Introduction

The impact of surgery is reflected by the function of specific organs, and hormonal, immunologic, and metabolic changes. The limited number of reports on the effects of minimally invasive techniques in children is focused in particular on organ functions or cell products, but the complex responses have not been investigated as a whole yet. Today, up to 60% of abdominal procedures in children can be performed laparoscopically (Ure et al. 2000) and there is an increasing use of minimally invasive techniques in children with specific conditions, such as in premature babies and newborns (Fujimoto et al. 1999b), and children with cancer (Holcomb 1999; Warmann et al. 2003). However, very little is known about the impact on specific organs and on endocrinologic and immunologic parameters in this age group. The present chapter summarizes the available data.

Specific Organs and System Function

Cardiovascular

Cardiovascular changes are mainly the result of hypercarbia from an increase in intra-abdominal pressure, peritoneal absorption of carbon dioxide (CO₂), and a stimulation of the neurohumoral vasoactive system. These conditions result in a decrease in venous return, preload, cardiac output and an increase in heart rate, mean arterial pressure, and systemic and pulmonary vascular resistance. These effects have been documented in numerous series of adults (Neudecker et al. 2002).

Also in infants, the heart rate, mean arterial pressure, left ventricular end-systolic and end-diastolic volumes, and meridional wall stress increase (de Waal and Kalkman 2003; Gentili et al. 2000; Laffon et al. 1998). However, Bozkurt et al. (1999) reported on transient arrhythmias in 10 out of 27 children aged 1–12 months, but they did not find significant alterations of cardiovascular parameters and the base excess during and after laparoscopy. In a prospective study on 33 children undergoing laparoscopic fundoplication, no significant changes in the heart rate, blood pressure, partial oxygen saturation, or base excess were detected when the insufflation pressure did not exceed 10 mmHg (Mattioli et al. 2003). Fujimoto et al. (1999b) reported no cardiac decompression or fluid and electrolyte balances in 65 laparoscopically operated neonates. De Waal and Kalkman (2003) reported that low pressure CO₂ pneumoperitoneum did not alter the cardiac index in a series of 13 children aged 6–36 months. Therefore, in otherwise healthy infants and children cardiovascular changes during pneumoperitoneum may be expected to be without clinical consequences and to vanish after desufflation (Gueugniaud et al. 1998).

Since hemodynamic effects of pneumoperitoneum are volume dependent, adequate pre- and intraoperative loading is essential, in particular in patients with cardiac diseases (Neudecker et al. 2002). Tobias and Holcomb (1997) concluded from two cases with decreased myocardial function that avoiding agents with negative inotropic effects and including those that dilate the peripheral vasculature allows laparoscopic procedures to be performed. However, the authors observed a substantial increase in arterial and end-tidal CO₂. Van der Zee et al. (2003) retrospectively analyzed 20 neonates with various cardiac anomalies, such as tetralogy of Fallot, defects of the ventricular or atrial septum, or open ductus Botalli. No adverse effects were encountered during and after laparoscopy.

Lung Physiology and Gas Exchange

Carbon dioxide pneumoperitoneum causes considerable hypercarbia and respiratory acidosis, reduces pulmonary compliance, and increases airway resistance (Neudecker et al. 2002). Manner et al. (1998) found that head-down tilt in children induced a mean decrease of 17% in lung compliance, which was further decreased by 27% during pneumoperitoneum. The peak airway pressure increased by 32%. Hsing et al. (1995) investigated 126 children during brief pneumoperitoneum of 15 min. Although the airway pressure and end-tidal CO₂ tension were increased, this did not differ between age groups. Tobias et al. (1995) investigated 55 children with brief pneumoperitoneum. An increase in ventilatory parameters was not required.
Information on the impact of long pneumoperitoneum on lung physiology and gas exchange in small children and newborns is lacking. Relaxation of the diaphragm in combination with increased abdominal pressure may lead to compression of the lower lung lobes. In particular in small children, this may result in a decreased tidal volume, ventilation-perfusion mismatch, increased dead space, and decreased pulmonary compliance (Rayman et al. 1995). The clinical impact in children with impaired lung function remains to be determined.

