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Review

Paediatric minimally invasive abdominal and urological surgeries: Current trends and perioperative management

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ABSTRACT

Minimally invasive surgery during abdominal, thoracic and urological procedures has become the standard management of many surgical interventions in adults. Recent development of smaller devices has allowed the management of many paediatric surgeries using these minimally invasive techniques. However, the lack of knowledge of (a) adequate management of haemodynamic and respiratory alterations occurring during those procedures and (b) postoperative advantages of these techniques over open surgeries, still impairs their development. The current review aimed to clarify mechanisms of those haemodynamic and respiratory alterations, propose easy rules in order to overcome them and shed the light on potential postoperative advantages of minimally invasive surgery in paediatrics.

1. Introduction

The popularity of endoscopic surgery, and more widely minimally invasive surgery, has increased among surgeons over these last years and it has now become the standard management of many abdominal and urological procedures such as appendectomy and cholecystectomy in adults. Moreover, many more complicated surgeries such as colonic and even thoracic surgeries are now performed by many teams over the world using minimally invasive endoscopic techniques [1–3].

In children, there is also a trend toward the development of this technique [4–7]. This has been possible thanks to the miniaturisation of devices used for endoscopic procedures and the development of robotic surgery that allowed more freedom and precision in performing the adequate surgical treatment in a limited space [8]. However, despite these developments, many surgeons and anaesthesiologists are still reluctant to use these minimally invasive techniques [9]. Part of their scepticism comes from the intraoperative haemodynamic and respiratory consequences of endoscopic procedures and the lack of knowledge of great advantages of these techniques in providing rapid postoperative recovery and discharge from hospital [8,10].

Minimally invasive surgery is now widely used all over the world from neonates to adolescents [11,12]. It is still necessary that it is performed by experimented surgeons and anaesthesiologists, specifically in extremely low birth weight premature babies [9,13]. The introduction of laparoscopy in paediatric surgery started in the 1990s. The indications were the same as those practiced in adults and encompassed cholecystectomy, Nissen fundoplication and splenectomy [4,12,14,15]. Laparoscopy was extended to younger children and for a wide variety of pathologies, from congenital anomalies to acquired ones [16–18]. In neonates, this approach is currently used for numerous patients either for congenital anomalies or as a diagnostic tool. Indeed, in very preterm babies with enterocolitis, laparoscopy has been introduced as a diagnosis and therapeutic tool in order to rapidly decrease the inflammatory process [18–20]. Patent ductus

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arteriosus ligation has also been performed for many years using thoracoscopy on patient weighing at least 1500 g [21,22]. Duodenal atresia and oesophageal atresia with trachea-oesophageal fistula are now currently operated using minimally invasive surgery [5,7,18,23]. Others congenital anomalies such as intestinal duplication, cystic neonatal ovary and even sometimes at this age Nissen fundoplication are also operated using these minimally invasive techniques.

Moreover, congenital pulmonary malformations are now operated by thoracoscopy in infants no older than 3 months [14]. This technique allows the developing of fast track protocols with early patients discharge (at day 1 postoperative) or the day of the surgery in selected patients [14].

Patients with urological pathologies can also beneficiate of these techniques. Retro-peritoneoscopy performed for nephrectomy, hemi nephrectomy. Equally, reconstructive surgery with treatment of an obstructive pyeloureteral junction or ureteral stenosis are also performed using the same techniques with good results [15,24].

Minimally invasive surgeries are offering a magnified view of the operative field, making the surgery easier. In addition, with a well-trained surgeon, the operative time is reduced. Future developments will consist in smaller instrument adapted to smaller infants and a wider use of robotic surgery [8].

The goal of this review is to summarise the current knowledge concerning major indications on minimally invasive surgeries, including abdominal, thoracic and urological procedures, in paediatrics (both in children and infants); the perioperative management during these procedures and their advantages in providing safe and rapid postoperative rehabilitation. Minimal invasive procedures in orthopaedics were not described in this review because of their minimal effect on the cardiovascular and respiratory systems.

2. Intraoperative anaesthesia management

Most consequences of endoscopic surgeries involve their haemodynamic and respiratory effects and are tightly related to the location of the surgery and CO_2 insufflation. In order to allow an easier understanding of phenomenon occurring during those laparoscopic procedures, a distinction was established according to the site of surgery:

- intraperitoneal;
- retroperitoneal;
- intrathoracic (or thoracoscopic surgeries).

