Tolerance of Laparoscopy and Thoracoscopy in Neonates

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ABSTRACT. ***Objectives.*** **Video-surgery in neonates is recent. Data on the respiratory, hemodynamic, and thermic effects during the first month of life are still sparse. This study aimed to evaluate the tolerance of video-surgery in neonates and to determine the risk factors of per-operative complications.**

Methods. **From 1994 to 2004, 49 neonates (mean age: 11 days; weight: 3285 g) underwent 50 video-surgical procedures. Indications for laparoscopy were duodenal atresias, volvulus with malrotation, pyloric stenosis, gastroesophageal reflux, cystic lymphangiomas, ovarian cysts, biliary atresia, and congenital diaphragmatic hernias; indications for thoracoscopy were esophageal atresias and tracheoesophageal fistula.**

Results. **Median operative time was 79 minutes. Mean insufflation pressure was 6.7 mm Hg (range: 3–13). Oxygen saturation decreased, especially with thoracic insufflation or high-pressure pneumoperitoneum. Systolic arterial pressure, which decreased in 20% of the patients, was controlled easily with vascular expansion. Thermic loss (mean postoperative temperature: 35.6°C) was proportional to the duration of insufflation. No surgical incident was noted. Ten anesthetic incidents occurred (20%), 3 of which required temporary or definitive interruption of insufflation (O_2 saturation <70%). Risk factors for an incident were low preoperative temperature, high variation of end-tidal pressure of CO_2, surgical time >100 minutes, thoracic insufflation, and a high oxygen or vascular expansion requirement at the beginning of insufflation.**

Conclusion. **The neonate's high sensitivity to insufflation is an important limiting factor of video-surgery. The described profile of the neonate at risk may help to reduce the frequency of adverse effects of this technique and improve its tolerance.** ***Pediatrics*** **2005;116:e785–e791. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2005-0650;** ***laparoscopy, minimally invasive surgery, thoracoscopy, neonate.***

ABBREVIATIONS. $ETCO_2$, end-tidal pressure of CO_2; O_2 sat, oxygen saturation; HR, heart rate; PIP, peak inflating pressure.

After the success of minimally invasive surgical techniques in adults, application in pediatric patients was a logical next step.[1,2] The use of these techniques in young children spread slowly, however, because the surgical instruments had to be downsized, the learning curve was relatively long, and safe and reliable anesthetic procedures had to be developed to ensure good tolerance of pneumoperitoneum and pneumothorax. Recently, progress has accelerated and the number of procedures that are being performed in children is rising rapidly. More than 40 indications for video-surgery are currently listed, the most widely acknowledged of which are the cholecystectomy,[3,4] fundoplication for gastroesophageal reflux,[5–7] and splenectomy.[8]

Increasingly younger patients now benefit from these techniques, with laparoscopy and thoracoscopy in neonates among the most recent applications.[9] Nevertheless, the potential impact of carbon dioxide pneumoperitoneum and pneumothorax on an immature neonatal cardiopulmonary system is a matter of great concern. Relatively few studies reporting on the cardiorespiratory consequences have been published,[10] and most of those that support the feasibility and the safety of these methods in the first month of life are case reports or short clinical series. The advent of this new surgical procedure in such young children, given their cardiovascular, pulmonary, and thermoregulatory specificities, nevertheless requires a thorough evaluation of its tolerance. The aims of this study were to evaluate the respiratory, hemodynamic, and thermic effects of video-surgery in the first month of life and to determine the risk factors associated with per- and postoperative complications.

METHODS

Patients

From January 1994 to September 2004, 49 neonates who were undergoing 50 laparoscopic or thoracoscopic procedures in our Department of Pediatric Surgery were enrolled in this study. The indications were congenital or acquired gastrointestinal, thoracic, or genital pathologies and are summarized in Table 1. The mean age was 11 days (range: 0–28 days), and body weight ranged from 2130 to 4750 g (mean: 3285 g). The gender ratio was 2 girls to 1 boy. Eight percent of the infants were premature, but the causes (maternal–fetal infection, ruptured membranes, etc) were in all cases independent of the pathology requiring surgery. The preoperative hemodynamic status was stable in all patients. Those with mal-

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TABLE 1. Indications for Laparoscopy and Thoracoscopy in 39 Neonates

