Anesthetic Management For Laparoscopic Surgery In Children

Essay

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Anesthesiology

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INTRODUCTION

For many years, conventional surgical procedures were the ultimate solutions for many medical conditions and even life saving in others ; however, these procedures were not free of complications. After a lot of trials and updates, the era of laparoscopic interventions became an alternative for some conventional procedures.

Laparoscopic surgery, compared to conventional surgery, has many advantages for the patient, including smaller incisions, lesser postoperative pain, earlier oral intake, quicker mobilization, faster discharge and a better cosmetic effect ***(Bannister et al., 2003)***.

In recent years, there has been a considerable improvement in laparoscopic surgical techniques and equipments and this has led to an increasing number of diagnostic and surgical procedures being done laparoscopically not only in adults but also in pediatric patients (Fig. 1) ***(Ure et al., 2000)***.

The common laparoscopically performed procedures in children include appendicectomy, pyloromyotomy, diagnosis of contralateral inguinal hernia, cholecystectomy, gastric fundoplication etc *(Bergesio et al., 1999)*.

Several other laparoscopic procedures have been reported in the pediatric population including liver biopsy, cholangiograms, splenectomy, colectomy, nephrectomy, and rectal pull-through *(Holcomb et al., 1994).*

In addition to the routine anesthetic considerations for the individual patient, the choice of the anesthetic technique in these patients should consider changes in hemodynamic and respiratory functions induced by the pneumoperitoneum and carbon dioxide (CO_2) insufflation *(Aliya, 2006).*

This essay describes the physiological changes produced by laparoscopy in children and the anesthetic considerations for laparoscopic procedures in the pediatric patient population.

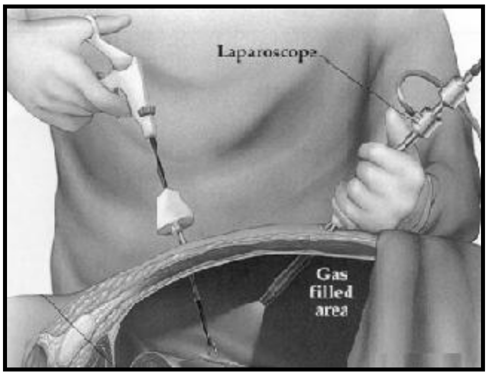

Fig. (1): Abdominal laparoscopic field.

Aim Of The Work

To describe the physiological changes produced by laparoscopy in children and the anesthetic considerations for laparoscopic procedures in the pediatric patient population.

Chapter 1

PHYSIOLOGICAL AND PHARMACOLOGICAL FACTORS THAT INFLUENCE ANESTHESIA IN INFANTS AND CHILDREN

The provision of safe anesthesia for pediatric patient depends on a clear understanding of the physiologic, psychologic and pharmacologic differences between children and adults. One of the major differences is the ability of infants to grow and mature. Child's emotional response and the need for adequate preparation for anesthesia and surgery should be considered.

Physiological differences in children

a) Cardiovascular system :

Fetal circulation is shared equally between right and left ventricles by virtue of the communications between pulmonary and systemic circulation. As a result, the development of the two ventricles is similar, with approximately equal wall thickness. At birth, the establishment of adult pattern of circulation, with a relatively high systemic pressure, places a greater burden on the left ventricle.

Consequently, there is progressive hypertrophy of the myocardium of left ventricle which attains relative adult proportions by the age of 3 months ***(Friedman et al., 1976).***

Changes in cardiac output during infancy and childhood mirror those in pulmonary ventilation. At birth, resting cardiac output is 200ml/kg/min, declining gradually to 100ml/kg/min by adolescence. As resting stroke volume remains fairly constant at about 1ml/kg, increased cardiac output in younger patients is achieved mainly by an increase in heart rate, this is approximately 120-160beats/min at birth, falling to 70-80beats/min by puberty ***(George, 1995).***

Average systolic blood pressure at birth is 65-80mmHg ; it increases to 90-100mmHg by about 1 year, where it remains until 6-7 years. Thereafter, there is a gradual increase in systolic pressure to 120mmHg at puberty. Also it is evident that parasympathetic control of cardiovascular system is well developed at birth while sympathetic control is immature. Low sympathetic neural output in infants may explain their susceptibility to reflex bradycardia and hypotension. Furthermore, a low level of baroreceptor activity in infants may reduce their ability to adapt hypotension by an increase in heart rate. Reflex bradycardia and hypotension in infant during anesthesia are potentially caused by laryngoscopy, tracheal intubation, and traction on eye muscles and viscera. Also, bradycardia may be caused by a variety of anesthetic drugs including suxamethonium, halothane and neostigmine. These effects can be avoided or treated with intravenous atropine 0.02mg/kg ***(Gregory, 1982)***.

