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Thoracoscopy in children: anaesthesiological implications and case reports

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ABSTRACT

Aim. Videoassisted thoracic surgical technique in children is being used with increasing frequency for an extensive variety of diagnostic and therapeutic procedures. The aim of the study was to assess respiratory, cardiocirculatory and body temperature changes in children undergoing thoracoscopy and to identify if the trend of such changes was modifiable by factors such as lung exclusion, length of the thoracoscopy and preoperative respiratory compromise.

Methods. A total of 50 patients (38 boys and 12 girls) undergoing general anaesthesia for diagnostic and therapeutic thoracoscopic procedures were analysed. The values of the monitored parameters were compared at 6 specific times: T1 - at the end of anaesthesia induction (considered the basal level); T2 - after lateral position; T3 - before pleural CO_2 insufflation; T4 - 10 min after pleural CO_2 insufflation; T5 - before pleural deflation; T6 - 10 min after pleural deflation.

Results. All patients tolerated the thoracoscopy well, without intraoperative complications. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were significantly lower, and end-tidal CO2 ($PETCO_2$) significantly higher during thoracoscopy. Body temperature (BT) had a statistically significant reduction during thoracoscopy and after pleural deflation. During one-lung ventilation the $PETCO_2$ increased compared to two-lung ventilation with intrapleural insufflation, while during two-lung ventilation with intrapleural insufflation SBP and DBP decreased compared to one-lung ventilation. The length of the thoracoscopy increased the $PETCO_2$ and reduced the BT. The preoperative respiratory compromise increased the $PETCO_2$.

Conclusion. Although thoracoscopy in children brings about certain respiratory, cardiocirculatory and body temperature changes, it is nevertheless a safe and efficient surgical technique.

Key words: Thoracoscopy - Pediatrics - Anaesthesia - Respiratory physiologic processes - Cardiocirculatory system - Body temperature - Ventilation, mechanical, methods - Insufflation.

The videoassisted thoracic surgical technique in children is being used with increasing frequency for a variety of diagnostic and therapeutic procedures. Thoracoscopy in the paediatric patient reduces surgical trauma and minimizes postoperative morbidity. The advantages of thoracoscopy compared with open thoracotomy include decreased postoperative pain, shorter hospital stay, more rapid return to normal activities, better cosmetic results and decreased incidence of chest wall deformity.[1-3]

An optimal approach to the planning of anaesthesia for thoracoscopy requires a good knowledge of the technical requirements and an understanding of the physiological alterations associated with the procedure. The approach needs to take into account the problems and risks related to airway management, potential preoperative respiratory compromise and respiratory consequences associated with a possible lung resection, as well as those connected with the changes due to the lateral decubitus position, the lung exclusion and the CO_2 insufflation in the pleural cavity.[3]

From a respiratory point of view the sequence

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TABLE I.—*Surgical interventions treated with thoracoscopic procedures.*

Surgical interventions	Number of patients
Lung evaluation	5
Pleural decortication	4
Lung and mediastinal mass biopsy	23
Lung resection (congenital malformation)	5
Lung resection (oncologic diseases)	11
Tunnel retrosternal evaluation	1
Diaphragmatic biopsy	1

of physiopathologic events is related to the peculiarity of the thoracoscopic procedure. First of all, alterations occur in the ventilation-perfusion relationship induced by the lateral decubitus position in the anaesthetized patient. Secondly, both lung exclusion, if feasible, or CO_2 insufflation in the pleural cavity may cause further damage to ventilatory conditions by avoiding or limiting the ventilation of the nondependent lung. Finally, the creation of an artificial pneumothorax may lead to CO_2 absorption across the pleura causing systemic hypercarbia. The effects of thoracoscopy on the cardiovascular system, rarely studied in children, are mainly related to the CO_2 insufflation under positive pressure resulting in significant haemodynamic compromise which reduces preload, stroke volume, cardiac index and mean arterial pressure.[3, 4]

The aim of the present study was firstly to assess the respiratory, cardiocirculatory and body temperature changes in children undergoing thoracoscopic surgery. A secondary aim of the study was to understand if the trend of such changes was modified by factors such as lung exclusion with one-lung ventilation, length of the thoracoscopy and the preoperative respiratory compromise related to undelying disease.

Materials and methods

Our case series, which runs from May 1996 to December 2004, includes 50 consecutive paediatric patients (38 boys and 12 girls) undergoing diagnostic and therapeutic thoracoscopic procedures; the mean age of patients was 7.1±5.2 years (age range: 15 days - 15 years), mean weight 26.1±17.1 kg (range: 3-52 kg). Four patients belonged to ASA class II, 45 to ASA class III, and 1 to ASA class IV. The surgical interventions are shown in Table I.

All patients were premedicated with diazepam (0.2 mg/kg) and atropine (0.015 mg/kg) orally 1 h preoperatively. General anaesthesia was induced intravenously with propofol (2.5-3 mg/kg), except for patients younger than 5 years for whom the inhalatory approach was adopted, with sevoflurane at a concentration increasing from 1% to 8%.

In the cases with high probability of a difficult airway secondary to tracheal deviation or compression, anaesthesia was induced, with inhalatory technique, always maintaining spontaneous breathing and inserting a tracheal tube with topical administration of lidocaine (4 mg/kg) to the larynx and the trachea. In all the cases tracheal intubation was preceded by a fentanyl infusion (2 μg/kg) and facilitated by the administration of atracurium besylate (0.4-0.5 mg/kg) or cisatracurium besylate (0.2 mg/kg). Depending on the age and the surgical procedure was performed either with nasal tracheal tube (uncuffed in patients younger than 7 years, cuffed in patients older than 7 years) for two-lung ventilation or with devices to allow one-lung ventilation (double lumen endotracheal tube, Univent tube, Arndt bronchial blocker). A flexible bronchoscope (Karl Storz, Tutlinge, Germany) was used to verify the correct position of the devices to allow one-lung ventilation.