Diagnosis	Procedure	No. of Cases	Surgical Outcome
Laparoscopy			
Neonatal ovarian cysts	Resection of cysts (14) or ovariectomy (6)	20	No relapse, no second procedure required.
Congenital diaphragmatic hernia*	Reduction of hernia, diaphragmatic closure	6	Immediate closure without prosthetic material. Conversion to laparotomy in 3 cases (difficult to expose as a result of dilated bowel loops or liver). Postoperative chylothorax in 1 case.
Duodenal atresia	Duodeno-duodenal anastomosis	6	Neither postoperative fistula nor stenosis.
Volvulus with malrotation	Reduction of volvulus and Ladd procedure	5	Early postoperative feeding. Residual Ladd bands in 1 case. Conversion to laparotomy if >3 turns of volvulus.
Ileal atresia, duplication, or cystic lymphangioma	Ileo-ileal anastomosis	3	No postoperative complication. Feeding well tolerated.
Hypertrophic pyloric stenosis	Pyloromyotomy	1	No mucosal perforation.
Gastroesophageal reflux†	Fundoplication (Nissen)	1	Resolution of reflux symptoms.
Extrahepatic biliary atresia	Hepato-enterostomy	1	Complete regression of clinical and biological signs of cholestasis. No complication of the hepatojejunal anastomosis.
Thoracoscopy			
Esophageal atresia	Tracheoesophageal fistula closing and esophageal anastomosis	5	Immediate esophageal anastomosis in 4 cases. No anastomotic leakage. Esophageal stenosis in 1 case. Cul-de-sac was only approximated in 1 case with long gap atresia.
Tracheoesophageal fistula	Tracheoesophageal fistula closing	1	Definitive closure of fistula.

One patient had an esophageal atresia and a duodenal atresia.
* Operated on for respiratory compromise and after stabilization of pulmonary hypertension.
† The indication for surgical treatment of gastroesophageal reflux was severe and threatening complications with cardiorespiratory symptoms.

formation underwent extensive preoperative examination, including cerebral ultrasonography, Doppler echocardiography, and cardiologic consultation if needed. In all cases, the parents were informed of the standard surgical procedure and the advantages and risks of video-surgery.

We excluded all newborns who required emergency surgery and had unstable preoperative hemodynamic status. Exploratory laparoscopies for diagnostic or biopsy purposes (eg, exploration of the biliary tract, liver biopsy) were also excluded, and only cases of therapeutic video-surgery were retained.

Surgical and Anesthetic Methods

The standard procedure for trocar insertion was always performed with an open technique for laparoscopy and with a Veress needle for thoracoscopy. A 3.5- to 5-mm scope with 0-degree or 30-degree vision was used. Two to 4 operative trocars were necessary. Most of the ports were 3.5 mm for 2.7-mm instruments. Anastomoses were performed with intracorporeal-knotted stitches using 5/0 resorbable sutures. The procedures for each indication are summarized in Table 1.

Premedication consisted of rectal Atropine (Renaudin, Itxassou, France) 20 μg/kg. An inhaled induction was performed with 7% sevoflurane (Sevorane [Abbott, Rungis, France]) in air and oxygen. A catheter was placed preoperatively in a major vein in all cases of intestinal atresia or diaphragmatic hernia and in low-weight infants who were at risk for hemodynamic instability. Muscle relaxation was needed for 83% of the patients (atracurium; Tracrium [Glaxo-Smith-Kline, Marly-Le-Roi, France]; 0.5 mg/kg). This was done either immediately (principally for abdominal surgery because of insufficient working space) or at the surgeon's request (elevated insufflation pressure). Peridural anesthesia with ropivacaine (Naropin [Astra-Zeneca, Rueil-Malmaison, France]; 1 mL/kg, dilution 2 mg/mL) completed the analgesia for surgery of the lower pelvis (ovarian cyst).

A controlled ventilation initially maintained the tidal volume at 10 mL/kg until hypercapnia developed. The respiratory and hemodynamic perturbations caused by insufflation were evaluated by monitoring end-tidal pressure of CO_2 ($ETCO_2$), oxygen saturation (O_2 sat; pulse oximetry), heart rate (HR), and blood arterial pressure (measured noninvasively with an automatic electronic sphygmomanometer). The adjustments in ventilatory minute volume and peak inflating pressure (PIP), to ensure an $ETCO_2$ <40 mm Hg and O_2 sat >90%, were recorded every 5 minutes. The volume of fluid that was administered to maintain arterial systolic blood pressure >50 mm Hg was also measured. In cases of persistent alterations in ventilatory or hemodynamic constants, we noted the time to return to baseline values after the end of the insufflation. Rectal temperature was monitored continuously.