b) Respiratory System :

Oxygen consumption in neonate is 7ml/kg/min, or about twice the adult value. This is reflected by an increase in the resting minute ventilation which is 200ml/kg/min. in newborn compared with 100ml/kg/min at puberty. Tidal volume remains constant at 7ml/kg throughout life so, the increased ventilation in younger patients is brought about by an increase in respiratory rate, which is approximately 30 breaths/min at birth, 24 breaths/min at one year and 12 breaths/min in adult. Alveoli increase in number and size until the child is approximately 8 years old, further growth manifest as an increase in size of the alveoli and airways ***(Davis and Reid, 1994).***

Normal lung capacities are the result of a balance between the elastic forces of the chest wall and the lung. In infants and children, the chest wall is more compliant than lungs, with the result that functional residual capacity is reduced and small airways have an increased tendency to close at end expiration. Another important factor is the composition of diaphragmatic and intercostal muscles. These muscles do not achieve the adult configuration of muscle fibers until the child is approximately 2 years old when muscles have the ability to perform repeated exercise. During pediatric anesthesia, any factor increases the work of breathing contributes to early fatigue of respiratory muscles which is leading to apnea, carbon dioxide retention, hypoxia and respiratory failure. These effects can be prevented by use of controlled ventilation with a large tidal volume 12ml/kg ***(Keens et al., 1978).***

After the neonatal period, control of breathing is generally similar to that in adults. Prematurely born infants are a notable exception to this rule as maturation of neuronal respiratory control is related to post-conceptual age rather than postnatal age. Immaturity of respiratory control, together with an increased susceptibility to fatigue of respiratory muscles, may be responsible for the increased risk of postoperative apnea in preterm infants ***(Liu et al., 1983).***

c) *Renal function and fluid balance :*

Renal function is markedly diminished in neonate because of low perfusion pressure and immature glomerular and tubular function. Nearly complete maturation of glomerular filtration and tubular function occurs by approximately 20 weeks after birth, although maturation is somewhat delayed in premature infants. Complete maturation of renal function occurs by about 2 years of age. Thus, the ability to handle free water and solute loads, especially Na^+, may be impaired in the neonate, and the half-life of medications excreted by means of glomerular filtration will be prolonged ***(Leake and Trygstad, 1994)***.

At birth, total body water constitutes 80% of body weight, but this falls dramatically to around 60% by the end of the first year. Most of this reduction is accounted for by a decrease in the extra-cellular fluid volume, which declines from 46% at birth to 26% at one year of age. There is a further gradual reduction in extra-cellular volume throughout childhood, so in adult it constitutes about 16% of body weight. The increased volume of extra-cellular fluid in infants compared with adults enables them to tolerate a somewhat greater degree of dehydration before developing clinical symptoms. It also provides a greater volume of distribution for highly ionized drugs such as muscle relaxants ***(Friis, 1995)***.

d) Blood :

Average blood volume ranges from 80 to 90ml/kg at birth depending on whether the umbilical cord is clamped early or late. By one month of age, the blood volume is 70-80ml/kg as in adult. Also, hemoglobin concentration ranges from 16-19g/dl and red cell count is 3.74-6.54 x 10^{12}/L at birth. These values are greater than corresponding values in adult because the relatively hypoxic environment of the uterus stimulates production of erythropoietin, which in turn triggers red cell production. After birth there is a sharp fall in erythropoietin activity due to greater availability of oxygen. As a result, hemoglobin concentration and red cell count decline steadily to reach 9.5-11g/dl and 3.4 x 10^{6}/L respectively by 7-9 weeks. By 6 months, mean hemoglobin of 12.5g/dl is achieved, which is maintained until 2 years of age. Thereafter, there is a gradual increase up to puberty ***(Letski, 1991)***.