General anaesthesia was maintained with propofol (9-12 mg/kg/h), while for children younger than 5 years with sevoflurane (expired concentration 1.5-3%); anaesthesia was supplemented with fentanyl (1-2 μg/kg/h) and muscle relaxation was maintained with atracurium besylate (0.15-0.3 mg/kg/h) or cisatracurium besylate (0.1-0.15 mg/kg/h).

Initially, patients were mechanically ventilated (Servo Ventilator 900 C or Kion, Siemens-Elema, Solna, Sweden) using an oxygen/air mixture with oxygen inspired fraction (FiO_2) between 0.35 and 0.45; tidal volume (TV) was adjusted between 10 and 11 mL/kg and respiratory frequency (RF) was regulated on the basis of the patient's age. The ratio of inspiratory time to expiratory time was 1:2. Positive end-expiratory pressure (PEEP) was set at 4 cm H_2O. During lung exclusion or

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intrapleural insufflation, tidal volume was reduced to 7-8 mL/kg, the respiratory rate was increased by 20% compared to the one initially recorded and the FiO_2 was increased to 0.5-0.8. At the end of thoracoscopy the respiratory setting was brought back to previous conditions. Nitrous oxide was never used.

Intrasurgical infusion rate was 20 mL/kg during the first hour in patients under 3 years and 15 mL/kg for older patients; in the hours that followed, the infusion dosage was 8-10 mL/kg/h for all patients. The infusions used were 5% dextrose in quarter-strength normal saline solution (0.2% NaCl) and lactated Ringer's solution.

The surgical interventions in the study were performed with the aid of trocars from 1 to 4. A video-thoracoscope was inserted through the cannula and the operative field was visualised. The thoracoinsufflator, light source, video camera, 5-10 mm telescope and all the reusable instruments were from Karl Storz (Tutlinge, Germany). The flow of CO_2 was kept lower than 2 L/min. In the cases without lung exclusion the final intrathoracic pressure (ITP) was 4 mmHg in patients under 12 months of age, 6 mmHg in patients up to 8 years, 8 mmHg in those over 8 years. In the cases with lung exclusion the ITP was always 1-2 mmHg. Intrapleural insufflation was always performed in stages and never attained the desired ITP in less than 60 s. All thoracoscopic interventions were performed in the lateral decubitus position and prepared for open thoracotomy should this have proved necessary.

Intraoperative monitoring was both invasive and non invasive. For the cardiovascular function heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were monitored (Integrated Modular HP System, Hewlett-Packard, Palo Alto, CA); when clinically necessary radial arterial catheter and central venous catheter (CVC) were placed for invasive monitoring of blood pressure and central venous pressure (CVP), respectively.

For the respiratory function, patients underwent continuous arterial oxygen saturation (SpO_2) by pulse oximetry (Integrated Modular HP System, Hewlett-Packard, Palo Alto, CA) and end-tidal CO_2 ($PETCO_2$) by capnometry (5250 RGM, Ohmeda, Louisville, CO), associated with spirometric evaluation (respiratory frequency, tidal volume both inspiratory and expiratory, minute volume), as well as peak and mean inflating airway pressure by means of a mechanical ventilator (Servo Ventilator 900 C or Kion, Siemens-Elema, Solna, Sweden). Monitoring also included body temperature (BT), urine output and inspiratory and expiratory concentration of the inhalation anaesthetics (5250 RGM, Ohmeda, Louisville, CO). In all patients the neuromuscular blockade was monitored by stimulating the ulnar nerve using the train-of-four pattern of stimulation.

The intrasurgical course of values of monitored parameters was analysed and compared at 6 specific times, common to all patients undergoing thoracoscopic videosurgery:

T1: at the end of anaesthesia induction (considered the basal level);

T2: after lateral decubitus position;

T3: before CO_2 insufflation in the pleural cavity;

T4: 10 min after CO_2 insufflation in the pleural cavity;

T5: before deflation in the pleural cavity;

T6: 10 min after deflation in the pleural cavity.

In addition to the general data given, other factors were considered that may have influenced the trend of the vital parameters: one-lung ventilation with lung exclusion, the length of the thoracoscopy (more or less than 60 min), and the preoperative respiratory compromise related to basal disease and radiologically documented by diffuse parenchymal abnormalities. To assess the influence of each of the factors mentioned above the patients were divided into 2 groups (one-lung ventilation with lung exclusion *vs* two-lung ventilation with intrapleural insufflation, thoracoscopy <60 min *vs* >60 min, preoperative respiratory compromise *vs* non parenchymal abnormalities) and the basal parameters (T1) were compared to the percentile change of each group detected at times T4 (10 min after insufflation in the pleural cavity), T5 (before deflation in the pleural cavity) and T6 (10 min after deflation in the pleural cavity).

After approval by the institutional ethics committee written informed consent was obtained from the parents before beginning the study.

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Statistical analysis

The global data are given as mean and standard deviation; statistical analysis was performed using t-test, ANOVA and Bonferroni-test; a P value less than or equal to 0.05 was considered significant. The changes from baseline and the differences between the 2 groups with respect to lung exclusion, thoracoscopy <60 min or >60 min and preoperative respiratory compromise were evaluated using Wilcoxon's rank sum test. Comparisons were considered significant if the P value was less than 0.05.

Results

In all 50 subjects the anaesthetic management allowed a valid and regular performance of the thoracoscopy. All patients tolerated the procedures well and there were no intraoperative complications. In 4 cases thoracoscopy had to be turned into open thoracotomy (1 removal of mediastinal ganglioneuromas, 1 excision of extra-lobar pulmonary sequestration and 2 lung resections for oncologic diseases) due to surgical problems related to the sizeable mass to be removed. In the patients undergoing only thoracoscopic procedures, without shift into open thoracotomy, no intraoperative or postoperative bleeding occurred. Therefore no blood, blood products or plasma expanders were needed before, during or after the interventions.

