Low flow practice for laparoscopic colorectal surgery in pediatric patients

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ABSTRACT

Low flow anaesthesia and laparoscopic techniques in pediatric patients are two of many developments in the modern medical field. Both techniques were established to support environmentally friendly, safe, and comfortable anaesthesia practices for patients. Presented in this case series, laparoscopy was done in all three cases (two digestive cases, and one urology case). All three cases were performed with general anaesthesia using the low flow anaesthesia technique with volatile sevoflurane combined with caudal block regional anaesthesia. In all cases, no morbidity was found after anaesthesia or surgery to influence the patient’s outcome. Improvements in the outcome of pediatric patients were seen using the low flow anaesthesia techniques. These improvements include a significant reduction of volatile used, faster wake up times, and reduction of agitation after anaesthesia.

Keywords: low flow anaesthesia, laparoscopic, colorectal, pediatric surgery, infant, toddler


INTRODUCTION

Low flow anaesthesia is one kind of modern medical field development. This technique has progressed rapidly to be used across all age groups. Low flow anaesthesia was first used in 1993 by Weiser.1 This technique has some specific characteristics such as rebreathing process, respiratory circuit with closed or semi-closed system usage, and the use of carbon dioxide (CO2) absorbent in the rebreathing technique.2 Until today, usage of this low flow technique in pediatric patients required applying a gas rate of approximately 500 mL/min.3-5 In addition, laparoscopic surgery is a minimally invasive procedure that is frequently performed and suggested according to Enhanced Recovery Paediatrics (ERP) protocols.6 This technique has the characteristic of CO2 usage in the insufflation process to obtain a better operation field.2 This technique causes a separate challenge in low flow technique application for a laparoscopic procedure. This is because there is a risk of hypercarbia that could make the patient’s outcome unfavourable. However, in this case series, it was demonstrated that low flow anaesthesia usage during a laparoscopic operation is a safe technique that could be done. This is because of the continuous and careful monitoring of every change in the patient's condition.2

CASE REPORT 1

A 2 months old infant weighing 4.7 kg, physical status of American Society of Anaesthesiologist (ASA) II, was admitted to the hospital and planned for a laparoscopic assisted transendorectal pull-through (LATEP) for his hirschsprung anomaly. His family complained about his difficulty in defecation since the infant was born. There was no history of jaundice and cyanosis and the patient was a term at birth. His physical examination was normal according to his age with his haemoglobin level was 10 g/dL and his packed cell volume (PCV) was 30.05%. The patient was prepared in the preparation room with the premedication drugs Sulphate CrossMark

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CASE REPORT

lowered the fresh gas flow (FGF) to 0.5 L/min. The ventilator was set to target P inspiration 12 mmHg, tidal volume (TV) 6-8 mL/kg of body weight (BW), respiration rate (RR) 30x/min, end tidal carbon dioxide (EtCO₂) 30-40 mmHg, fraction inspired oxygen (FiO₂) inspiration around 30% and minimal alveolar concentration (MAC) 0.5-1. After these processes, we permitted the surgeon do the surgery.

After the draping process was done, they started to inflate the infant's abdomen until the intra-abdominal pressure (IAP) reached 10 mmHg. We found that after the raising the IAP, it was more difficult to ventilate the patient and the TV decreased to 3 – 4 mL/kgBW. We raised the inspiration pressure until we preserved the normoventilation. Throughout the surgery, the haemodynamic status showed HR at 115 – 120 bpm, RR at 30 bpm, temperature at 35.9°C, O₂ saturation at 98%, and EtCO₂ at 30 – 40 mmHg. The surgery lasted for about 4 hours and 30 minutes until the rectal tube was placed, the surgery’s blood loss was 30 mL, and the urine output was about 20 mL. Total fluid given was 200 mL of Ringerfundin, and no analgesics or drugs were added.