Conversion to open surgery and any surgical or anesthetic incidents were recorded, including the precipitating factor and consequences. Finally, the short-term postoperative course was studied (weaning of mechanical ventilation, length of stay in intensive care).

Statistical Methods

χ^2 tests for qualitative data and Student's t tests for quantitative data were used with SPSS 11.1 software (SPSS Inc, Chicago, IL). Tests for equal variances and 1-tailed tests were applied. Significance was accepted at the $P < .05$ level.

RESULTS

All procedures were performed with insufflation, with the duration and pressure of CO_2 pneumoperitoneum and pneumothorax varying according to the surgical indication. The mean time was 79 minutes (range: 10–190 minutes), and the mean pressure was 6.7 mm Hg (range: 3–13 mm Hg), with a maximum output of 6 L/min. For pneumothorax, the insufflation pressure ranged from 5 to 8 mm Hg (mean: 7 mm Hg, 125 minutes).

Respiratory Consequences of Insufflation (Table 2)

O_2 sat decreased in 29 (58%) patients, from 99.1% ± 0.8 to 94.2% ± 4.8 ($P < .01$). In most of these infants, the decrease was moderate and O_2 sat remained >90%. It returned to its preoperative value

TABLE 2. Respiratory Consequences of Pneumoperitoneum and Pneumothorax, With Required Adjustments in Ventilation

	Before Insufflation	During Insufflation	*P* Value
Laparoscopy (*n* = 44)			
O_2 sat, %	98.8 ± 1.4	96.9 ± 4.6	<.05
$ETCO_2$, mm Hg	28.2 ± 5.4	36.1 ± 6.9	<.05
Tidal volume, mL	33.7 ± 12.1	37.1 ± 11.9	<.05
Peak inspiratory pressure	16.9 ± 3.8	21.6 ± 4.8	<.05
Thoracoscopy (*n* = 6)			
O_2 sat, %	99.2 ± 1.3	86.8 ± 8.1	<.05
$ETCO_2$, mm Hg	20.4 ± 8.2	34.2 ± 4.0	<.05
Tidal volume, mL	31.0 ± 12.5	48.5 ± 15.1	<.05
Peak inspiratory pressure	20.8 ± 4.3	29.2 ± 5.9	<.05

Data are mean ± SD.

during surgery in 12 cases, but a moderate hypoxia, between 90% and 95%, persisted in 8 children despite high fraction of inspired $_2$ (≥75%) with a spontaneous correction within 15 minutes of the end of insufflation. However, the O_2 sat decreased markedly under 80% in 4 cases. The insufflation was temporarily interrupted in 2 cases (O_2 sat <70%) to restore an acceptable saturation level and definitively stopped in 1 case. The greatest alteration in O_2 sat was observed during thoracic insufflation for thoracoscopic procedures (eg, esophageal atresia), with a mean decrease of 12.4% (maximum: 21%). These perturbations were significantly greater than during abdominal insufflation ($P < .01$). Per-operative correction nevertheless was reached in all cases once the tracheoesophageal fistula was closed.

$ETCO_2$ increased in 88% of the cases by an average of 9.1 ± 5.3 mm Hg. The increase was considered to be high in 8 cases (>15 mm Hg) and very high in 3 cases (>20 mm Hg). In 56% of the cases, hyperventilation did not completely correct the $ETCO_2$, and the return to the baseline value was reached only at the end of the insufflation; this occurred within 15 minutes in all cases. Both the pressure and the duration of CO_2 insufflation influenced the variations in $ETCO_2$. The smallest variations were observed with insufflation <6 mm Hg, and the $ETCO_2$ was significantly correlated to insufflation pressure ($P < .05$; Fig 1). These variations tended to be greater in cases of long procedures ($P > .05$; Fig 2). In 84% of the cases, an increase in ventilatory minute volume was needed to limit the perturbations once insufflation began (mean: 22.6%). The tidal volume increased from 33.4 ± 12.1 mL to 38.5 ± 12.5 mL ($P < .05$), and the PIP increased from 17.3 ± 4.0 cm H_2O to 22.2 ± 5.4 cm H_2O ($P < .05$).