Airway management was difficult in 9 patients (18%) in whom the physical examination and the radiographic findings (chest X-rays and CT scans) revealed deviation or compression of the tracheobronchial tree. In all 9 cases there was an anterior mediastinal mass due to non-Hodgkin's lymphoma. In these patients anaesthetic induction was performed avoiding the loss of spontaneous respiration and tracheal intubation was made easier by topical administration of lidocaine. The procedure was always carried out successfully. In all 9 children flexible bronchoscopy confirmed the tracheobronchial deviation or compression revealed radiologically.

The two-lung ventilation was performed in 26 patients with a mean age of 6.9±3.5 years. One-lung ventilation with lung exclusion was performed in 24 patients (mean age 8.4±4.1 years): in 16 cases the double lumen endotracheal Robert-Shaw tube was used, in 3 cases the Univent tube, and another 5 cases the Arndt bronchial blocker.

The mean duration of the thoracoscopic procedure was 67±46 min (range: 15-210): 22 patients (mean age: 6.8±4.9 years) were submitted to brief procedures and 28 patients (mean age: 7.1±5.3 years) to long procedures.

In 25 children (mean age: 8.1±5.4 years) there was a preoperative respiratory compromise related to underlying pulmonary disease: 13 due to diffuse metastatic lesions, 4 to pulmonary congenital malformation (3 congenital cystic adenomatoid malformation and 1 pulmonary sequestration), 4 to intraparen-chymal infectious infiltrates and 4 due to chronic lung diseases (3 pulmonary fibrosis and 1 bronchopulmonary dysplasia). In the remaining 25 patients (mean age: 6.8±4.2 years) preoperative respiratory function was normal.

SpO_2 remained absolutely stable, without variations from 99-100% value during the entire treatment. In all cases it was necessary to increase FiO_2 to over 0.5 during artificial pneumothorax. There was a statistically significant increase between the $PETCO_2$ determinations made during the thoracoscopy compared to the levels shown at the end of the anaesthesia induction, after lateral decubitus position and before CO_2 insufflation in the pleural cavity. Ten minutes after deflation $PETCO_2$ decreased with respect to the values during thoracoscopy, remaining at slightly higher levels than at the end of the anaesthesia induction.

The trend of the cardiocirculatory parameters (HR, SBP, DBP) corresponded to the normal age-related target when they were carried out (Table II). HR remained consistently regular with no statistically significant variations at the different stages of the surgical procedure, nor were there any other alterations or ECG abnormalities. On the other hand, SBP and DBP, compared to the values registered at the end of induction, were significantly lower in all surveys obtained during thoracoscopy; 10 min after pleural deflation the SBP and DBP values increased, compared to levels shown during artificial pneumothorax, and stayed at the same values registered at the end of anaesthesia induction.

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TABLE II.—*Haemodynamic, ventilatory and body temperature changes during thoracoscopy.*

	T1	T2	T3	T4	T5	T6
HR	116±18	115±16	116±15	117±16	116±18	115±16
SBP	97±17	97±17	98±15	88±15§	86±15*	96±14
DBP	48±10	47±10	45±12	43±11**	43±11**	49±19
SpO_2	99.8±0.4	99.7±0.6	99.1±1.2	98.9±1.3	98.9±1.5	99.6±0.5
$PETCO_2$	35.5±3.9	35.0±3.0	37.9±5.3	41.5±8.5*	44.5±8.5*	36.9±3.4
BT	36.2±0.6	36.1±0.7	36.0±0.6	35.9±0.5§	35.9±0.5§	35.9±0.4§

Values are mean ± standard deviation (SD). T1: at the end of anaesthesia induction (considered the basal level); T2: after lateral decubitus position; T3: before CO_2 insufflation in the pleural cavity; T4: 10 min after CO_2 insufflation in the pleural cavity; T5: before deflation in the pleural cavity; T6: 10 min after deflation in the pleural cavity.

HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; SpO_2: continuous arterial oxygen saturation; $PETCO_2$: end-tidal CO_2; BT: body temperature.

* P<0.001 *vs* T1; §: P<0.01 *vs* T1; ** P<0.05 *vs* T1.

Body temperature (Table II) had a statistically significant reduction during thoracoscopy; 10 min after pleural cavity deflation the values were similar to those recorded during artificial pneumothorax.

At the end of surgical treatment the children were moved to the paediatric intensive care unit (PICU): 7 of them (14%) were extubated in the operating room, 19 (38%) were extubated in the PICU after 4 h of continuous positive airway pressure (CPAP), whereas the other 24 (48%) continued to need tracheal intubation and respiratory support. One patient suffering from severe mediastinal syndrome died from respiratory and cardiocirculatory complications due to tumour invasion of the tracheobronchial tree and great intrathoracic vessels.

In addition to the global data, the possible influence of factors such as lung exclusion, length of thoracoscopy (more or less than 60 min), and preoperative respiratory compromise was also considered.

Lung exclusion entailed respiratory and cardiocirculatory changes (Figure 1). Patients that underwent one-lung ventilation with lung exclusion, presented a greater increase in $PETCO_2$ during (T4, T5) and after (T6) thoracoscopy (21%, 24% and 8%, respectively), compared to the basal condition (T1), than patients submitted to two-lung ventilation with intrapleural insufflation (8%, 14%, 0.5%) and this was statistically significant. On the contrary, SBP and DBP were reduced more during two-lung ventilation with intrapleural insufflation (15%, 18% for SBP and 12%, 12% for DBP, respectively) than patients undergoing one-lung ventilation with lung exclusion (5%, 5% for SBP and 6%, 6% for DBP) and this was also statistically significant.