As soon as the operation ended, we stopped the sevoflurane (MAC 0.4, sevoflurane inspiration 1.0 vol%), and we increased the fresh gas flow to 5 L/min. Within 2 minutes, we observed that the MAC decreased to 0.1 (sevoflurane inspiration 0.3 vol%, EtCO₂ 37) and spontaneous breathing started lightly. After 3 minutes, the MAC was observed at 0 (inspiration sevoflurane 0 vol%, EtCO₂ 42) and the spontaneous tidal volume was sufficient enough. After 5 minutes, the emergence process started and we gently cleaned his oral cavity. After the airway was cleared and the paediatric’s Aldrete score reached 10, we extubated the patient. The patient was observed in the Post Anaesthesia Care Unit (PACU) and discharged to the ward within 2 hours after anaesthesia. On PACU, the Paediatrics Agitation Emergence Delirium (PAED) score recorded was 8 – 6 – 6 during first 30 minutes. The patient was monitored for the first 24 hours in the ward. We were informed that he experienced postoperative nausea vomiting (PONV) 3 hours after anaesthesia and no more PONV was recorded. After 5 days, the patient was discharged home without any anaesthesia or surgery complications recorded.

CASE REPORT 2

A 1.5 months old infant weighing 3.9 kg, ASA II, was admitted to the hospital and was planned for laparoscopic assisted bilateral herniotomy for bilateral hernia inguinal lateralis. His family complained about masses since he was born that became swollen, especially when the patient was crying. The patient has no history of jaundice and cyanosis, and the patient was a term during birth. His physical examination was normal according to his age with his haemoglobin level at 10.91 g/DL and PCV at 33.57%. The patient was prepared in the preparation room with the premedication drug Sulphate Atropine (0.1 mg) intramuscularly. After that, the patient was moved to the operating theatre. Anaesthesia began with an inhalational induction technique with O₂ – sevoflurane. The nurse set up an IV line in his right hand with ringer lactate that continued throughout the operation. His base hemodynamic monitoring showed his HR at 125 bpm. RR at 24 bpm, temperature at 36.5°C, and O₂ saturation at 98% with 100% O₂ and Sevoflurane 8 vol%. We gave him Fentanyl (8 mcg), Atrocurium (3 mg), Dexamethasone (2 mg), Metamizole (30 mg), and prophylactic antibiotics while giving pre-oxygenation. After 3 minutes we intubated the patient with a 3.5 Fr ETT. After confirming the ETT placement, we affixed the pharyngeal packing and precordial stethoscope. We proceed by giving him caudal block to optimize intra- and postoperative analgesia. We gave him Bupivacaine (0.2%) and Clonidine (5 mcg) in 4 mL of volume to reach a high lumbar block for somatic and visceral pain. We lowered the FGF to 0.5 L/min and the ventilator was set to target Pinsp 12 mmHg, TV 6-8 mL/kgBW, RR 30x/min, EtCO₂ 30-40 mmHg, fO₂ inspiration around 30% and MAC at 0.5-1. Following these processes, we allowed the surgeon do the operation.

After the draping process is done, the toddlers abdomen was inflated until its IAP reached 10 mmHg. We found that after raising the IAP it was more difficult to ventilate the patient and TV decreased to 2 – 3 mL/kgBW. We raised the inspiration pressure until we can preserve the normoventilation. Throughout the operation, haemodynamic status showed the HR at 95 – 115 bpm, RR at 30 bpm, temperature at 36.0°C, O₂ saturation at 98%, and EtCO₂ at 30 – 40 mmHg. The operation lasted for about 3 hours and 50 minutes until the dressing was placed. The operation blood loss was 2 mL and urine output collected was about 15 mL. Totally, 100 mL of ringer lactate was given with no added analgesics or drugs.

