Pediatric Minimally Invasive Surgery
Implementation into current surgical practice and impact on neonatal physiology

Minimaal Invasieve Kinderchirurgie
Implementatie in de hedendaagse praktijk en gevolgen voor de neonatale fysiologie
(met een samenvatting in het Nederlands)

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Minimally invasive pediatric surgery: Increasing implementation in daily practice and resident’s training
Abstract

Background
In 1998, the one-year experience in minimally invasive abdominal surgery in children at a pediatric training center was assessed. Seven years later, we determined the current status of pediatric minimally invasive surgery in daily practice and surgical training.

Methods
A retrospective review was undertaken of all children with intra-abdominal operations performed between 1 January 2005 and 31 December 2005.

Results
The type of operations performed ranged from common interventions to demanding laparoscopic procedures. 81% of all abdominal procedures were performed laparoscopically, with a complication rate stable at 6.9%, and conversion rate decreasing from 10% to 7.4%, compared to 1998. There were six new advanced laparoscopic procedures performed in 2005 as compared to 1998. The children in the open operated group were significantly smaller and younger than in the laparoscopic group ($p<0.001$ and $p=0.001$, respectively). The majority (64.2%) of the laparoscopic procedures were performed by a trainee. There was no difference in the operating times of open versus laparoscopic surgery, or of procedures performed by trainees versus staff surgeons. Laparoscopy by trainees did not have a negative impact on complication or conversion rates.

Conclusions
Laparoscopy is an established approach in abdominal procedures in children, and does not hamper surgical training.

Keywords: Pediatric surgery, Minimally invasive surgery, Training
Learning curve of thoracoscopic repair of esophageal atresia
Abstract

Background
Thoracoscopic repair of esophageal atresia is considered to be one of the more advanced pediatric surgical procedures, and it undoubtedly has a learning curve. This is a single-center study that was designed to determine the learning curve of thoracoscopic repair of esophageal atresia.

Methods
The study involved comparison of the first and second five-year outcomes of thoracoscopic esophageal atresia repair.

Results
The demographics of the two groups were comparable. There was a remarkable reduction of postoperative leakage or stenosis, and recurrence of fistulae, in spite of the fact that nowadays the procedure is mainly performed by young staff members and fellows.

Conclusions
There is a considerable learning curve for thoracoscopic repair of esophageal atresia. Centers with the ambition to start up a program for thoracoscopic repair of esophageal atresia should do so with the guidance of experienced centers.
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The influence of the CO$_2$ pneumoperitoneum on a rat model of intestinal anastomosis healing
Abstract

Background
The CO₂ pneumoperitoneum, which is used for laparoscopic surgery, causes local and systemic effects in patients. Concern arises about what the pressurized anoxic environment of the CO₂ pneumoperitoneum has on intestinal healing. Earlier experimental work showed a negative correlation between intestinal healing and the applied intra-abdominal pressure. To further elucidate this, we developed a rat model, in which enterotomy healing can be compared after open or laparoscopic surgery. Possible mechanisms of injury, such as impaired neoangiogenesis or injury through hypoxia-induced pathways were studied.

Methods
A new experimental mechanically ventilated rat model was developed. An enterotomy was made and closed via laparotomy (group I) or laparoscopy under CO₂ pressures of 5 mmHg (group II) or 10 mmHg (group III). Intestinal healing was tested in vivo after 1 week by bursting-pressure analysis. The effect of the operative procedure on neoangiogenesis was tested by counting factor VIII positive vessels in biopsies of the perianastomotic granulation tissue after 1 week. Intestinal anoxia was tested by quantifying HIF-1α protein levels in intestinal biopsies, taken before the enterotomy closure.

Results
The bursting pressures were significantly lower after laparoscopic surgery at 10 mmHg CO₂ pneumoperitoneum (group III) compared with rats that had undergone open surgery (group I) or laparoscopic surgery at 5 mmHg CO₂ pneumoperitoneum (group II). There was no significant quantitative difference between the three groups in the neoangiogenesis nor was there a difference in the amount of HIF-1α measured in the intestinal biopsies.

Conclusions
We developed a surgical model that is well fitted to study the effects of pneumoperitoneum on intestinal healing. With this model, we found further evidence of CO₂ pressure-dependent hampered intestinal healing. These differences could not be explained by difference in neoangiogenesis nor local upregulation of hypoxic factors.

