THORACOSCOPIC SURGERY IN NEWBORNS AND INFANTS: STRATEGIES AND LIMITS

1. INTRODUCTION

In the 1980, minimal access procedures largely consisted of arthroscopy, endoscopy, and gynaecologic procedures. The advantages of using several small openings rather than a large upper abdominal incision were clear, and general surgeons worldwide rapidly learned the technique and began to explore additional applications of minimally invasive surgery (MIS). Gradually, more and more procedures traditionally performed with major open exposures were tried with MIS, so that at the present MIS is became the gold standard for several operations (1,2).

MIS and Open Surgery share certain principles: exposition and lighting. Laparoscopic instruments have been developed which allow the surgeons to perform operative manipulations – division, dissection, haemostasis, repair of structures, and removal of tissue. Moreover, MIS showed potential advantages over open surgery such as improved cosmetic results, diminished postoperative pain, accelerated recovery, reduced degree of adhesion formation, and a shorter hospital stay (3,4).

After the success of minimally invasive surgery in adults, application in paediatric patients was a logical next step. While some paediatric surgeons found MIS as a revolution in surgical practice, others felt that the benefit of MIS in children was less evident. Children recover from major procedures faster than adults, need less analgesic requirement and return to full activity quickly. Nonetheless, surgery in any patient is traumatic and MIS was seen as an opportunity to minimize the insult of operations in young patients (5,6).

The development of MIS in the paediatric population has progressed more slowly than in adults. The surgical instruments had to be downsized, the learning curve was relatively long, and safe and reliable anaesthetic procedures had to developed to ensure tolerance of pneumoperitoneum and pneumothorax (7,8).

Leaders such as Gans, Rodgers, Georgeson and Lobe showed that MIS was certainly applicable to the paediatric patient and in the last years the use of MIS has expanded dramatically in older children (1).

Currently, instruments and techniques are adapted that even the most complicated neonatal procedures can be performed laparoscopically or thoracoscopically. Nonetheless up to know, minimally invasive neonatal surgery has been limited to specialized canters, the incidence is low, and the evidence of its benefits is scarce. The reasons may be due to the presumed greater technical challenge and/or unacceptably high risks in neonates and infants (9,10).

Since Gans, in 1973, first described neonatal laparoscopy in a 1-day-old patient, numerous steps forward have been done in the neonatal MIS. Despite that, continues to be a great debate about

the safety and efficacy of MIS in neonates and infants. This concern is based mainly on the assumed physiological effects of MIS as well as the small surgical field (11).

2. RATIONALE OF THE STUDY

Thoracoscopic procedures were introduced in paediatric surgery as early as the mid 1970's. At the time, the thoracoscopic spectrum consisted mainly of biopsy, decortication, and deroofing of pulmonary cysts (12,13).

In 1993, on the Annals of Thoracic Surgery, Rodgers highlighted that thoracoscopy was an accurate method of tissue diagnosis and surgical treatment but may not be applicable in children who weigh less the 8 kg (14).

Today, more than 20 types of thoracoscopic procedures have been introduced for infants and children. The benefits of the thoracoscopic approach include less postoperative pain, shorter hospital stay, better cosmesis, and less long-term musculoskeletal morbidity such as shoulder movement impairment, rib fusions, and scoliosis. Despite that, there is considerable concern about the safety of thoracoscopy for neonates and infants (13).

Experimental data have demonstrated and increased CO2 absorbance in the young and higher sensitivity of the neonatal cardiovascular system to CO2. Neonatal MIS could cause unwanted physiologic side-effect on an immature neonatal cardiopulmonary system. These adverse effects, such us acidosis and desaturations, may be even bigger in the thoracoscopy. Some authors suggested that some of these difficulties could be overcome by having a good paediatric anaesthetist who is familiar with thoracoscopic procedures (15).

However, the level of evidence for neonatal thoracoscopy is low as there are no randomized controlled trials dealing with MIS versus open for intrathoracic procedures (1).

The aim of this thesis is to review our experience with different thoracoscopic procedures and evaluates its safety and feasibility in neonates and infants.

3. MATERIALS AND METHODS

A retrospective database was reviewed looking for all thoracoscopic procedures performed in neonates and infants from June 2011 until September 2021.

There were no exclusions and all patients who were hemodynamically stable, on conventional ventilation, and who could be transferred to the operating room for their procedure were attempted using MIS techniques.

The all procedures were performed by the members of the Paediatric Surgery Department of Braga Hospital.

Some patient underwent a mainstem intubation of the opposite lung to provide single-lung ventilation.

Patient's demographics, disease, age at surgery, weight at surgery, type of surgery, operative time, intraoperative and postoperative complications, need of conversation, length of stay, re-do surgery, and mortality.