Immediately following the operation, we stopped the sevoflurane (MAC 0.4, sevoflurane inspiration 1.2 vol%), and we increased the fresh gas flow to 5 L/min. Within 2 minutes, the MAC decreased to 0.1 (Sevoflurane inspiration 0.5 vol%, EtCO₂ 38) and spontaneous breathing started lightly. After 3 minutes, the MAC was observed at 0 (inspiration sevoflurane 0 vol%, EtCO₂ 45) and the spontaneous tidal volume was sufficient enough.
Then, after 7 minutes, emergence processes started, and we gently cleaned his oral cavity. After the airway was cleared and the paediatrics Aldrete score reached 10, we extubated the patient. The patient was observed in the PACU and discharged to the ward in 2 hours post-anaesthesia. On PACU, the PAED score recorded was 8 – 8 – 6 during first 30 minutes. The patient was monitored for the first 24 hours in the ward, and no PONV was recorded. After 2 days, the patient was discharged home without any anaesthesia or surgery complications recorded.

**CASE REPORT 3**

A 1 year old toddler weighing 7.9 kg, ASA I, was admitted to the hospital and was planned for laparoscopic assisted left orchidopexy for the left undescended testis. His family complained about the missing left testicle since he was born. His family also complained about urethrae in his penis shaft since birth. There was no history of jaundice or cyanosis and the patient was a term at birth. His physical examination was normal according to his age with his haemoglobin level at 11.57 g/dL and PCV at 37.35%. The patient was prepared in the preparation room with the premedication drugs of Midazolam (0.1 mg/kgBW) and ketamine (3 mg/kgBW) intramuscularly. After being calmed, the patient was moved to the operating theatre. Anaesthesia began with an inhalational induction technique with O₂ Sevoflurane. The nurse set up a 1L in his right hand with ringer lactate and no PONV was recorded. After 2 days, the patient was observed in the PACU and discharged to the ward within 2 hours post-anaesthesia. On PACU, the PAED score recorded was 4 – 0 – 0 during first 30 minutes. The patient then monitored for the first 24 hours, and no PONV was recorded. After 2 days, the patient was discharged homewoafter any anaesthesia or surgery complications recorded.

**DISCUSSION**

**Laparoscopy**

This laparoscopic technique is a noninvasive technique that is newly introduced in pediatric patients. This technique is only now being introduced for many reasons. Mostly, this is because of the potential morbidity that occurred in pediatric patients and the tools required were not designed for pediatric patients. The training for these laparoscopy techniques were also not yet feasible for pediatric patients because of the expensive cost of providing and maintaining the laparoscopic tools. The physiological differences in pediatric patients frequently becomes an obstacle for operators when choosing this laparoscopy procedure. However, after some authors published the benefit of this laparoscopy technique, pediatric surgeons slowly implement this technique in their daily clinical practices. The advantages of this technique are the small size of incision, low loss rate of heat and fluid, low tissue drawing, better visualization for the area that is hard to reach by camera, better post-operation...
cosmetics, early mobilization and improvement post-operation, shorter ileus period post-operation, fewer wound and respiratory complications, lower post-operation pain, and quicker discharge for patients. The invention and development of the laparoscopy procedure also lead to the development of operation procedures in pediatric patients.

Special attention in the laparoscopy procedure is given to the patient's position alteration and insufflation effect of CO₂ in intra-abdominal pressure (IAP) in relation to the cardiorespiratory mechanical, CO₂ absorption, pneumothorax, and CO₂ emboli. This is also applicable to pediatric cases.

Increasing IAP and the patient's position (Trendelenburg) can interfere with the diaphragm movement that could lead to physiologic and anatomic changes.

Airway
Increasing IAP leads to endobronchial intubation, laryngeal mask airway (LMA) position change, and an increase in the risk of regurgitation in the upper digestive tract procedure.

Respiration
Increasing IAP causes functional residual capacity (FRC) reduction, decreased pulmonary compliance, increased airway resistance, and reduction of tidal volume and one-minute volume. These changes also lead to an increase of intrapulmonary shunt, raised alveolar-arteriole oxygen (AaO₂) gradient, increase alveolar dead space, and hypoxemia.