Keywords: Anastomosis healing, Rat model, CO₂, Pneumoperitoneum, Neoangiogenesis, HIF-1 alpha
The effects of CO$_2$-insufflation with 5 and 10 mmHg during thoracoscopy on cerebral oxygenation and hemodynamics in piglets: an animal experimental study
Abstract

Objective
To evaluate the effect of CO\textsubscript{2}-insufflation with 5 and 10 mmHg on cerebral oxygenation and hemodynamics in neonates.

Background
An increasing percentage of surgical interventions in neonates are performed by minimal invasive techniques. Recently, concerns have been raised regarding a decrease of cerebral oxygenation in neonates during thoracoscopy as a result of CO\textsubscript{2}-insufflation.

Methods
This was an animal experimental study. Piglets were anesthetized, intubated, ventilated, and surgically prepared for CO\textsubscript{2}-insufflation. Insufflation was done with 5 or 10 mmHg CO\textsubscript{2} during 1 h. Arterial saturation (SaO\textsubscript{2}), heart rate (HR), mean arterial blood pressure (MABP), and cerebral oxygenation (rScO\textsubscript{2}) were monitored. CFTOE, an estimator of cerebral oxygen extraction \((\text{SaO}_2 - \text{rScO}_2)/\text{SaO}_2\)), was calculated. Arterial blood gases were drawn every 15’: pre (T0), during (T1-T4) and after CO\textsubscript{2}-insufflation (T5).

Results
Ten piglets (4 kg) were randomized for 5 (P5) and 10 (P10) mmHg CO\textsubscript{2}-insufflation. Two P10 piglets needed resuscitation after insufflation, none P5. Linear mixed-effect modeling of paCO\textsubscript{2}, pH, and SaO\textsubscript{2} showed that values were dependent on time and time squared \((p < 0.001)\) but were not different between the 5 and 10 mmHg groups. Analysis demonstrated significant changes over time in heart rate and MABP between the 5 and 10 mmHg groups, with a significant higher heart rate and lower blood pressure in the 10 mmHg group \((p < 0.001)\). For rScO\textsubscript{2} and cFTOE, no group differences could be demonstrated, but a significant effect of time was found: rScO\textsubscript{2} increased and cFTOE decreased \((p < 0.001)\).

Conclusions
Insufflation of CO\textsubscript{2} during thoracoscopy with 10 mmHg caused more severe hemodynamic instability and seems to be related with a decrease of cerebral perfusion as represented by a higher oxygen extraction. CO\textsubscript{2}-insufflation of 5 mmHg for thoracoscopy seems to have no adverse effects on cerebral oxygenation.

Keywords: Thoracoscopy, CO\textsubscript{2}, Cerebral oxygenation, Neonatal surgery, Esophageal atresia, Pediatric Endoscopy.
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Carbon dioxide gas pneumoperitoneum induces minimal microcirculatory changes in neonates during laparoscopic pyloromyotomy
Abstract

Background
Little is known about the direct consequence of pneumoperitoneum (PP) on microcirculation and its influence on the quality of tissue perfusion. This study aimed to investigate the intraoperative effects of carbon dioxide (CO₂) gas PP on microcirculation density and perfusion in neonates receiving laparoscopic surgery for hypertrophic pyloric stenosis.

Methods
In a single-center observational study, the oral microcirculation in 12 neonates receiving laparoscopic pyloromyotomy was investigated. Intraoperative hemodynamic parameters, intermittent buccal mucosa capillary density measurements (pre- and postoperative), and continuous intraoperative sublingual microcirculation measurements (i.e., vessels with a diameter <25 µm) of total vessel density (TVD), perfused vessel density (PVD), proportion of perfused blood vessels (PPV), blood vessel diameters (BVD), and microvascular flow index (MFI) were obtained before (at baseline), during, and after PP insufflation in all patients using sidestream dark-field imaging for the duration of the complete surgical procedure.

Results
With the exception of a significantly elevated end-tidal CO₂ (34±4 mmHg to 40±8 mmHg, p<0.05 vs. before (baseline); 1-way ANOVA) during intraoperative insufflation, no significant differences were found between time points for intraoperative hemodynamic parameters. Pre- and postoperative buccal capillary density revealed no significant changes in mucosal perfusion. Analysis of continuous intraoperative sublingual microcirculation parameters revealed a statistically significant increase in BVd during insufflation (8.8±2.4 to 9.3±2.5 µm, p<0.05; 1-way ANOVA) and a significant decrease after exsufflation (8.2±2.3 µm, p<0.01 vs. during and p<0.05 vs. before; 1-way ANOVA respectively), no other significant differences were found between time points for other microcirculatory parameters.

