Anesthesia Considerations for Laparoscopic Procedures in Children

Carolyn F. Bannister, MD

Widespread application of the laparoscopic approach to surgical procedures had a slower onset in pediatric surgery than that in adult patients for a number of reasons. Compared to the open cholecystectomy in adult patients, there was not a commonly performed pediatric surgical procedure with significant increased morbidity using the open technique. Surgical instruments were designed for adults and age-appropriate pediatric instruments were not available early on. Surgeons had no training in this technique, leading to a relatively long learning curve which was not appealing to senior surgeons who were very skilled with open techniques. There was a relatively high start-up cost with instrumentation and monitoring equipment for the OR. Reported physiologic changes which occurred in adults undergoing laparoscopic procedures were of concern in the pediatric patient. Risk/benefit was not clearly established in pediatric patients who seemed to recover faster than adult patients in general. However, once the benefits over traditional 'open' operative techniques were reported in adults, pediatric surgeons rapidly moved to derive the same advantages for their patients. Some of these benefits include smaller incisions, less fluid and heat loss, less retraction of tissues, better visualization of difficult areas due to the use of cameras, improved cosmesis, earlier postoperative mobilization and recovery, shorter postop ileus and earlier oral intake, fewer respiratory and wound complications, less postop pain and earlier discharge.

The advent and improvement of laparoscopic surgical techniques have lead to expanded surgical and diagnostic indications for this technology in the pediatric patient. Recent reports discuss 44 different surgical procedures in children using laparoscopic techniques. (1,2,3,4,5,6)

Early adult studies reported physiologic alterations induced by patient positioning and the intra-abdominal insufflation of CO2 including increased intra-abdominal pressure (IAP), with attendant alterations in pulmonary and cardiovascular mechanics, absorption of CO2 across the peritoneum, pneumothorax and rarely, CO2 embolism. (7,8,9,10,11, 12) Similar physiologic alterations induced by CO2 peritoneum were reported in pediatric studies. (13,14,15)

Increased IAP potentially impairs diaphragmatic motion, decreases functional residual capacity, diminishes pulmonary compliance, increases airway resistance and decreases tidal volume and minute ventilation. These changes lead to intrapulmonary shunting, increased alveolar to arterial O2 gradient, increased alveolar dead space and hypoxemia.

Patient positioning may impact cardiopulmonary function during laparoscopy.

Trendelenburg position limits diaphragmatic excursion due to the weight of intra-abdominal contents; cephalad position of the diaphragm and mediastinum increases the risk of endobronchial intubation.

Cardiac output may be decreased by the effect on venous return and systemic vascular resistance. Small increases in IAP (less than 8-10mm Hg) increase splanchnic venous return and increase preload. Higher pressures decrease preload. Impaired renal, hepatic and splanchnic flow may result; decreased urinary output during laparoscopy occurs as a result of decreased renal perfusion and increased vasopressin release.

Increased systemic vascular resistance resulting from catecholamine and vasopressin release as well as a direct effect of the increased IAP may also reduce cardiac output (8). Joris (9) et al reported cardiovascular changes in 15 ASA I adults having laparoscopic cholecystectomy in which the IAP was maintained at 14 mm Hg. Compared to baseline parameters, mean arterial pressure increased 35%, cardiac index decreased 20% and systemic vascular resistance increased 65%; when Trendelenberg position was superimposed the cardiac index decreased 50% from baseline. Sakka (10) reported a significant decrease in cardiac index documented by transesophageal echocardiography in 2-6 year old patients with initial insufflation of CO2 when the pressure was limited to 12 mmHg; CI returned to baseline when the insufflation pressure was decrease to 6 mmHg and was maintained after a subsequent increase in pressure to 12 mmHg. Sfez (14) reported one case of bradycardia in 25 children having laparoscopic fundoplication and hypertension (>120% of baseline) requiring increased anesthetic concentration in 10 of 25 children.

A significant amount of CO2 may be absorbed during laparoscopy. Adult studies suggested that minute ventilation required a 50-75% increase to maintain normocarbia (11). Sfez eported end-tidal CO2 concentrations >40 mmHg in only 3 of 25 children during laparoscopic fundoplication when insufflation pressure was limited to 10 mmHg. Tobias (15) et al reported changes in peak inflating pressure and ET CO2 in 55 children having brief (<10 minute) peritoneoscopy during general anesthesia; peak inflating pressure increased 5 cm H2O or more in 11% of patients and ET CO2 increased 5 mmHg or more in 33 % of patients. Similar results were reported in 20 infants less than 12 months of age undergoing laparoscopic procedures when Pmax was limited to 12 mmHg for infants < 5Kg body weight and 15mmHg for those infants >5 Kg (16). At Pmax, peak inspiratory pressure (PIP) increased 18%, tidal volume decreased 33%, dynamic compliance decreased 48% and O2 saturation fell in 41% of patients. Twenty ventilator adjustments were required to bring these parameters to within 10% of baseline measurements.

