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Minimal invasive surgery in the newborn: Current status and evidence

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ABSTRACT

The evolution of minimally invasive surgery (MIS) in the newborn has been delayed due to the limited working space and the unique physiology. With the development of smaller instruments and advanced surgical skills, many of the initial obstacles have been overcome. MIS is currently used in specialized centers around the world with excellent feasibility. Obvious advantages include better cosmesis, less trauma, and better postoperative musculoskeletal function, in particular after thoracic procedures. However, the aim of academic studies has shifted from proving feasibility to a critical evaluation of outcome. Prospective randomized trials and high-level evidence for the benefit of endoscopic surgery are still scarce. Questions to be answered in the upcoming years will therefore include both advantages and potential disadvantages of MIS, especially in neonates. This review summarizes recent developments of MIS in neonates and the evidence for its use.

Introduction

With the widespread implementation of minimally invasive surgery, there has been a revolution in surgical practice over the last decades. While this technology was quickly assimilated in the care of adults, its introduction was much slower in children, and especially in small infants and neonates. The obstacles included a lack of specialized equipment suitable for the size of the patient. Also, technical developments were delayed due to the limited number of surgeons performing these procedures. Currently, both instruments and techniques are adapted that even the most complicated neonatal procedures can be performed laparoscopically or thoracoscopically. Large series could demonstrate safety and feasibility of various minimally invasive procedures in the neonatal period.

This review aims to summarize the current state of the art in neonatal laparoscopic and thoracoscopic surgery with special focus on recent developments of the most common indications today.

Physiologic aspects of neonatal endoscopic surgery

The immediate postpartum period is a time of significant physiological adaptation, including changes in organ and immune function. Moreover, the transition from fetal to postpartum blood circulation makes the neonate unique in its physiology.

There is limited data regarding the impact of laparoscopy, thoracoscopy, and insufflation of CO_2 on the physiologic response of the newborn. Nevertheless, experimental and clinical data point towards a higher sensitivity of the neonate to CO_2 insufflation and therefore potential negative effects.[1–3]

Cardiocirculatory effects

Experimental data have demonstrated an increased CO_2 absorbance in the young[4] and a higher sensitivity of the neonatal cardiovascular system to CO_2.[2] The increased abdominal pressure during laparoscopy leads to a compression of the vena cava with a decrease in preload and cardiac output. Therefore a sufficient intraoperative hydration is mandatory. However, clinical observations point towards a good tolerance of the neonate to a capnoperitoneum with pressures up to 8–10 mmHg maximum and increased slowly. Experimental data confirmed that a moderate pressure insufflation does not result in any significant decrease of capillary perfusion in splanchnic organs, thereby limiting cardiocirculatory effects of a pneumoperitoneum.[5–7] In contrast, laparoscopic procedures with higher-pressure insufflation or operations with a duration over 2 h frequently lead to a decrease in circulatory blood volume, central venous oxygen saturation, and metabolic acidosis.[8] To prevent this, the administration of colloidal instead of crystalloid fluids is recommended. It is also important to recognize that not only the insufflation but also the desufflation of

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the pneumoperitoneum and the concomitant decrease in intra-abdominal pressure may impair macrocirculation.[9,10] Therefore, thorough postoperative monitoring is warranted.

One characteristic in the newborn is the persistence of fetal circulation with patent umbilical vessels and potential right-to-left shunts. This puts neonatal patients undergoing laparoscopy at increased risk for severe forms of inadvertent gas embolism, which has been described in several cases.[11]

Respiratory effects

The respiratory system of the newborn is immature as its postnatal development continues through early childhood. Compared to adults the neonatal ratio of alveolar surface to body surface area is only one-third. To account for an increased oxygen demand, alveolar minute ventilation and oxygen consumption in neonates is twice that of the adult. Even under normal physiologic circumstances, the immature cardiac and respiratory systems must function near the limit of their functional reserve to satisfy this metabolic need. Therefore, any rise of intraabdominal pressure with resorption of CO_2 may compromise the respiratory function of the neonate.

When establishing a pneumoperitoneum, the lung compliance is decreased by 30–50% and by another 20% if the neonate is placed in Trendelenburg position.[12] Insufflation of CO_2 leads to a decrease of functional residual capacity while increasing oxygen consumption, pulmonary resistance, and alveolar minute ventilation. In addition, an increased intraabdominal pressure is transmitted to the thorax, where it worsens the ventilation/perfusion index with opening of intrapulmonary arteriovenous shunts. A good way for the anesthetist to counteract these patterns is hyperventilation.

