotension and elevated central venous pressure. Paradoxical embolism can also occur through an anatomically or functionally patent foramen ovale.[4]

Management of gas embolism includes immediate deflation of the abdomen, providing 100% oxygen, hyperventilation, and turning the patient head down and left lateral decubitus to allow gas to rise into the apex of the right ventricle and not enter the pulmonary artery. Aggressive haemodynamic resuscitation with fluids and inotropes may also be needed.[8]

Inadvertent Extraperitoneal Insufflation

Gas insufflation can be complicated by subcutaneous emphysema, pneumomediastinum, pneumopericardium and pneumothorax. These occur most commonly because of misplaced needles or trocars. However, gas under pressure can also dissect through existing defects in the diaphragm or along surgically traumatised tissue planes in the retroperitoneum, the diaphragm or the falciform ligament. The extraperitoneal dissection of gas is related to the magnitude of the IAP.[4]

Accidental Injuries

Fatal bleeding can occur from accidental injury of major abdominal vessels e.g. aorta, IVC, or common iliac vessels by misplaced needles or trocars. Visceral injuries (e.g. small or large bowel, mesentery, liver, spleen, stomach) can also occur for similar reasons. Gastric decompression for upper gastrointestinal surgery and bladder decompression for pelvic surgery helps to prevent these complications.[8]

Postoperative Nausea and Vomiting

Postoperative nausea and vomiting (PONV) is common after laparoscopic surgery, and is an important factor determining length of stay after ambulatory surgery.[2] Interventions likely to reduce its incidence include the use of propofol TIVA (total intravenous anaesthesia), limiting opioid use, avoidance of nitrous oxide, suctioning of gastric contents at the end of the procedure, and anti-emetic drugs. Ondansetron (and other 5-HT3 antagonists) is an effective anti emetic, particularly when administered towards the end of surgery. Dexamethasone as a single dose administered at the beginning of surgery is effective for up to 24 hours post operatively.[8]

Postoperative Pain

Postoperative pain in laparoscopic surgery is less severe compared to an open procedure, but can still be considerable. It is mostly visceral in nature and often referred to the shoulder due to peritoneal irritation caused by residual carbon dioxide.[8] Pain from the puncture wounds of the trocars is generally mild

because the wounds are small and are produced without the cutting of muscle fibres.[4] Multimodal analgesic techniques offer the most effective treatment strategy, combining reduced doses of opioids, local anaesthetics, nonsteroidal anti-inflammatories, and paracetamol. This results in minimal side effects such as PONV and respiratory depression which can delay discharge in ambulatory anaesthesia.[8]

Local anaesthetics (e.g. bupivacaine, levobupivacaine, ropivacaine, lignocaine) used for peripheral nerve blocks have been shown to reduce opioid reqirements in laparoscopic surgery. A variety of techniques have been described, including rectus sheath blocks, transverses abdominis plane (TAP) blocks, paravertebral and epidural blocks, and local wound infiltration.[2]

There is controversy regarding the effectiveness of intraperitoneal local anaesthetic infiltration. The evidence seems to support its use in laparoscopic cholecystectomy as part of a multimodal approach to pain management. According to a systematic review conducted by Boddy et al. the technique seemed to be safe and resulted in a statistically significant reduction in early postoperative abdominal pain, which may be of particular benefit in ambulatory surgery.[9]

Thorascopic procedures

Additional anaesthetic challenges are encountered during thorascopic procedures, such as sympathectomy, vagotomy and oesophagectomy. Complete isolation of one lung is necessary to provide adequate surgical access. Difficulties may arise in proper positioning of the double-lumen endobronchial tube and maintaining oxygenation during one-lung ventilation. The pressure in the pneumothorax created with the gas insufflator must be carefully regulated to avoid excessive mediastinal displacement and cardiovascular collapse. The heart and great vessels are in close proximity to the surgical site and may be accidentally damaged with potentially fatal consequences.

Laparoscopic surgery during pregnancy

Pregnancy is no longer regarded as a contraindication to laparoscopic surgery, provided the gestational age is less than 32 weeks. The advantages include less exposure of the fetus to potentially toxic agents, decreased pain with less need for analgesics, and more rapid recovery and mobilisation. The pneumoperitoneum is associated with an increased risk of hypoxaemia, hypercarbia and hypotension because of the physiological and anatomical changes of pregnancy.[11] Left uterine displacement, maintaining end-tidal CO_2 between 32-34 mmHg and maternal blood pressures within 20% of baseline, and limiting abdominal insufflation pressure to 12-15 mmHg are essential features of anaesthetic management.[12]

Laparoscopic vascular surgery

Laparoscopic-assisted repair of abdominal aortic aneurysms is a feasible and reliable therapeutic approach as a minimally invasive alternative to an open procedure. The clinical advantages include better visualization of the aneurysm neck resulting in safer dissection, shorter ICU and hospital stay, and less postoperative

ileus. However, the hemodynamic and respiratory changes associated with patient position and pneumoperitoneum, difficulty in evaluating blood loss, and high incidence of co-existing coronary artery disease must be considered when laparoscopic vascular surgery is undertaken.[13]