CO2 may also dissect into subcutaneous tissues, mediastinum and thorax as a result of increased IAP with gas passage through congenital or surgically induced defects in the diaphragm (12,13). Air embolism may result if the insufflating gas enters the circulation. Failure to evacuate CO2 at the end of surgery can lead to impaired ventilation, hypercarbia, shoulder pain and vomiting. Air/O2 combination is recommended to avoid expansion of pneumoperitoneum or pneumothorax which may otherwise be clinically insignificant.

So what do the physiologic alterations mean to the anesthesiologist whose goals differ significantly with those of the surgeon? The anesthesiologist is attuned to optimum ventilation and, thereby, lower IAP while the surgeon strives for optimum visibility and exposure often necessitating higher IAP. In one 1999 report (17), children younger than 8 months of age were not considered candidates for laparoscopic inguinal hernia repair because of the concern of the effects of pneumoperitoneum on young infants. One year later, the same authors (18) reported

use of laparoscopy in children as young as 4 months of age; numerous studies now report this technique in newborns with minimal complications and excellent surgical results (16, 20). Currently the most common reasons for conversion to open techniques in children is the inability to accomplish the procedure with laparoscopy and to repair bleeding/damage to internal organs (although the latter complication may be readily treated through the laparoscope.) Overall complication rate in pediatric patients is approximately 1.5% and most complications are related to blind insertion of trocars.

Anesthetic technique for the vast majority of cases involves general anesthesia with standard ASA monitors +/- invasive monitors determined by the patients' ASA status and type/extent of planned surgical procedure. Some small studies have reported the use of regional anesthesia with sedation in older cooperative patients. Brief procedures may be performed with mask or laryngeal mask airway, but most procedures will require intubation and controlled ventilation.

In preparation for increased intra-abdominal pressure and Trendelenberg position, the endotracheal tube in children should be positioned well above the carina; consideration may be given to the use of cuffed endotracheal tubes even in small patients in order to preserve tidal ventilation at Pmax. Otherwise, a leak around an uncuffed ETT at a higher pressure than customarily considered acceptable would be desirable.

To avoid hypercarbia and respiratory acidosis that accompany CO2 absorption and the negative impact on pulmonary mechanics, ventilatory changes should be anticipated. Increased minute ventilation may be accomplished in a variety of ways and may require a combination of increases in respiratory rate, tidal volume, and peak inspiratory pressure. Mild degrees of permissive hypercarbia is generally well-tolerated by the vast majority of patients and pose no significant clinical threat. Slight declines in SaO2 may require no treatment; ventilatory changes implemented to restore Vt and Et CO2 alone often correct mild hypoxemia with no changes in FIO2.

Studies have shown a statistically significant linear correlation between insufflation pressure and undesirable changes in Vt, PIP, dynamic compliance and EtCO2 (16). Measures should be taken to minimize the insufflation pressure to that needed for adequate safe, if not luxurious, surgical visualization and exposure. Insufflation pressures limited to 10 mmHg may provide excellent exposure and lead to minimal physiologic changes.

Impaired venous return and decreased cardiac output may be masked by increased intrathoracic pressure and right atrial pressures measured during pneumoperitoneum. In this case, elevated measured central venous pressure does not reflect increased filling pressure. Increased SVR may lead to normal or elevated mean arterial pressure despite falling cardiac output. With further increases in IAP, blood pressure may fall as cardiac output is further impaired. These effects will be minimized if normovolemia is maintained during the procedure. Urinary output may decrease due to impaired renal perfusion and decreased glomerular filtration combined with increased vasopressin levels. Fluid and heat losses will be less than those occurring with open procedures which expose bowel and viscera to the environment.

Special consideration should be given to potential physiologic changes which may be induced in patients with ventriculoperitoneal shunts. Distal shunt obstruction may lead to increased intracranial pressure and lower cerebral perfusion pressure. Hypercapnia, Trendelenberg position, increased intrathoracic pressure and decreased cardiac output in combination may lead to significant decreases in cerebral perfusion.