The length of the thoracoscopic procedure influenced the $PETCO_2$ and BT trends in a statistically significant way (Figure 2). When thoracoscopy was longer than 60 min the percentile changes in $PETCO_2$ compared to baseline are evident before deflation in the pleural cavity (T5), with increases of more than 27%, while in patients where thoracoscopy was shorter than 60 min an increase of 17% was recorded. In the patients submitted to thoracoscopy longer than 60 min body temperature at T5 and T6 decreased respectively by 18% and 19% compared to basal values. On the contrary, in patients where the thoracoscopy was shorter than 60 min, it decreased less (7% and 9%, respectively).

As far as the preoperative respiratory compromise is concerned, a statistically significant influence was seen only for the changes in the $PETCO_2$ (Figure 3). Patients with parenchymal abnormalities showed increases of 19%, 28% and 8% at times T4, T5 and T6, respectively, compared to patients with no preoperative respiratory compromise, who showed more modest increases (11%, 11% and 3%).

Discussion

The development of thoracoscopic techniques in paediatric age has allowed surgeons to perform with minimal invasiveness procedures that once required an open thoracotomy. When developing

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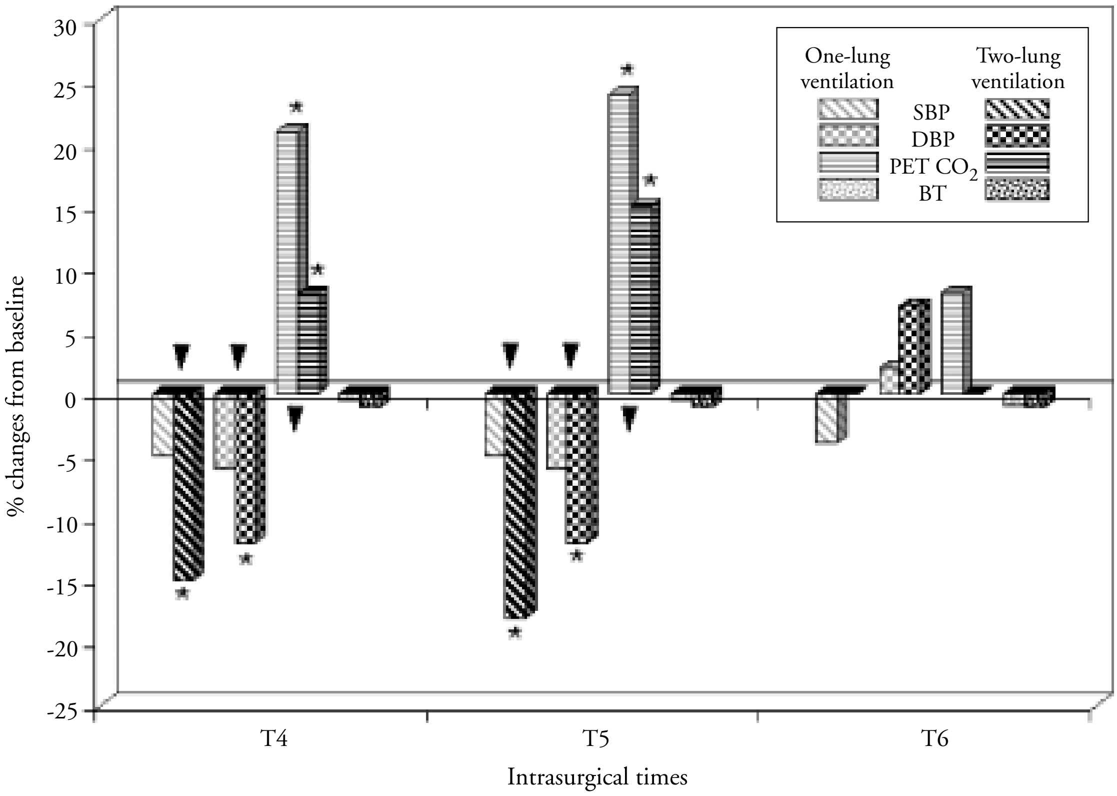

Figure 1.—Trend of systolic blood pressure (SBP), diastolic blood pressure (DBP), end-tidal CO_2 ($PETCO_2$) and body temperature (BT) during one-lung ventilation with lung exclusion compared to two-lung ventilation with intrapleural insufflation. Changes from baseline at the times T4 (10 min after insufflation in the pleural cavity), T5 (before deflation in the pleural cavity) and T6 (10 min after deflation in the pleural cavity). * A statistically significant change from baseline within the group by Wilcoxon's signed rank test, $P<0.05$. ▼ A statistically significant difference between the 2 groups (one-lung ventilation or two-lung ventilation) by Wilcoxon's signed rank sum test, $P<0.05$.

an anaesthetic plan for children undergoing thoracoscopic surgery, consideration should be given not only to the alterations imposed by the surgical procedure, but also to the patient's underlying status. During anaesthesia for thoracoscopic surgery, the main problems are related to the respiratory and cardiovascular changes mainly associated with the patient's lateral decubitus position, the lung exclusion, the increased intrapleural pressure and the CO_2 absorption and its general effects. In addition, the magnitude of the physiological disturbances associated with thoracoscopy is influenced by the patient's age, the patient's underlying myocardial and respiratory function and the anaesthetic agents administered.[3-5]

The respiratory and cardiovascular system of a child have characteristics that differ from those of an adult: the lung has less functional residual capacity (FRC), collapse volume is much closer to FRC, and both lung compliance and airway resistance are adversely related to lung size. Blood pressure is lower and heart rate is higher in infants. The infant's systemic vascular resistance is lower, a factor that well correlates with high metabolism and O_2 consumption. Cardiac output is also higher in infants, especially when calculated according to body weight. Heart rate plays a more important role in determining cardiac output.[6-8]