At full term, 70-80% of hemoglobin in the circulating red cells is in the form of fetal hemoglobin (Hb. F), the remainder being adult hemoglobin (Hb. A). Hb. F has a higher affinity for oxygen, which is advantageous in the hypoxic intrauterine environment. However, after birth persistence of Hb. F becomes a problem because oxygen cannot be unloaded so easily in the tissues. In term infants, Hb F is virtually all replaced by Hb. A by the age of 6 months and there is an increased levels of 2, 3-diphosphoglycerate (2, 3-DPG) ; these changes shift oxygen dissociation curve to the right. The net result is that, although hemoglobin concentration in normal infant decreases in the first 3 months of life, oxygen delivery to the tissues increases progressively from birth to 8 months of age when it achieves adult values. These observations make the point that anemia should be judged by its effect rather than by any arbitrary concentration of hemoglobin. Increase in cardiac output or elevation of blood lactate are rarely seen in normal individuals until hemoglobin concentration falls below 6g/dl ***(Oski, 1995)***.

e) Liver :

At term, functional maturity of the liver is somewhat incomplete. Most enzyme systems for drug metabolism are developed but not yet induced by the agents they metabolize. As the infant grows, the ability to metabolize medications increase rapidly due to increased hepatic blood flow delivering more to the liver and also due to development and induction of enzyme systems. Conjugation reactions are often impaired in neonate, resulting in jaundice ; diminished degradation reactions lead to long drug half-lives. Thus, it is common to have a longer drug elimination half-life in neonate but a shorter drug half-life in infant and older child than in adults ***(Besunder et al., 1988).***

The premature neonatal liver has minimal glycogen stores and is unable to handle larger protein loads. This difference accounts for the tendency to hypoglycemia and acidemia. Additionally, plasma levels of albumin and other proteins necessary for drugs binding are lower in term newborns than in older infants. This condition has clinical implications regarding neonatal coagulopathy, as well as for drug binding and pharmacodynamics ; the lower the albumin value, the less protein binding and the greater the levels of free drug ***(Wood, 1986).***

f) Thermoregulation :

The infant is particularly vulnerable for hypothermia owing to a very large ratio of body surface area to weight, and to a limited ability to cope with cold stress. Premature infant is even more susceptible because of very thin skin and limited fat stores. The infant may compensate by means of shivering and non-shivering cellular thermogenesis. The minimal ability to shiver during first 3 months of life makes cellular thermogenesis, through metabolism of brown fat, the principal method of heat production ***(Himms, 1976).***

During anesthesia, temperature control mechanisms are less effective or absent, and body temperature tends to fall towards that of the environment. Hypothermia is associated with reductions in oxygen consumption, metabolic rate, respiratory rate, heart rate and cardiac output. The potency of inhaled anesthetics is increased and the duration of action of muscle relaxants and opioids is prolonged. Postoperatively, metabolic activity is increased to restore body temperature. However, if the depressed respiratory and cardiovascular systems are unable to meet the greatly increased oxygen demands in cold stress, hypothermia and lactic acidosis will appear. So, all efforts are done to prevent or minimize heat loss during pediatric anesthesia ***(Nightingale and Meakin, 1986).***

g) Perception of Pain :

Somatic pain is a subjective sensory experience resulting from the intermixing of three main components : (1) motivational-directive, conveyed by unmyelinated C fibers (slow pain or true pain), which leads to protective reflexes such as autonomic reactions, muscle contraction and rigidity ; (2) sensory-discriminating, propagated by myelinated A-delta fibers (fast pain), which permits accurate identification and location of the nociceptive stimulus and elicits withdrawal reactions ; and (3) cognitive-evaluative, a multifactorial, but typically cerebral process which does not involve any peripheral receptors. C-fibers are functioning from early fetal life ; thus, the motivational-directive component (true pain) is entirely perceived by the neonate and the fetus. As A-delta fibers are thinly myelinated, the velocity of nerve impulses depends on the progression of myelinization ***(Gissen et al., 1980).***

The main difference in pain perception between children and adults pertains to the cognitive-evaluative component that develops throughout childhood and adolescence. This is influenced by a panel of environmental, educational, social, cultural and individual factors including previous experiences of pain. A major difficulty is the assessment and sometimes identification of pain in young children. The younger the patient, the greater the difficulty to communicate with, as his ability to express distress and discomfort is limited. During last decade, pediatric pain has received considerable attention and reliable age-related pain scales have been developed to evaluate both pain and the efficacy of its treatment ***(Dalens and Strome, 1990).***

Pharmacological view on pediatric anesthesia

The response of infants and children to medications is modified by many factors like body composition, protein binding, body temperature, distribution of cardiac output, maturation of Blood Brain Barrier (BBB) and functional maturity of liver and kidneys. Total body water content is significantly higher in infants ; water soluble drugs like suxamethonium have a larger volume of distribution