Neuromuscular blockade may facilitate surgical exposure and implementation of any desired ventilatory changes. ET CO2 monitoring may not accurately reflect arterial pCO2 particularly in small patients or in the presence of pulmonary disease; in prolonged procedures requiring high insufflation pressures, direct measurement of capillary or arterial CO2 will assist with appropriate ventilation maneuvers.

Postoperative analgesia may be accomplished with local anesthetic infiltration to surgical trocar sites and nonsteroidal anti-inflammatory agents in patients with minimal surgical intervention; systemic or oral opioids are needed for extensive intra-abdominal procedures.

Physiologic changes during laparoscopy are of concern in pediatric patients. Several studies, however, demonstrate that alterations that are significant when taken as absolute values may have effects that are of minimal clinical significance and rarely affect patient outcome. Restoration of pulmonary parameters to baseline measures is generally achievable and well tolerated without adversely affecting patient outcome or the conduct of surgery. Total correction may not be necessary or desirable in all situations.

References

1. Ure BM, Bax NMA, van der Zee DC. Laparoscopy in Infants and Children: a prospective study on feasibility and the impact on routine surgery. J Paediatr Surg 2000; 35: 1170-3.
2. Gans SL, Berci G. Peritoneoscopy in infants and children. J Paediatr Surg 1973; 8: 399-405.
3. Gans SL, Berci G. Advances in endoscopy of infants and children J. Paediatr Surg 1971; 6: 199-232.
4. Leape LL, Ramenofsky ML. Laparoscopy in infants and children. J Paediatr Surg 1977; 12: 929-38.
5. Holcomb GWIII, Olsen DO, Sharp KW. Laparoscopic cholecycstecomy in the pediatric patient. J. Paediatr Surg 1991; 26: 1186-90.
6. Holcomb GWIII, Brock JW III, Morgan WM III. Laparoscopic evaluation for a contralateral patent processus vaginalis. J. Paediatr Surg 1994; 29: 970-4.
7. Hsing CH, Hsu SS, Tsa SK et al. The physiologic effect of CO2 pneumoperitoneum in pediatric laparoscopy. Acta Anaesthesiol Sin 1995; 33: 1-6.
8. O'Leary E, Hubbard K, Tormey W. et al. Laparoscopic cholecystectomy: haemodynamic and neuroendocrine responses after pneumoperitoneum and changes in position. Br J Anaesth 1996; 76: 640-6.
9. Joris JL, Noirot DP, Legrand MJ et al. Hemodynamic changes during laparoscopic cholecystectomy. Anesth Analg 1993; 76: 1967-71.

10. Sakka SG, Huettmann E, Petrat G et al. Transoesphageal echocardiographic assessment of haemodynamic changes during lapatoscopic herniorrhapy in small children. Br J Anaesth 2000; 84(3): 330-4.
11. Liu SY, Leighton T, Davis I et al. Prospective analysis of cardiopulmonary responses to laparoscopic cholecystectomy. J Laparoendosc Surg 1991; 1: 241-6.
12. Gabbott DA, Dunkley AB, Roberts FL et al. Carbon dioxide pneumothorax occurring during laparoscopic cholecystectomy. Anaesthesia 1992; 47: 587-8.
13. Joris JL, Chiche JM, Lamy ML et al. Pneumothorax during laparoscopic fundoplication: diagnosis and treatment with positive end-expiratory pressure. Anesth Analg 1995; 81: 930-1000.
14. Sfez M, Guerard A, Desruell P et al. Cardiorespiratory changes during laparoscopic fundoplication in chiloden. Paediatr Anaesth 1995; 5: 89-95.
15. Tobias JD, Holcomb GWIII, Brock JWIII et al. Cardiorespiratory changes in children during laparoscopy. J Paediatr Surg; 1995: 30: 33-6.
16. Bannister CF, Brosius KK, Wulkan M. The effect of insufflation pressure on pulmonary mechanics in infants during laparoscopic surgical procedures. Paed Anaesth 2003; 13: 1-5.
17. Montupet P, Esposito C. Laparoscopic Treatment of Congenital Inguinal Hernia in Children. J Ped Surg March 1999; 34(3): 420-3
18. Esposito C, Montupet P, Amici G etal. Complications of laparoscopic antireflux surgery in childhood. Surg Endosc 2000; 14: 622-4.
19. Manner T, Aantaa R, Alanen M. Lung compliance during laparoscopic surgery in paediatric patients. Paediatr Anaesth 1998; 8: 25-9.
20. Rubin SZ, Davis CM, Sehgal Y et al. Does laparoscopy adversely affect gas exchange and pulmonary mechanics in the newborn? An experimental study. J Laparoendosc Surg 1996; 6: S69-73.