When planning anaesthetic management it is essential to assess the pathology and clinical status of the patient undergoing thoracoscopy. The preoperative examination should also attempt to identify previously undiagnosed problems, such as an abnormal airway or extrinsic tracheal compression, which may place the patient at increased risk during anaesthesia.[5] As documented in a series of

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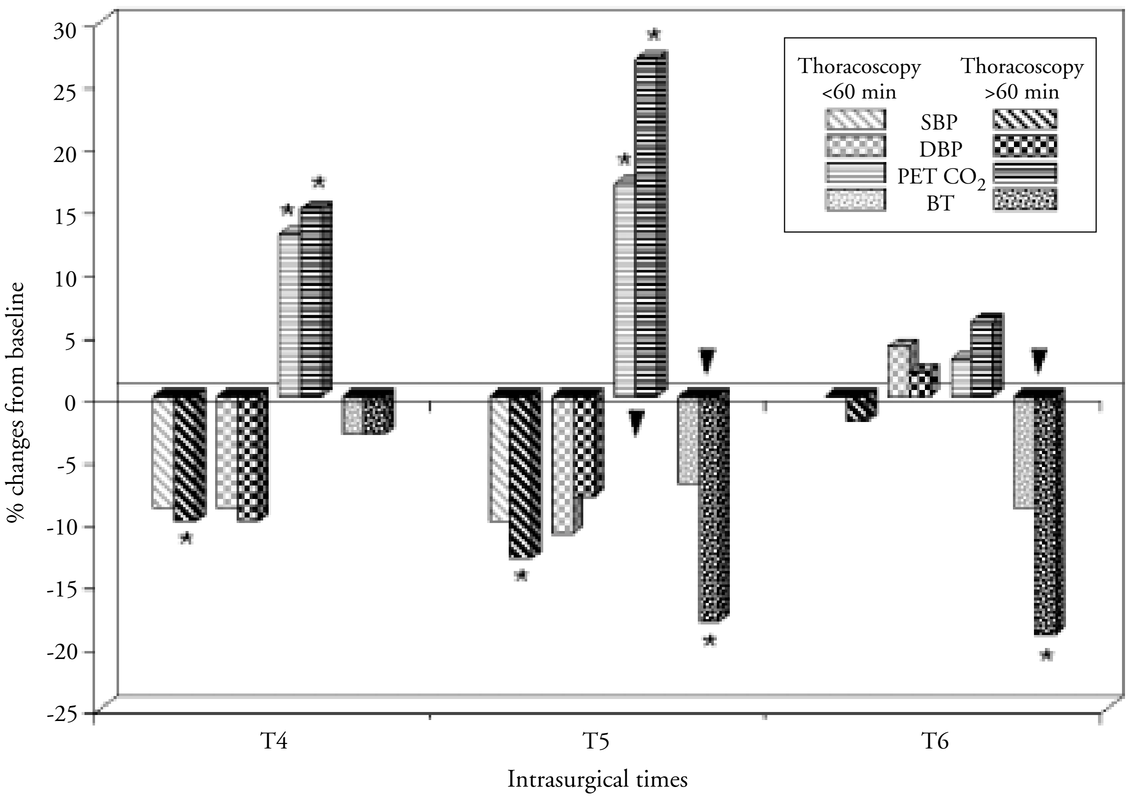

Figure 2.—Trend of systolic blood pressure (SBP), diastolic blood pressure (DBP), end-tidal CO_2 ($PETCO_2$) and body temperature (BT) during thoracoscopy <60 min compared to thoracoscopy >60 min. Changes from baseline at the times T4 (10 min after insufflation in the pleural cavity), T5 (before deflation in the pleural cavity) and T6 (10 min after deflation in the pleural cavity). * A statistically significant change from baseline within the group by Wilcoxon's signed rank test, P<0.05. ▼ A statistically significant difference between the two groups (one-lung ventilation or two-lung ventilation) by Wilcoxon's signed rank sum test, P<0.05.

cases reports, children with anterior mediastinal masses may demonstrate severe cardiopulmonary compromise on induction of anaesthesia, including cardiac arrest and death.[9-12] The tumour may surround the large airways, the heart, and the great vessels, resulting in 3 types of intrathoracic compromise: compression of the tracheobronchial tree, compression of the pulmonary artery, and superior vena cava syndrome. Compression greater than 50% of the trachea cross sectional area on CT imaging has been suggested for the identification of a high risk population where anaesthesia would be preferably induced maintaining spontaneous respiration and tracheal intubation made by topical administration of lidocaine associated with flexible tracheobronchoscopic evaluation.[5, 13-16] Rigid bronchoscopy may be life-saving in the event of tracheal or bronchial collapse under anaesthesia.[16] Our experience is in accordance with other studies: in 9 patients out of 50 there was a high probability of difficult airway management secondary to tracheal deviation or compression; in all these cases the method described allowed correct tracheal intubation without any complications.

Respiratory changes may occur during thoracoscopy in children. In anaesthetized patients in a lateral decubitus position during two-lung ventilation there is relatively good ventilation and a reduced perfusion in the nondependent lung due to the gravitational distribution of the blood flow. On the other hand, the dependent lung is relatively hypoventilated while overperfused. During one-lung ventilation an obligatory right-to-left transpulmonary shunt is created through the nonventilated lung.[3, 17] Hypoxia may commonly occur