Despite these ventilatory alterations, extubation on the operating table was possible in 60% of the patients. Nineteen infants required postoperative ventilatory assistance, however (mean: 3 days; range: 1–6 days). These were neonates with severe malformative disease (esophageal atresia) or pulmonary consequences of their pathology (diaphragmatic hernia), or they presented respiratory distress at extubation (Table 3).

Cardiovascular Consequences of Insufflation

In 80% of the children, the systolic blood pressure was stable during insufflation (with no variation or

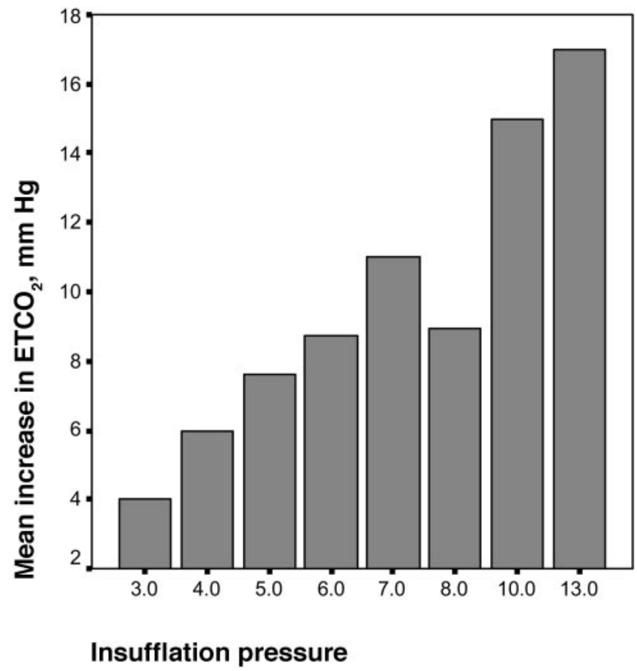

Fig 1. The mean variation in $ETCO_2$ depends on the insufflation pressure of pneumoperitoneum or pneumothorax ($P = .05$).

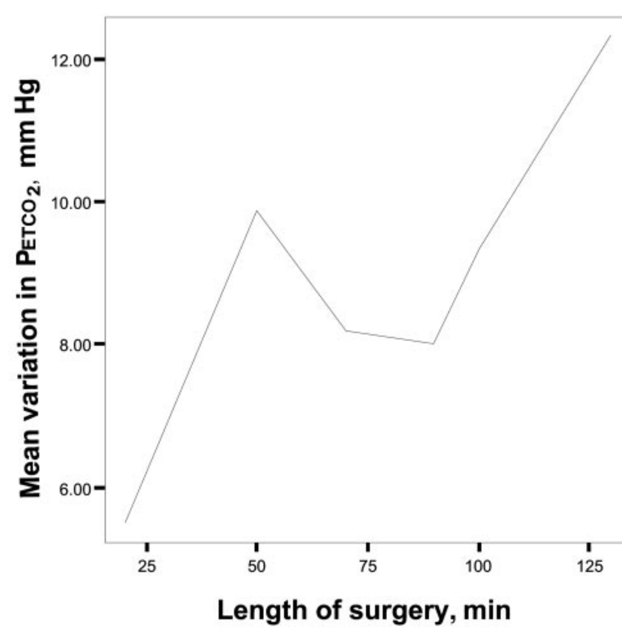

Fig 2. Variations in $ETCO_2$ according to the length of surgery. The observations were gathered per 25-minute insufflation period. The patients with extreme per-operative variations in $ETCO_2$ are not represented in this diagram.

<5 mm Hg). In these patients, an increase in HR nevertheless was observed (from 128 ± 15.9 to 140 ± 16.3 beats per minute; $P < .05$). This phenomenon was either transitory or resolved quickly when pneumoperitoneum was stopped. In 20% of the patients, blood pressure decreased by 10 mm Hg or more. Nine infants required per-operative vascular expansion with 4% albumin because of systolic blood pressure <45 mm Hg. In all cases, this single expansion was sufficient. The variation in arterial blood pressure tended to be greater in cases of esophageal

TABLE 3. Cause, Treatment, and Outcome of Incidents Encountered in 8 Neonates During Video-Surgery