Conclusion
The installation of CO₂ gas PP during laparoscopic pyloromyotomy procedures regulates microcirculatory perfusion by inducing changes in microvascular diameters, but does not alter microcirculation density in neonates.

Keywords
laparoscopy; microcirculation; neonate; pneumoperitoneum; SDF imaging
Brain oxygenation during laparoscopic correction of hypertrophic pyloric stenosis
Abstract

Background
Concern remains about the safety of carbon dioxide (CO₂) pneumoperitoneum (PP) in young infants having surgery for pyloric stenosis via laparoscopy. Interests here mainly focus on possible jeopardized organ perfusion and in particular brain oxygenation with possible adverse neurodevelopmental outcome. The aim of this study was to investigate the intraoperative effects of CO₂ gas PP on cerebral oxygenation during laparoscopic surgery for hypertrophic pyloric stenosis in young infants.

Methods
In this single-center prospective observational study, we investigated brain oxygenation in 12 young infants receiving laparoscopic pyloromyotomy with CO₂ PP, with a pressure of 8 mm Hg and flow of 5 L/min. Intraoperative hemodynamic parameters and transcranial near-infrared spectroscopy (tcNIRS) to assess regional cerebral oxygen saturation (rScO₂) were monitored continuously during the whole procedure. Parameters were analyzed in four intervals: before insufflation (T0), during (start (T1), end (T2)), and after cessation of the CO₂ PP (T3).

Results
Blood pressure and etCO₂ increased during the procedure; (MAP (T0) 35±5 to (T2) 43±9 mmHg), (etCO₂ (T0) 35±4 to (T3) 40±3 mmHg). The rScO₂ remained stable throughout the whole anesthetic period. In none of the patients the rScO₂ drop below the safety threshold of 55 (rScO₂ (T0) 68±14 to (T3) 71±9 %).

Conclusion
Our results indicate that a laparoscopic procedure with a CO₂ PP of 8 mm Hg can be performed under safe anesthetic conditions in the presence of gradually increasing blood pressure and etCO₂ without altering regional brain oxygenation levels.

Keywords: Cerebral oxygenation Laparoscopy Near-infrared spectroscopy Young infants Pneumoperitoneum
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Neonatal brain oxygenation during thoracoscopic correction of esophageal atresia
Abstract

Background
Little is known about the effects of carbon dioxide (CO$_2$) insufflation on cerebral oxygenation during thoracoscopy in neonates. Near-infrared spectroscopy (NIRS) can measure perioperative brain oxygenation (regional cerebral oxygen saturation (rScO$_2$)).

Aims
To evaluate the effects of CO$_2$ insufflation on rScO$_2$ during thoracoscopic esophageal atresia (EA) repair.

Methods
Observational study during thoracoscopic EA repair with 5 mmHg CO$_2$ insufflation pressure. Mean arterial blood pressure (MABP), arterial oxygen saturation (SaO$_2$), partial pressure of arterial carbon dioxide (paCO$_2$), pH, and rScO$_2$ were monitored in 15 neonates at seven time points: baseline (T0), after anesthesia induction (T1), after CO$_2$-insufflation (T2), before CO$_2$-exsufflation (T3), and postoperatively at 6 (T4), 12 (T5), and 24 hours (T6).

Results
MABP remained stable. SaO$_2$ decreased from T0 to T2 (97±3% to 90±6% (p<0.01)). PaCO$_2$ increased from T0 to T2 (41±6 mmHg to 54±15 mmHg (p<0.01)). pH decreased from T0 to T2 (7.33±0.04 to 7.25±0.11 (p<0.05)). All parameters recovered during the surgical course. Mean rScO$_2$ was significantly higher at T1 compared to T2 (77±10% to 73±7% (p<0.05)). Mean rScO$_2$ levels never dropped below a safety threshold of 55%.

Conclusion
The impact of neonatal thoracoscopic repair of EA with insufflation of CO$_2$ at 5 mmHg was studied. Intrathoracic CO$_2$ insufflation caused a reversible decrease in SaO$_2$ and pH and an increase in paCO$_2$. The rScO$_2$ was higher at anesthesia induction but remained stable and within normal limits during and after the CO$_2$ pneumothorax, which suggest no hampering of cerebral oxygenation by the thoracoscopic intervention. Future studies will focus on the long-term effects of this surgery on the developing brain.

Keywords: cerebral oxygenation, esophageal atresia, neonate, thoracoscopy, near infrared spectroscopy