Cardiovascular
Decreased cardiac output can be caused by a reduction in venous return and systemic vascular resistance. Mild IAP increase (less than 8 – 10 mmHg) can cause an increase in venous return from the splanchnic vein and increase the preload. An increase of IAP more than 12 mmHg would cause a reduction of preload, kidney, liver, and splanchnic flow disturbance that could lead to a decreased urine production while in the laparoscopic procedure as a consequence of renal perfusion and a raised vasopressin perfusion. An increase in systemic vascular resistance occurs as a result of catecholamine and vasopressin release which is a direct effect of IAP increase that could also reduce cardiac output. In many pieces of literatures, it needs dose adjustments from volatile anaesthesia.

Temperature
The probability of hypothermia incidence is high in neonatal and child patients. It happens as a result of CO₂ gas use and prolonged operation duration.

Furthermore, CO₂ insufflation itself could bring many physiological changes and complications. IAP itself could increase the CO₂ absorption into circulation. Meanwhile, CO₂ could dissect the tissue with minor loci that lead to pneumothorax, CO₂ emboli, etc. If the CO₂ level in blood at the end of the anaesthesia is still high, then it will lead to a condition called hypercarbia which has a negative clinical impact on various organ systems. As a result, appropriate anaesthesia management is needed for laparoscopy procedure implementation in pediatric patients.

Specific Intra-operation Complications
Intraoperative complications during the laparoscopic procedure with pneumoperitoneum CO₂ includes vascular trauma, gastrointestinal trauma, cardiac arrhythmia, subcutaneous emphysema, pneumothorax, pneumomediastinum/pneumopericardium, and CO₂ gas emboli. In all cases within this case series, there was no aforementioned complications found.

Anaesthesia Management
The anaesthesia approach for laparoscopic surgery in pediatric patients is general anaesthesia with controlled ventilation that is considered as the safest and the most comfortable technique for laparoscopic surgery in pediatric patients of young age.

Airway Management
Endotracheal intubation and controlled mechanical ventilation are used to reduce pressure arterial carbon dioxide (PaCO₂) increase and avoid ventilation disturbance as a result of pneumoperitoneum and Trendelenburg position at the beginning of the operation. LMA has been used in pelvic laparoscopy widely. LMA, mainly pro-seal LMA, was successfully used to replace ETT insertion in short procedures for one day care (ODC) patients. In the three cases above, we used endotracheal intubation with ETT without cuff in the two digestive operation cases and for the urologic case we used LMA instead of an endotracheal tube. The reason for this choice is to get positive pressure ventilation when controlling PaCO₂. The cuff was replaced with packing in all cases to absorb regurgitant and salivary gland secretion. A NGT pipe was placed for decompression so that the positive ventilation pressure is not disrupted by a full stomach.

Muscle Relaxant
Muscle relaxant drugs choice depends on the operation duration and side effects profile of the individual drugs. Reverse against muscle relaxant drugs with neostigmine will increase PONV after laparoscopy compared to spontaneous reverse, and some clinicians avoid this reverse. In all cases...
above, the use of muscle relaxant was limited at induction to facilitate the laryngoscopy intubation action. The operation field relaxation was obtained by a combination of anaesthesia plane depth and the use of caudal block regional anaesthesia.

**Anaesthesia Induction**

In these pediatric cases, inhalation induction was used because it proved more comforting for patients. The volatile agent used was sevoflurane, which is not irritable for the pediatric airway. Next, in anaesthesia maintenance, the same volatile agent in combination with a caudal block regional anaesthesia was used. At the induction of the anaesthesia it is important to avoid gastric inflation during ventilation since this will increase the risk of trauma to the stomach during thoracic insertion. A NGT and gastric decompression were used to minimalize visceral organ perforation during the thoracic insertion and optimize visualization. Intubation gives the advantage for obese patients to reduce hypoxemia, hypercarbia, and aspiration. The use of a spontaneous ventilation technique is not suggested in case of intraoperative pneumoperitoneum and patient’s position.