Type of Incident	Frequency	Cause	Treatment	Outcome
Hypotensive episode	3	Initial insufflation	Temporary reduction of insufflation pressure	Spontaneous correction, no relapse
Moderate desaturation (O_2 sat >80%)	1	Initial insufflation	FIO_2 at 100%	Complete and quick regression (<10 min)
Severe desaturation (O_2 sat <70%)	3	Initial insufflation	Insufflation stopped, ventilation with 100% O_2	Video-surgery continued in 2 cases, stopped in 1 case
Bradycardia with hypothermia <35.5°C	1	Length of surgery	Per-operative warming	Per-operative correction of bradycardia
Respiratory distress at extubation	2	Bilateral superior atelectasis	Re-intubation, kinesiotherapy	Extubation at day 2
		Cardiac malformation*	Re-intubation	Extubation at day 2

FIO_2 indicates fraction of inspired oxygen.
* Not noted during the preoperative work-up; surgical correction of the malformation required.

atresia and congenital diaphragmatic hernia than in other indications (−4.4 vs −1.6 mm Hg; not significant).

Thermic Consequences of Insufflation

The postoperative core body temperature was <36°C in 50% of the patients and <34.5°C in 12%. For 1 infant, the hypothermia (33.6°C) was complicated by an episode of bradycardia. Linear regression analysis according to the Pearson test showed a low but significant correlation ($\rho = .4$, $P < .05$) between the length of surgery and decreased temperature. The per-operative temperature loss in degrees Celsius was 0.01 of the surgical time in minutes (Fig 3). This loss was not influenced by the patient's age at the time of surgery or by weight.

Per-Operative Incidents and Risk Factors

We report no surgical incidents in our series, such as vascular lesion or intestinal perforation. No emergency conversion to laparotomy was needed. However, 10 insufflation-related incidents occurred: 5 minor incidents that did not require interruption of insufflation and 5 more threatening incidents. The incidents, causes, and outcomes are summarized in Table 3. The risk factors or events that were significantly linked to the occurrence of an incident were low preoperative body temperature, high variation of $ETCO_2$, high PIP after insufflation, an inspiratory oxygen fraction = 100% necessary from the start of surgery, and more frequent need of vascular expansion to maintain correct hemodynamic status (Table 4). Prematurity was not a risk factor for an incident. The premature infants (8% of the cases) nevertheless were extubated later than the others (3 ± 3 vs 0.9 ± 2.9 days; $P < .05$), whatever the surgical indication (ovarian cyst, diaphragmatic hernia).

Fourteen (32%) of the surgical procedures lasted >100 minutes. The ratio of laparoscopies ($n = 10$) to thoracoscopies ($n = 4$) did not differ significantly from that of the shorter surgeries (<100 minutes). Long operative time was associated with lower postoperative core body temperature; higher PIP increase; more frequent incidents, both minor and major; and more frequent stays in intensive care (Table 5).

The effects of pneumothorax were assessed in 6 patients. When compared with pneumoperitoneum, the initial required inspiratory fraction of oxygen was higher (100% fraction of inspired O_2 for the thoracoscopies vs 58% for the laparoscopies; $P < .01$), and vascular expansion was more often required (75% of the patients for the thoracoscopies vs 25% for the laparoscopies; $P < .01$). The frequency of incidents was also higher for thoracoscopy than for laparoscopy (60% vs 13%). The incidents occurred notably in cases of large permeable tracheoesophageal fistulas.

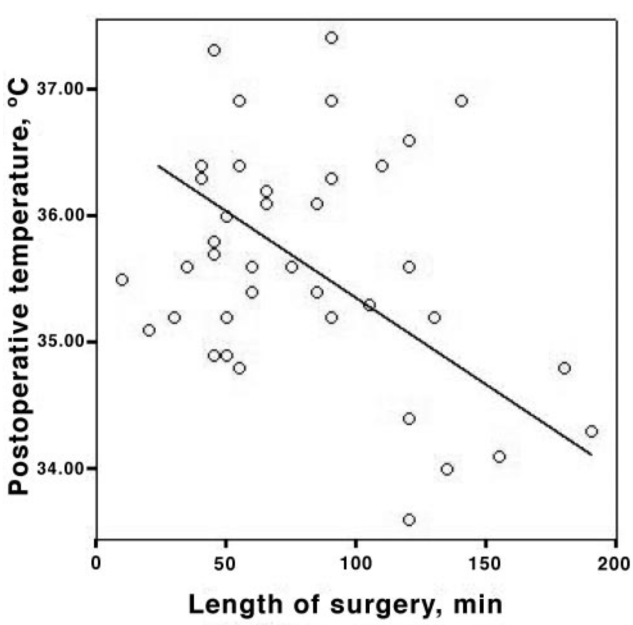

Fig 3. The decrease in body temperature during surgery is proportional to the length of insufflation (linear regression analysis, $P < .05$).