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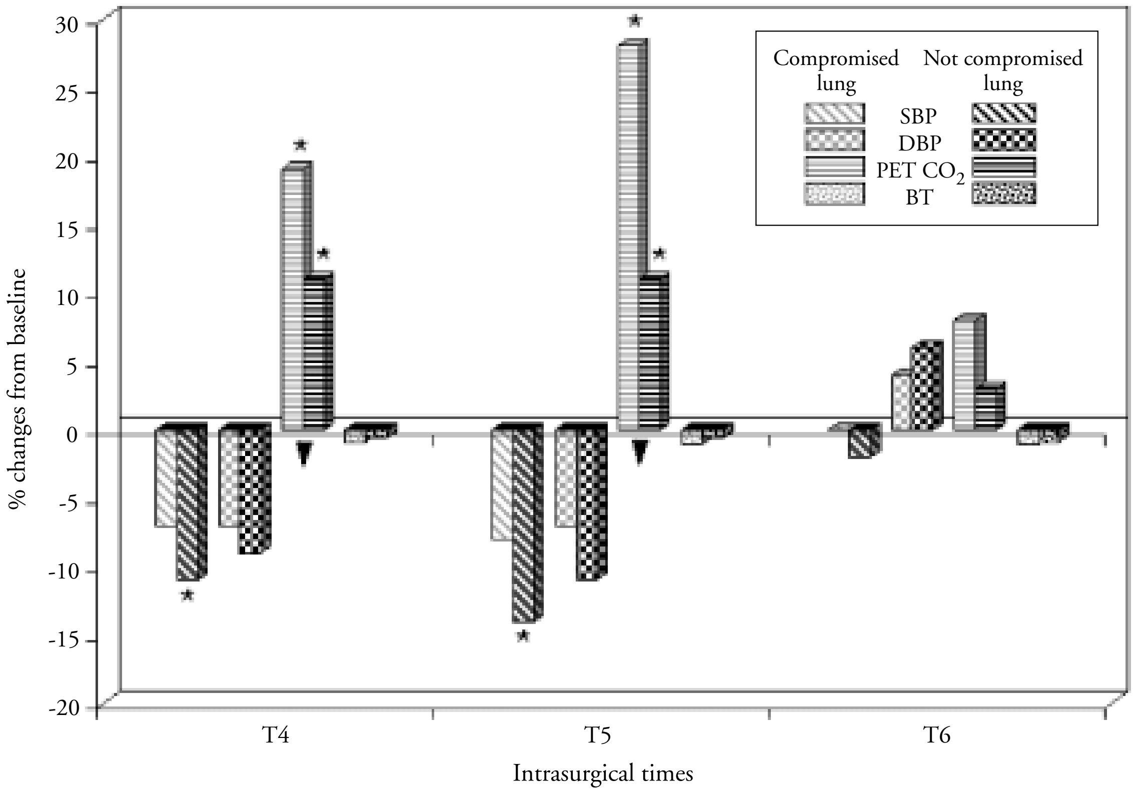

Figure 3.—Trend of systolic blood pressure (SBP), diastolic blood pressure (DBP), end-tidal CO_2 ($PETCO_2$) and body temperature (BT) in patients with preoperative respiratory compromise compared to patients with non parenchymal abnormalities. Changes from baseline at the times T4 (10 min after insufflation in the pleural cavity), T5 (before deflation in the pleural cavity) and T6 (10 min after deflation in the pleural cavity). * A statistically significant change from baseline within the group by Wilcoxon's signed rank test, $P<0.05$. ▼ A statistically significant difference between the two groups (one-lung ventilation or two-lung ventilation) by Wilcoxon's signed rank sum test, $P<0.05$.

in paediatric age, mainly during one-lung ventilation. The increase of FiO_2 is the principal manoevre allowing an adequate oxygenation. Hypoxic pulmonary vasoconstriction is a second way to maintain oxygenation during one-lung anaesthesia by restricting pulmonary blood flow to the nonventilated lung. One-lung ventilation management should reduce to the minimum any clinical conditions that might directly vasodilate hypoxically constricted lung vessels, such as the presence of infection, vasodilator drug infusion and the use of certain anaesthetics.[3, 18] Intravenous anaesthesia does not influence pulmonary vasoconstriction, while isoflurane, desflurane and sevoflurane have been shown to have less of an effect on hypoxic pulmonary vasoconstriction than halothane. To limit their effects on oxygenation, inhalation agents should be used at minimal alveolar concentration (MAC) or less.[5, 15] The intraoperative hypoxia can be reduced by delivering low-flow oxygen to the operated lung through a double-lumen bronchial tube or a bronchial blocker with a distal port.[17, 18] The overall data of our study show no evidence of any oxygenation problems, thus proving the efficiency of the above mentioned measures which were always included in our protocol for ventilation in thoracoscopy.

Hypercapnia may occur during thoracoscopic surgery, partly due to CO_2 absorption across the pleura, and partly because, even when lung exclusion is avoided, thoracoscopy brings about a mechanical constriction on the pulmonary parenchyma, reducing tidal volume, functional residual capacity, total lung capacity and pulmonary compliance.[4, 5, 19] Moreover, the literature

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generally agrees that CO_2 should be allowed to rise while reducing tidal volume and minute ventilation in order to prevent alveolar overdistention or the propagation of lung injury.[20, 21] The use of excessive airway pressures may increase pulmonary vascular resistance in the dependent lung and increase flow through the nondependent lung. In all children undergoing thoracoscopy the lungs should be protected against high airway pressures, during one-lung ventilation or two-lung ventilation with intrapleural insufflation, by carefully balancing tidal volume, respiratory rate, minute ventilation and $PETCO_2$.[5, 15, 21, 22] In our study, $PETCO_2$ showed the tendency to increase during the course of the thoracoscopy. All the values observed during thoracoscopic surgery, although sometimes higher than the normal range, were nevertheless always within the ranges foreseen for moderate permissive hypercapnia.[20]

There are few reports about the cardiocirculatory effects during thoracoscopy in paediatric age. The pleural CO_2 insufflation always brings about a fall in blood pressure, which is generally well tolerated in the euvolemic patient with normal cardiac function. An insufflating pressure limitation, a slow artificial pneumothorax and cardiovascular function optimization (by fluid administration or possible use of inotropic agents) can be useful to limit negative cardiocirculatory effects. Excessive pneumothorax creation may lead to decreased cardiac preload resulting in significant hypotension and reflex tachycardia.[4, 14, 23] Our data, in accordance with the literature mentioned above, demonstrate a statistically significant fall in systolic and diastolic blood pressure at the times monitored during thoracoscopy compared to baseline, yet always remaining within the normal range. Throughout the surgical operation the heart rate remained stable.