The adverse effects of neonatal minimally invasive surgery may be even bigger in thoracoscopy. Multiple studies showed that a massive CO_2 absorption in the thoracic cavity may be neurotoxic to the neonate.[13–16] Recent reports on significant hypercapnia and severe acidosis during thoracoscopic repair of CDH have therefore called into question the safety of this practice and require further evaluation.[16]

Renal function

In contrast to adults, renal perfusion and corresponding urine production appear to be more affected by increased abdominal pressures in neonates. As the majority of infants develop temporary anuria during laparoscopic procedures, meticulous and well-balanced fluid substitution is mandatory in these patients.[17] However, fluid replacements should not be calculated based on urinary output in order to prevent fluid overload.

Laparoscopy in the neonate

Pyloromyotomy

Laparoscopic pyloromyotomy for hypertrophic pyloric stenosis was first described by Alain et al.[18] in 1991. It is usually performed using a three-port technique with 3-mm instruments but can also be conducted in a single-incision laparoscopic approach.[19] Several authors reported that laparoscopic pyloromyotomy does have a considerable learning curve and experience in laparoscopy seems to be an important factor to safely perform this procedure.[20] In the last decade, several authors with varying experience reported that this operation is associated with potential complications, especially intraoperative perforation and inadequate division of the stenosis.[21,22] However, at the same time, several meta-analyses on laparoscopic versus open pyloromyotomy have been conducted[23,24] (Tables 1 and 2). In the most recent one, Oomen et al.[23] included four randomized controlled trials with a total of 502 patients. The incidence of complications such as incomplete myotomy, mucosal perforation, and reoperation was 4.9% in the laparoscopic group compared to 2.0% in the open group, which was not significantly different. The mean difference in time to full feeds was 2.3 h in favor of the laparoscopic approach and therefore has limited clinical relevance. In conclusion, laparoscopic pyloromyotomy might be acknowledged as the standard of care with equal safety and effectiveness when performed in centers with expertise. It may be left at the discretion of the surgeon to choose between the two techniques.

Table 1
CEBM Levels of Evidence.

Level	Type of study
1a	SR/MA of RCTs
1b	Individual RCT
2a	SR/MA of cohort studies
2b	Individual cohort study (including low quality RCT)
3a	SR/MA of case–control studies or retrospective comparative studies
3b	Individual case–control Study or retrospective comparative study
4	Case-series (and poor quality cohort and case–control studies)
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or “first principles”

SR: systematic review; MA: meta-analysis; RCT: randomized controlled trial. Adapted with permission from Oxford Centre for Evidence-Based Medicine.[126]

Ovarian cysts

Cystic ovarian masses are common in the fetal and neonatal period. With no spontaneous resolution and increasing size, these cysts have an increased risk of torsion, rupture, intestinal obstruction, hemorrhage, and necrosis. Although there is controversy about the best treatment, depending on their ultrasound pattern and diameter, most authors recommend treatment of cysts larger than 4 cm.[25] Potential therapeutic interventions include aspiration, open surgery, or laparoscopic exploration. The main advantage of laparoscopy is that it provides both diagnostic and treatment possibilities. No advanced laparoscopic skills are required to exclude differential diagnoses and provide adequate treatment.

The first technique was described by Waldschmidt and Schier[26] and reported in a series by van der Zee et al.[27] Several technical modifications for the neonatal period have been suggested, including single-incision approaches.[28–31] In case of adnexal torsion, the ovary can be detorsed and either resected or preserved.[32–34] It has been shown in adolescent girls that the intraoperative assessment of adnexal necrosis by the surgeon is poor and therefore, if possible, the adnexa should be preserved after detorsion.[35] However, neonatal ovarian cysts with an origin in the fetal period frequently undergo autoamputation in utero, therefore resection may be the only option in many cases.[32]

Ultrasound-guided aspiration of suspected ovarian cysts has been reported and might be even less invasive than laparoscopy but carries the risk of false diagnosis including intestinal duplications or cysts of other origin. Simple puncture of those structures may lead to disastrous complications.[36]

Fundoplication

Numerous authors suggest potential benefits of laparoscopic versus conventional fundoplication in infants and children. A meta-analysis performed by Siddiqui et al.[37] showed that these advantages include shorter time to full feeding, shorter hospital