DISCUSSION

The use of minimally invasive surgery has been expanding steadily in pediatric surgical practice. Although it has been difficult to prove that infants who undergo this technique have a shorter and simpler postoperative course, some indications such as the fundoplication[5] have clearly shown better cosmetic results and more rapid recovery. Neonates, however, have distinct physiologic and anatomic characteristics that increase the rate of surgical complica-

TABLE 4. Characteristics of Neonates Who Presented Incidents During or After Video-Surgery

	Neonates With Anesthetic Incidents ($n = 10$)	Neonates Without Anesthetic Incidents ($n = 39$)	*P* Value
Preoperative body temperature, °C; mean ± SD	35.3 ± 0.5	36 ± 0.6	<.05
Variations of $ETCO_2$	11.9 ± 34	7.6 ± 28	<.05
PIP after insufflation, cm H_2O; mean ± SD	26 ± 22	21.4 ± 27	<.05
Proportion of patients who required an inspiratory fraction of oxygen at 100% to maintain O_2 sat >90% at the start of insufflation	40%	7.7%	<.05
Frequency of vascular expansion	60%	15.3%	<.05

TABLE 5. Effects of Video-Surgical Procedures Longer Than 100 Minutes in Neonates

	Surgery <100 Min	Surgery >100 Min	*P* Value
Postoperative body temperature, °C	35.8 ± 0.5	34.1 ± 1.1	<.05
PIP increase, cm H_2O	2.7 ± 3.4	9 ± 4.1	<.01
Frequency of incidents, %	11.4 ($n = 4$)	42.8 ($n = 6$)	<.05
Frequency of postoperative intensive care, %	25.7 ($n = 9$)	71.4 ($n = 10$)	<.05

Data are mean ± SD.

tions.[11,12] Laparoscopy and thoracoscopy thus have not been used widely in these patients, despite the reduced per-operative stress demonstrated in older populations by Fujimoto et al.[10] This study was designed to evaluate the repercussions of CO_2 insufflation in infants who are younger than 1 month and to determine the characteristics of patients who are at risk for complication.

Neonatal ventilatory limitations, particularly the small airway caliber and the important instrumental deadspace, could explain the markedly perturbed gas exchanges noted in our series. The 33% increase in $ETCO_2$ over its initial value, despite ventilatory adjustment, was higher than that observed in adults.[13–15] The peritoneal and pleural absorption surface per unit of weight is high in newborns.[16] The low quantity of peritoneal fat and the slight distance between vessels and the serous surface increase the permeability of the peritoneum to CO_2. We found that the $ETCO_2$ was all the more heightened with high-pressure, thoracic, and long-duration insufflation and that a major increase in $ETCO_2$ was a risk factor for preoperative incident. It may expose the infant to the risk of per-operative acidosis and alteration of the cerebral circulation because it is correlated with high CO_2 arterial pressure and low pH.[17,18]

For controlling $ETCO_2$ and counterbalancing a reduced respiratory compliance induced by insufflation,[19] a great increase in ventilatory minute volume (22.6% in our series, 40% for Fujimoto[10]) and PIP was essential. However, it was applied to neonatal lungs that are highly sensitive to both volume and pressure. Although it is likely that the long-term consequences are minimal, given the short duration of the mechanical ventilation, this remains to be demonstrated.

Despite a low compliance in the neonatal myocardia,[20] a low functional reserve, and heightened sensitivity to changes in systolic pressure and telediastolic volume,[21] the hemodynamic tolerance of insufflation in small infants is overall acceptable. Gueugniaud et al[22] evaluated the cardiac performance in infants of 6 to 30 months by per-operative cardiac echography and showed that the variations of cardiac output were without threatening clinical consequences. Bozkurt et al[23] confirmed the stability of arterial systolic pressure after 30 minutes of insufflation at <10 mm Hg in 27 infants of 1 month to 1 year. No hemodynamic instability in newborns was reported with an insufflation pressure of 8 mm Hg.[10] In our series, the systemic arterial pressure was overall stable. The variation was null or <5 mm Hg in 80% of the cases. The use of minimal pressure nevertheless is advocated because tolerance is unknown above 13 mm Hg, and the stability of the arterial pressure does not exclude alterations of the cardiac output.[24,25]