**Anaesthesia Maintenance**

Anaesthesia maintenance in laparoscopy procedures could be maintained by inhalation anaesthesia. The main target is to maintain oxygenation, ventilation, anaesthesia depth, and hemodynamic adequacy during anaesthesia. The increase of minute volume by 25 - 30%, increase of oxygen fraction, and the use of PEEP may be considered. During pneumoperitoneum, ventilation control is adjusted to maintain end-tidal carbon dioxide (PETCO₂) at approximately 35 mmHg. Increased respiratory frequency is preferred rather than an increase in tidal volume to avoid an increase in alveolar inflation and to decrease the risk of pneumothorax. Provision of vasodilator drugs, such as nicardipine, α2-adrenergic, and remifentanil agonists, reduce the hemodynamic impact of pneumoperitoneum and may facilitate anaesthesia management in patients with heart disease. Intra-abdominal pressure should be monitored and kept as low as possible to reduce hemodynamic and respiratory alterations and should not exceed 10 mmHg. Increased intra-abdominal pressure can be avoided by maintaining anaesthesia depth. Due to the tendency for reflexes to increase vagal tone during laparoscopy, atropine should be reserved for injection if necessary. In the cases above, anaesthesia managed in all cases with a combination of general anaesthesia and regional anaesthesia with the caudal block. The caudal block itself was used because of laparoscopic procedure performed was a colorectal laparoscopic procedure. This combination with regional anaesthesia is good in blocking both somatic and visceral pain. Furthermore, the monitoring used was routine monitoring, CO₂ monitoring, volatile levels, and oxygen fraction. Strict monitoring of CO₂ gas embolism is absolutely necessary to avoid possible complications.

**Low Flow Anaesthesia**

The use of low flow techniques on anaesthesia management in pediatric patients was reported with the use of a gas rate of <20% from minute volume. In laparoscopy cases, its use remains controversial. One study demonstrated that the low flow anaesthesia technique is a safer technique compared to the high flow anaesthesia technique in pulmonary fever in healthy adult patients. Later studies showed no difference in outcome from pediatric patients under anaesthesia and maintained its anaesthesia condition. This corresponds to the respiratory system in ideal pediatric patients in the concept of a reduction in the rate of this gas. Pediatric patients easily have a faster equilibrium point due to the low body weight of patients who have low oxygen consumption, absorb less N₂O, and store less dissolved nitrogen. This also corresponds to the volatile anaesthetic pharmacological properties that have low distribution volume. Anaesthesia in pediatric patients using a gas rate of 1 L/min and 0.5 L/min corresponds to the definition of low flow in adult patients or minimal flow anaesthesia. In an attempt to ensure the low flow anaesthetic technique is safe to perform in pediatric patients, the accuracy, and adherence of the anaesthesia machine should be highly considered. Extensive monitoring of volatile anaesthesia, inspired oxygen concentration, minute volume, oxygen saturation, CO₂, and pressure are important requirements of the low flow anaesthesia technique. Extensive monitoring function of the volatile, inspiratory oxygen concentration, volume minute, oxygen saturation, CO₂, and pressure are important in the implementation of low flow anaesthesia. The gas rate decoupling function provides anaesthesia advantage in reducing the gas rate to perform low flow or minimal flow technique with no doubt there will be side effects on tidal volume. In the gas recycling system, the volatile anaesthesia concentration in the respiratory circuit increases with the rate of gas decline. The absolute humidity for the inspiration gas is maintained between 17 and 30 mg H₂O/L and with the gas temperature maintained between 28 to 32°C. All the above cases were done by low flow anaesthesia techniques. In all cases, there were no complications reported such as hypercarbia, hypothermia, hypoxia, or post-esthetic agitation. This is because
of the advantages of low flow anaesthesia techniques in the preservation of temperature, oxygen fraction, and minimal use of sevoflurane.14-17,19,25