For each location, major haemodynamic, respiratory changes and consequences for anaesthesia management will be discussed.

2.1. Intraperitoneal insufflation

2.1.1. Haemodynamic effects of intraperitoneal CO_2 insufflation

Classically, the intraoperative insufflation of CO_2 into the peritoneal cavity has been associated with a decrease in cardiac output ranging from 15 to 30% [25–27]. However, looking closely to the data published shed light on some important factors influencing this decrease. First, intra-abdominal pressure is one of the most important factors influencing the decrease in cardiac output. Giebler *et al.* [28,29] have found an intra-abdominal pressure up to 10–12 mmHg to increase venous return to the heart and therefore to increase cardiac output. In contrast, higher levels of pressure are associated with a decrease in the venous return and cardiac output. These pressure-dependent effects have been interpreted as a "pushing pressure" favouring the increase of venous return at low intraperitoneal pressures while greater insufflation pressure impairs venous return leading to the decrease in venous return. In children, the same results were observed with intraperitoneal pressures bellow 6 mmHg causing no decrease of cardiac output [30,31] while higher ones ($\geq$ 12 mmHg) decreasing cardiac output [30]. Given the great impact of intra-abdominal pressure on cardiac output variations, muscle relaxation should be considered in order to increase the compliance of the peritoneum cavity and allow achieving a best surgical view with a minimal insufflation pressure. However, this practice is derived from adult evidences [32–34]: although administering muscle relaxation has been shown to improve intubation condition in children [35], there are no such evidences concerning their intraoperative administration during intra-abdominal laparoscopic procedures in children and infants. However, given the detrimental impact of an increase of intra-abdominal pressure on systemic haemodynamic, muscle relaxation is empirically recommended in this special indication.

The second modulator of the haemodynamic effect associated with intraperitoneal insufflation is the level of arterial CO_2. An increase of its concentration is commonly encountered because of its rapid diffusion from the peritoneal cavity to the blood, especially in younger patients (with a higher peritoneal surface-to-weight ratio in comparison to older children and adults) [10,36,37]. Hypercapnia is known as a powerful activator of the sympathetic system leading to the increase of both heart rate and contractility [38] and preserving hypercapnia might participate to the intraoperative management during intraperitoneal laparoscopy. This is highly supported by the study of DeWaal and Kalkman [31]. These authors did not correct the increase of end-tidal CO_2 induced by intraperitoneal insufflation and observed an increase (instead of the classically described decrease) of cardiac output. This "paradoxical" effect was explained by the stability of the stroke volume (insufflation pressure were set to 5 mmHg in this study) and the increase in heart rate [31]. In addition, the "fear" from the CO_2 increase occurring during insufflation leads to an inadequate ventilation correction by the anaesthesiologist (in order to correct CO_2 to its pre-insufflation value), leading to the exacerbation of the haemodynamic compromise induced by the rise of both intra-abdominal and intrathoracic pressures (see the next section). Finally, studies in adults have shown "permissive hypercapnia" to increase oxygen delivery to tissues (according to the physiological Bohr effect) [39,40]. Although such data are lacking in children and infants, the moderate increase of CO_2 during laparoscopy could be considered as more beneficial than harmful on general haemodynamic and tissue oxygenation [39,40].

Another factor influencing the cardiac output is the increase in the afterload occurring because of the release of many vasoactive compounds such as norepinephrine and vasopressin [41,42]. Although, studies in adults have shown this effect to be preventable by α2-agonists, no such evidences are available in paediatrics [42].

Some therapeutic interventions might also impact the haemodynamic-related effects of laparoscopy. Recently, a study using an optimal management of intravenous fluid intakes using the oesophageal Doppler found no variation of cardiac output when intra-abdominal pressure was increased up to 15 mmHg [43]. Interestingly, this study used protective ventilation (end-expiratory pressure of 5 cmH_2O and a tidal volume of 7 $mL \cdot kg^{-1}$) with no patient exhibiting an increase in end-tidal CO_2 greater than 50 mmHg. Given all these evidences, the optimal management of hemodynamic-related haemodynamic changes during intraperitoneal laparoscopy in children might be achieved following these rules: an intra-abdominal pressure between 6 and 12 mmHg, the administration of a muscle-relaxant, the absence of active correction of the increase in end-tidal CO_2 (or at least when a moderate increase up to 45 to 50 mmHg of end-tidal CO_2) and the correct management of the vascular feeling (Table 1).