Postoperative hypothermia was frequent and the final temperature was <35°C in 25% of the infants. The heightened sensitivity to hypothermia in the newborns, caused by an increased caloric loss and a per-operative drop in thermogenesis, was aggravated by the frequently prolonged surgical times and the use of cold and dry gas.[26–29] This hypothermia was well tolerated (only 1 case of bradycardia) and limited by the use of external heat sources (radiant lamps, pulsed air blankets). In all cases, it was rapidly corrected at the end of anesthesia. Nevertheless, the length of insufflation clearly influences the depth of hypothermia.

Technical innovations, advances in miniaturization, and experience have made laparoscopy and thoracoscopy safer and easier.[30,31] Numerous publications have demonstrated the feasibility of these techniques in newborns. The major problem today is the need to establish criteria that distinguish neonates who will benefit from the techniques from those with a low tolerance for insufflation. A profile of the neonatal patient who is at risk for an insufflation-related incident emerged from our series: initially low body temperature, high variations of $ETCO_2$, a need for vascular expansion, and major modification in the oxygen inspiratory fraction or

PIP at the start of insufflation. When surgery unfolds in a neonate who presents these risk factors, the surgeon and the anesthesiologist should be aware that this patient is at a heightened risk for poor tolerance of the procedure. The correction of hypothermia by external warming, a reduction in the length of surgery if at all possible, and close surveillance of the hemodynamic and ventilatory status are strongly advised.

Other circumstances appeared as aggravating factors in our series. The neonates were more sensitive to thoracoscopy than laparoscopy. Pneumothorax required ventilation with a higher oxygen fraction and more frequent vascular expansion. The direct pressures on the lung and heart may impair more extensively the gas exchanges and the cardiac output. Incidents thus were more frequent with thoracoscopy. The surgical indications for thoracoscopy (esophageal atresia, tracheoesophageal fistula) may also be aggravating factors because a part of the ventilation is lost through the fistula until it is closed. Some authors thus have proposed 1-lung ventilation for thoracoscopy in small infants to avoid pressure in the chest from insufflation. This pressure can affect cardiac performance and may even impair contralateral lung function.[32] One-lung ventilation has the advantage of providing good surgical exposure without the need to mechanically push back the contralateral lung and/or use insufflation to retract it into the pleural cavity.[33] However, 1-lung ventilation has never been described in neonates and would seem to pose some technical difficulties. Double-lumen endotracheal tubes of an adapted size are lacking. Bronchial blocking carries the risk for displacement of the blocker, causing tracheal obstruction because of the small size of the airways. Injury during bronchial blocking by nonspecific material such as the Fogarty balloon catheter is another risk, notably because of the high pressure generated by the balloon.[33] We observed a bronchial perforation caused by a Fogarty catheter in a young infant in our department (unpublished observation). Moreover, tolerance of thoracic video-surgery in very small children is worse under 1-lung ventilation than 2-lung ventilation.[34] It should also be noted that tracheal ventilation facilitates the detection of a tracheoesophageal fistula during the surgical repair of esophageal atresias, in which case, selective intubation would be inopportune. Last, insufflation of the pleural cavity, which is required to obtain a partial retraction of the lung, is accomplished with the same order of pressure as the intermittent positive intrathoracic pressure generated by mechanical ventilation.

Another risk factor of poor tolerance was the length of surgery. More than 100 minutes of insufflation required very close follow-up because of the heightened risks for hypothermia, anesthetic incidents, temporary interruption of insufflation, and delayed extubation. In contrast, patients' age and weight were not determining factors for insufflation tolerance.

Despite the diversity of surgical procedures seen in our series, this study points out the neonate's high sensitivity to insufflation as the main limitation to video-surgery. The pattern of the at-risk patient that emerged is as follows: a neonate undergoing thoracoscopy for >100 minutes, with high insufflation pressures and $ETCO_2$ variations, low body temperature, a need for vascular expansion, and major modification in ventilatory parameters at the start of insufflation. In addition to the widely reported feasibility of neonatal video-surgery, knowledge of these risk factors and precursor signs of incidents may help to improve the tolerance of this technique during the first month of life.

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