Our study demonstrates that factors such as lung exclusion, length of thoracoscopy, and preoperative parenchymal pulmonary abnormalities may influence some vital parameters during thoracoscopy.

Thoracoscopic procedure in paediatric age entails, as in adults, surgical access after provoking lung collapse, at least partially. There are 2 methods of achieving this. The first is lung exclusion by one-lung ventilation, allowing the lung to collapse passively, and the second is lung compression by carbon dioxide insufflation. It should also be noted that the pathology and age of the patient often influence lung exclusion achievement. Lung exclusion in paediatric age can be performed with the double-lumen tracheal tube in children over 6 years old, whereas the same technique can be adopted in younger children with the help of bronchial blockers.[5, 15, 22, 24-26] By using Arndt bronchial blocker we were able to achieve lung exclusion even in a 2-year-old child.

Both methods are associated with important respiratory and cardiocirculatory physiopathological problems that have been extensively studied in adult patients but very little in the paediatric age. With lung exclusion a marked decrease in arterial oxygenation results from an increased intrapulmonary shunt due to the unventilated and collapsed lung. While ventilation is penalized, there are only a few haemodynamic changes related to one-lung ventilation, causing a slight reduction in the preload, but without any major effects on cardiac output and mean arterial pressures.[14, 15, 26]

Intrapleural carbon dioxide insufflation positive pressure constricts the lung, reducing compliance, CFR and tidal volume, but has a limited effect on the ventilation-perfusion relationship and intrapulmonary shunt. Generally, respiration is only slightly compromised and haemogasanalytic changes are unremarkable. The rise in pleural cavity pressure brings about notable haemodynamic effects that greatly decrease the preload, stroke volume, cardiac output and mean arterial pressures.[15, 23, 27] Cardiovascular function is impaired proportionally to intrapleural insufflation values.[28]

A recent study on adult thoracoscopy compares the haemodynamic and respiratory effects of lung exclusion as compared to intrapleural carbon dioxide insufflation. The investigation shows a reduction in cardiac index due to intrapleural insufflation that is statistically greater than that provoked by one-lung ventilation, while the variations in the oxygenation index are statistically greater during one-lung ventilation with respect to intrapleural insufflation.[29] Our data seem to confirm such changes also in paediatric age. Intrapleural CO_2 insufflation brought about haemodynamic changes

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characterized by a fall in systolic and diastolic blood pressure greater than in one-lung ventilation. On the other hand, respiratory endangerment arose due to a greater rise in $PETCO_2$ in patients undergoing one-lung ventilation than in those where more intrapleural insufflation was applied.

The lengthening of the time necessary for thoracoscopic videosurgery does not lead to modifications in the cardiocirculatory parameters. However, both $PETCO_2$ and body temperature showed significant variations depending on the thoracoscopic time. In patients submitted to a pneumothorax lasting more than 60 min $PETCO_2$ values increased higher than in patients undergoing pneumothorax shorter than 60 min. Although no paediatric studies have specifically dealt with this matter, it appears evident that the longer the ventilatory strategies and surgical techniques take, the more some respiratory trends such as $PETCO_2$ increase. In the literature several authors report similar findings.[3, 5, 14, 22, 30-32] It is well known that hypothermia, which is of particular concern in neonates and young infants, is likely to occur following lengthy procedures in paediatric anaesthesia. Although progressive hyperthermia has been reported during thoracoscopic surgery in children secondary to local heat production by the endoscope,[33] our data nevertheless show a significant reduction in body temperature related to the time of thoracoscopy.

Preoperative parenchymal pulmonary abnormalities may be a further factor conditioning vital parameters during thoracoscopy. In our study this aspect did not affect cardiocirculatory trends, but only respiratory function. In children with preoperative parenchymal pulmonary abnormalities, $PETCO_2$ was statistically higher both during thoracoscopic times and after pleural cavity deflation. The presence of a primary tumour or metastatic lesions, pulmonary congenital malformation, infectious diseases, pulmonary fibrosis and bronchopulmonary dysplasia, represent a group of pathologies often related to restrictive, obstructive and mixed ventilatory defects that need careful ventilatory strategies. In such cases high intraoperative airway pressure should be avoided and a small increase in $PETCO_2$ is preferable both in extensive pulmonary resection and even in simple pulmonary biopsy.[34]

Conclusions

Our study confirms that thoracoscopy involves several anaesthesiological problems from both a physiopathological and practical point of view, as the procedure depends largely on acquired knowledge and experience. Patient evaluation and knowledge of physiological changes related to thoracoscopy are essential in order to minimize risks. The presence of anterior mediastinal masses represents the worst risk in airways management in patients undergoing thoracoscopy. In the present study systolic and diastolic blood pressure were significantly lower and $PETCO_2$ significantly higher during artificial pneumothorax. Body temperature had a significant reduction during thoracoscopy and after deflation of the pleural cavity. The lung exclusion with one-lung ventilation, the length of the thoracoscopic procedure and the preoperative respiratory compromise are factors that may affect the most important vital parameters. Our experience suggests that paediatric thoracoscopy is a safe and efficient surgical technique.