Monitoring
Standard intraoperative monitoring is recommended for all patients undergoing procedures with minimal access. The standard monitor used: pulse rate, continuous ECG, non-invasive blood pressure (NIBP) intermittent, pulse oximetry (SpO2), capnography (EtCO2), temperature, intra-abdominal pressure, and pulmonary airway pressure. Invasive hemodynamic monitoring is appropriate for patients with higher ASA physical status. Capnography and pulse oximetry are PaCO2 monitors and saturation of peripheral arterial oxygen that can be used. Postoperative EtCO2 monitoring is most commonly used as a noninvasive indicator of PaCO2 in assessing and guiding the adequacy of minute ventilation to maintain normocarbia during laparoscopic procedures. Monitoring of airway pressure is essential in an anaesthetized patient given intermittent positive-pressure ventilation (IPPV). High airway pressure alarms can help detect excessive increases in intra-abdominal pressure, as well as to prevent the sudden movement of patients during surgery that can lead to intra-abdominal trauma by laparoscopic equipment.5,9,11,21 In all cases within this case series, the monitoring performed were routine monitoring, expiration and inspiration CO2 concentration monitoring, and monitoring of volatile concentrations.

Analgesia
Opioids are still an important component of balanced general anaesthesia techniques for laparoscopic procedures. Short-acting opioids such as fentanyl, alfentanil, and remifentanil may be used intraoperatively to prevent severe surgical stimuli. Multimodal analgesia medications combined with opioids, NSAIDs, and local infiltration anaesthesia are very effective at reducing opioid doses to minimize side effects. The administration of local anaesthetic agents via the intraperitoneal pathway is very simple and does not involve a neuraxial block, especially for outpatient anaesthesia patients. The provision of the local anaesthetic agent bupivacaine (0.25% to 2.5 mg/kg BW in 1.25 mL/kgBW volume given) in regional anaesthesia caudal block significantly reduced the pain that occurred.8,9,11,23 In all cases above, the use of opioids is limited by providing them only at the time of induction of anaesthesia for facilitation of intubation laryngoscopy process. Analgesia in all procedures was given by a combination of caudal block regional anaesthesia, NSAIDs, and steroids to suppress inflammatory processes that occur.

Postoperative Nausea and Vomiting (PONV)
PONV is one of the main common complaints (40-75%) and is an important complaint of post-anaesthesia treatment. One of the risk factors is the use of intraoperative opioids. Drainage of gastric contents also reduces the incidence of PONV. Opioid dose reduction with multimodal analgesia drugs may decrease the incidence of PONV. A selective 5-HT antagonist, Ondansetron, at a dosage of 0.1 mg/kgBW is as effective as prophylaxis against postoperative laparoscopic emesis.5,9,11,23 In all cases, no anti emesis drugs were used, except dexmethasone, due to low opioid usage and minimal intraoperative manipulation.

Recovery and Post Operation Monitoring
The benefits from post laparoscopy operation include reduced surgical trauma, small wound size, reduced pain, reduced pulmonary dysfunction, faster healing wound, and shorter hospital care. PONV laparoscopy is common despite routine gastric emptying with NGT, for this to be considered for prophylactic medication. Bile duct injuries are more common after laparoscopy than open cholecystectomy and tend to be wider and taller. Postoperative pain and icterus often occur.5,9,11,23 In all cases within this case series, patients can be discharged after 2 x 24 hours postoperatively. This is due to the absence of postoperative complications and low incidence of PONV. The incidence of PONV was seen only in one case which is from postoperation LATEP, but this occurred only up to 6 hours postoperatively, resulting in a faster postoperative recovery.

CONCLUSION
Low flow anaesthesia is an anaesthetic technique that is environmentally friendly, safe, and comfortable to use in laparoscopic procedures in pediatric patients. Presented in this case series, laparoscopy was done in all three cases (two digestive cases, and one urology case). All three cases were performed with general anaesthesia by low flow anaesthesia technique with volatile sevoflurane combined with caudal block regional anaesthesia. In all those cases, no morbidity was found post-anaesthesia or post-operation that influenced the patient’s outcome. Improvement in the outcome of pediatric patients was seen with the low flow anaesthesia technique, which is a significant reduction of volatile used, faster wake up time, and reduction of agitation condition post anaesthesia.
REFERENCES