Laparoscopic urological surgery

The application of laparoscopy has been broadened to include a number of major urological procedures (e.g. cystectomy, nephrectomy, pyeloplasty, radical prostatectomy). Specific anaesthetic concerns regarding laparoscopic urological surgery include handling the genitourinary system (handling the kidney increases plasma renin and antidiuretic hormone release), organ-specific issues (e.g. renal protection), differences in patient profile and co-morbidities, and differences in patient positions intraoperatively. Stability of renal function can be maintained by limiting intra-abdominal inflation pressure and minimizing movement of the kidney. Forced diuresis with mannitol and/or lasix can be used to promote urine flow and maintain urinary tract patency, preserve renal function, and as a prophylactic against cerebral swelling (Trendelenburg position).[14]

Paediatric laparoscopic surgery

There are a number of diagnostic and therapeutic laparoscopic procedures reported in children including appendicectomy, splenectomy, Nissen fundoplication and pyloromyotomy. The differences between the anatomy and physiology of children and adults have been well described. The major differences are in neonates and infants. Important features include: a rate dependent cardiac output due to reduced ventricular compliance; a predisposition to bradycardia in response to visceral stimulation, hypoxia or hypovolaemia; a shorter trachea (increasing the incidence of endobroncial intubation); low total thoracic compliance; diaphragmatic respiration (which may make splinting of the diaphragm a serious problem); pleuroperitoneal membranes which may be patent; and the possibility of right to left cardiac shunts.[15]

The creation of a pneumoperitoneum in most healthy children results in a decrease in respiratory compliance, an increase in peak airway pressure, an increase in the end-tidal CO_2 concentration and an increase in the alveolar to arterial CO_2 concentration difference, which is consistent with an increase in physiological dead space. This results from the mechanical effects of the pneumoperitoneum and reduction in cardiac output.[15]

In infants more than four months old, cardiorespiratory changes are similar to those in adults as long as the IAP remains less than 15 mmHg. In neonates and children under four months of age, an IAP of more than 15 mmHg may seriously impair cardiac output due to a decrease in contractility and compliance of the left ventricle. Therefore, an IAP of no more than 6 mmHg is recommended in this age group.[15]

Conclusion

The proportion of surgical procedures performed laparoscopically will continue to increase in future. In addition,

procedures are being performed on sicker, younger and obese patients. Therefore, it is imperative that anaesthetists understand and safely manage the specific physiological alterations and practical challenges that laparoscopy presents. Careful monitoring and vigilance is crucial in preventing and treating these complications.

References

1. Srivastava A, Niranjan A. Secrets of safe laparoscopic surgery: Anaesthetic and surgical considerations. J Minim Access Surg. 2010 Oct-Dec;6(4):91-4

2. Nguyen JH, Tanaka PP. Chapter 15: Anesthesia for Laparoscopic surgery. Prevention and management of laparoendoscopic surgical complications. Third edition

3. Bellamy MC. Laparoscopic surgery: Problems for the anaesthetist. World Congress of Anaesthesiologists (WCA). 2008

4. Chui PT, Gin T, Oh TE. Anaesthesia for laparoscopic general surgery. Anaesth Intensive Care. 1993 April;21(2):163-71

5. Gharaibeh H. Anaesthetic management of laparoscopic surgery. Eastern Mediterranean Health Journal. 1998;4(1):185-188

6. Hayden P, Cowman S. Anaesthesia for laparoscopic surgery. Continuing Education in Anaesthesia, Critical Care & Pain. 2011 July;11(5): 177-180

7. Kaba A, Joris J. Anaesthesia for laparoscopic surgery. Current Anaesthesia & Critical Care. 2001;12:159-65

8. Mrara B. Anaesthesia for laparoscopic surgery. 6th North West Anaesthetic Refresher Course. 2008;Lecture 5:1-9

9. Boddy AP, Mehta S, Rhodes M. The Effect of Intraperitoneal Local Anesthesia in Laparoscopic Cholecystectomy: A Systematic Review and Meta-Analysis. International Anesthesia Research Society. 2006 September;103(3):682-688

10. Martín-Cancho MF, Celdrán D, Lima JR, Carrasco-Jimenez MS, Sánchez-Margallo FM, Usón-Gargallo J. 2011. Anaesthetic Considerations during Laparoscopic Surgery, Advanced Gynecologic Endoscopy, Dr. Atef Darwish (Ed.), ISBN: 978-953-307-348-4, InTech

11. Walton NKD, Melachuri VK. Anaesthesia for non-obstetric surgery during pregnancy. Continuing Education in Anaesthesia, Critical Care & Pain. 2006;6(2):83-85

12. O'Rourke N, Kodali BS. Laparoscopic surgery during pregnancy. Curr Opin Anaesthesiol. 2006 June;19(3):254-259.

13. Nakahata K. Laparoscopic vascular surgery: Surgical and anaesthetic implication and management. WCA. 2008

14. Conacher ID, Soomro NA, Rix D. Anaesthesia for laparoscopic urological surgery. British Journal of Anaesthesia. 2004 September;93(6):859-864

15. Wedgewood J, Doyle E. Anaesthesia and laparoscopic surgery in children. Paediatric Anaesthesia. 2001;11:391-399