Renal Function

Numerous experimental studies and some clinical trials in adult patients showed a significant and reversible decrease in renal blood flow, urinary output, and the glomerular filtration rate during pneumoperitoneum (Dunn and McDougall 2000; Schäfer and Krähenbühl 2001). These effects were pressure dependent (Kirsch et al. 1994). Several underlying mechanisms, such as decreased cardiac output, compression of the renal vein and parenchyma, ureteral obstruction, and hormonal effects have been proposed.

However, normalizing cardiac output with plasma expanders failed to improve diminished renal blood flow and glomerular filtration (Harman et al. 1982). In experimental studies, ureteral stents (McDougall et al. 1996) and intraoperative urograms (Kirsch et al. 1994) during pneumoperitoneum confirmed the absence of ureteral obstruction. Kirsch et al. (1994) found a decrease of 92% in vena cava blood flow in rats and concluded that the renal effects were caused by renal vascular insufficiency from central venous compression. Additional compelling evidence for the cause of renal effects is that of direct renal parenchymal compression (Razvi et al. 1996). Hamilton et al. (1998) confirmed that catecholamines may play an additional role. Endothelin, a potent vasoconstrictor, was increased in response to renal vein compression during pneumoperitoneum.

These effects have not been investigated in infants and children. They may not be clinically relevant in otherwise healthy children, but research on the renal effects of pneumoperitoneum in children with impaired renal function remains mandatory.

Hepatoportal and Splanchnic Function

Intestinal circulation of hollow viscus and solid organs reveals a decrease, similar to that of hepatic blood flow. Schilling et al. (1997) found a decrease in blood flow of up to 54% in the stomach, 32% in the jejunum, and 44% in the colon during laparoscopy in patients. In rats (Schäfer et al. 2000), microcirculation in solid organs compared to bowel was even more suppressed. This was a pressure-related phenomenon. When using mechanical retractors to lift the abdominal wall, no impairment of intestinal blood flow was detected (Kovusalo et al. 1997).

It remains unclear whether the impairment of microcirculation may cause clinically relevant damage to the mucosal barrier with subsequent translocation, in particular in small children. Alterations in organ perfusion could have detrimental effects in children with comorbidities or preexisting organ disorders. Bozkurt et al. (2002) reported a considerable increase in arterial and end-tidal CO2 in children with portal hypertension as compared to systemically healthy children.

Cerebral Function/Intracranial Pressure

Experimental studies using a small animal model showed that laparoscopy is associated with an elevation of basilar artery velocity and a decrease in resistance index values (Erkan et al. 2001). Malone dialdehyde values as an indicator for ischemia-reperfusion injury of brain tissue were not altered. In adults, CO2 pneumoperitoneum induced hypercapnia with a subsequent increase in cerebral blood volume (Kitajima et al. 1996) and cerebral blood flow velocity (Fujii et al. 1994).

It has been advocated that infants have a greater cerebrovascular sensitivity to changes in P CO2 (Wyatt et al. 1991). De Waal et al. (2002) tried to quantify the impact of CO2 pneumoperitoneum on cerebral oxygenation and blood flow by near-infrared spectroscopy, a method for determination of relative changes in regional cerebral oxygen saturation. There was a significant increase in cerebral blood volume and oxygen saturation, the latter not returning to normal 10 min after desufflation. However, all children had normal intracranial compliance and there was no indication of a clinically relevant increase in intracranial pressure.

To counteract these CO2-induced effects, the authors advocate more aggressive hyperventilation during CO2 insufflation. However, Huetteman et al. (2002) found an increase of cerebral blood flow velocity by Doppler sonography in young children independent from hypercapnia, whereas CO2 reactivity remained normal.

There are reports on an increase of intracranial pressure from 9 mmHg to over 60 mmHg within 10 min in patients with head injury undergoing diagnostic laparoscopy (Mobbs and Yang 2002). Similar data were reported from children with ventriculoperitoneal shunts undergoing laparoscopy (Uzzo et al. 1997). Clinically, laparoscopic surgery was well tolerated in several series of children with ventriculoperitoneal shunts (Jackman et al. 2000; Walker and Langer).