References

1. Rothemberg SS, Chang JHT, Toews WH. Thoracoscopic closure of patent ductus arteriosus: a less traumatic and more cost-effective technique. J Pediatr Surg 1995;30:1057-60.
2. Bianchi A, Sowande O, Alizai NK, Rampersad B. Aesthetics and lateral thoracotomy in the neonate. J Pediatr Surg 1998;33:1798-800.
3. Haynes SR, Bonner S. Anaesthesia for thoracic surgery in children. Paed Anaesth 2000;10:237-51.
4. Peden CJ, Prys-Roberts C. Capnothorax: implications for the anaesthetist. Anaesthesia 1993;48:664-6.
5. Tobias JD. Anaesthetic implications of thoracoscopic surgery in children. Paed Anaesth 1999;9:103-10.
6. Motoyama EK. Respiratory physiology in infants and children. In: Motoyama EK, Davis PJ eds. Smith's: Anesthesia for infants and children. 6th edition. St Louis: C.V. Mosby; 1996.p.69-104.
7. Strafford MA. Cardiovascular physiology. In: Motoyama EK, Davis PJ eds. Smith's: Anesthesia for infants and children. 6th edition. St Louis: C.V. Mosby; 1996.p.69-104.
8. Kern FH, Bengur AR, Bello EA. Developmental cardiac physiology. In: Rogers MC ed. Texbook of pediatric intensive care. 3th edition. Baltimore: Williams andWilkins; 1996.p.397-418.
9. Bray RJ, Fernandez FJ. Mediastinal tumour causing airway obstruction in anaesthetised children. Anaesthesia 1982:37:571-3.
10. Halpem SH, Chatten J, Meadows AT. Anterior mediastinal masses: anesthesia hazards and other problems. J Pediatr 1983;102:407-11.
11. Levin H, Bursztein S, Heifetz M. Cardiac arrest in a child with an anterior mediastinal mass. Anesth Analg 1985;64:1129-31.

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12. John RE, Narang VPS. A boy with an anterior mediastinal mass. Anaesthesia 1988;43:864-6.
13. Neuman GC, Weingarten AE, Abramowitz RM. The anesthetic management of the patient with an anterior mediastinal mass. Anesthesiology 1984;60:14-8.
14. Tobias JD. Anesthetic management for pediatric laparoscopy and thoracoscopy. In: Lobe TE, Schropp KP, eds. Pediatric laparoscopy and thoracoscopy. 1st edition. Philadelphia: WB Saunders Company; 1994.p.59-66.
15. Tobias JD. Anaesthesia for minimally invasive surgery in children. Best Pract Res Clin Anaesthesiol 2002;16: 115-30.
16. Hammer GB. Anaesthetic management for the children with a mediastinal mass. Paed Anaesth 2004;14:95-7.
17. Sfez M. Basic physiology and anesthesia. In: Bax NMA, Georgeson KE, Naimaldin A, Valla JS eds. Endoscopic surgery in children. 1st edition. Berlin: Springer; 1999.p.53-70.
18. Benumof JL. Anesthesia for Thoracic Surgery. 2nd edition. Philadelphia: WB Saunders Company; 1995.
19. Pfitzner J, Peacock MJ, McAleer PT. Gas movement in the nonventilated lung at the onset of single-lung ventilation for video-assisted thoracoscopy. Anaesthesia 1999;54: 437-43.
20. Hickling KG. Permissive hypercapnia. Respir Care Clin North Am 2002;8:155-69.
21. Laffey JG, O'Croinin D, McLoughlin P, Kavanagh BP. Permissive hypercapnia – role in protective lung ventilatory strategies. Int Care Med 2004;30:347-56.
22. Petrat G, Weyandt D, Klein U. Anesthetic considerations in pediatric laparoscopic and thoracoscopic surgery. Eur J Pediatr Surg 1999;9:282-5.
23. Jones DR, Greaber GM, Tanguilig GG, Hobbs G, Murray GF. Effects of insufflation on hemodynamics during thoracoscopy. Ann Thorac Surg 1993;55:1379-82.
24. Rehman M, Sherlekar S, Schwartz R, Choudhry D. One lung anaesthesia for video assisted thoracoscopic lung biopsy in a paediatric patient. Paed Anaesth 1999;9:85-7.
25. Arndt GA, Delessio ST, Kranner PW, Orzepowsky W, Ceranski B, Valtysson B. One-lung ventilation when intubation is difficult – presentation of a new endobronchial blocker. Acta Anaesthesiol Scand 1999;43:356-8.
26. Hammer GB, Harrison TK, Vricella LA, Black MD, Krane EJ. Single lung ventilation in children using a new paediatric bronchial blocker. Paed Anaesth 2002;12:69-72.
27. Wolfer RS, Krasna MJ, Hasnain JU, Mclaughlin JS. Hemodynamic effects of carbon dioxide insufflation during thoracoscopy. Ann Thorac Surg 1994;58:404-8.
28. Sato M, Muraji T, Asai T, Hamada Y, Hioki K. Hemodynamic effects of carbon dioxide insufflation of the thoracic cavity during thoracoscopic surgery. Ped Endosurg Inn Tech 2002;6:185-9.
29. Brock H, Rieger R, Gabriel C, Polz W, Moosbauer W, Necek S. Hemodynamic changes during thoracoscopic surgery. Anaesthesia 2000;55:10-6.
30. Tonz M, Bachmann D, Mettler D, Kaiser G. Effects of one-lung ventilation on pulmonary hemodynamics and gas exchange in the newborn. Eur J Pediatr Surg 1997;7:212-5.
31. Rowe R, Andropoulos D, Heard M. Anesthetic management of pediatric patients undergoing thoracoscopy. J Cardiothorac Vasc Anest 1994;8:563-7.
32. Hammer GB, Manos SJ, Smith BM, Skarsgard ED, Brodsky JB. Single lung ventilation in pediatric patients. Anesthesiology 1996;84:1503-6.
33. Sugi K, Katoh T, Hohra H. Progressive hyperthermia during thoracoscopic procedures in infants and children. Paed Anaesth 1998;8:211-3.
34. Hammer GB, Fitzmaurice BG, Brodsky JB. Methods for single-lung ventilation in pediatric patients. Anesth Analg 2000;91:248-52.

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