Surgical technique

Following the details of the principal surgeries performed.

Congenital Diaphragmatic Hernia

Right lateral decubitus with the left upper extremity left free and supported by the patients. Camera port of 5 mm is placed just at the tip of the scapula usually in the mid-axillary line of the 4^{th} or 5^{th} intercostal space. The intrathoracic position is carefully checked with the scope, and gentle insufflation of CO2 (low flow 1 L/min and low pressure max 6 mmHg). Two of 3 mm working ports are introduced under vision in the anterior and posterior axillary line of the 4^{th} or 5^{th} intercostal space. Gentle reduction of the abdominal contents in the abdominal cavity. Assessment of the defect size. Circumferential incision of the sac if it is present. Mobilization of the posterior rim of the diaphragm. Tension-free closure of diaphragmatic defect with horizontal mattres sutures with Ethibond 2/0. Anchored rib sutures at the lateral side of the defect. Suction and irrigation to clean the thoracic cavity. Port sited are closed with absorbable suture.

Oesophageal Atresia

Cuschieri position (modified prone position with the right side elevated approximately 30°). Camera port of 5mm is placed in the 6^{th} intercostal space behind the tip of the scapula. Other 3 mm working ports are placed along the anterior axillary line in the 3^{rd} and 5^{th} intercostal space respectively. Capnothorax was established with an inflation rate of 1 L/min and maintained at a maximum pressure of 4 mmHg. Identification of azygus vein and vagus nerve. Sharply incision of the pleura overlying the distal pouch. Identification of the lower oesophageal segment and isolation and ligation of the tracheoesophageal fistula with Hem'O'Lock. Identification of the upper pouch with the help of Replogue tube. Mobilization of the upper pouch. Once adequate mobilization of the distal and upper pouch, the tips of both pouches are resected, and anastomosis performed with interrupted suture with PDS 5/0. Once the anastomosis is completed,

a chest drain is introduced through the lower port site, and its tip is positioned near the anastomosis. The ports are removed, and the sites are closed with absorbable suture.

Lung Resection

Lateral decubitus position with the affected side up. The 5 mm telescope port is placed in the mid mid-to anterior axillary line in the 5^{th} or 6^{th} intercostal space. The working ports (3 mm or 5 mm) are place in the anterior axillary line above and below in the camera port. For a lower lobe, the inferior pulmonary ligament is taken first until the inferior pulmonary vein is exposed. Dissection into the parenchyma of the lower lobe to obtain adequate length of the segmental branches of the IPV, then sealed and divided. Examination of the major fissure, the branches of the pulmonary artery to the lower lobe are then sealed and divided at the segmental level. Pulmonary artery is sealed with ethibond 2/0 and its segmental branches with ultra-cision. IVP is sealed with ethibond 2/0. Bronchus of the left lower lobe is sealed with Ethibond 2/0. Left lower lobectomy and remotion of the specimen through a slightly dilated 5 mm trocar site. The ports are removed, and the sites are closed with absorbable suture.

Statistical Analysis

Data are presented as prevalence or medians and interquartile ranges (IQR).

4. RESULTS

During the study period, a total of 38 thoracoscopic procedures were performed in neonates and infantes. Seven patients were preterm (18%) [average of gestational age 36.5 (27-37 IQR); average of age at surgery 13.25 (2-108 IQR); average of weight at surgery 2317 (850-2250 IQR)], six of them presented oesophageal atresia (86%) and one congenital diaphragmatic hernia (14%).

The overall average of the age at surgery was 66 days (2-316 IQR).

The procedures performed include oesophageal atresia repair (20), congenital diaphragmatic hernia repair (5), diaphragm plication (2), pulmonary lobectomy (9), resection of pulmonary sequestrations (2).

The operative time of oesophageal atresia repair was 131 minutes (average, 70-254 IQR). The patients underwent this surgery at 12.8 days old (average, 2-108 IQR) and their weight at surgery was 2645 gr (average, 1240-4900 IQR). The length of stay was 27.4 days (average, 9-94 IQR). 17 patients had type C oesophageal atresia (85%), 1 type B (5%), 1 type D (5%), and 1 type A (5%).

Four patients had left congenital diaphragmatic hernia, and 1 had anterior or Morgagni diaphragmatic hernia. The average of the age at surgery was 2.3 days (2-3 IQR) and the weight was 2762 gr (average, 2100-3425 IQR). One patient showed respiratory acidosis and hypoxia after surgery. The length of stay was 26 days (average, 7- 45 IQR).

Eleven patients had congenital pulmonary airway malformations. Patients underwent surgery at average of 160 days old (11-316 IQR). Surgery last 133 minutes (average, 75-219 IQR). Bleeding from a branch of the pulmonary artery occurred that was promptly sealed, and two patients showed signs of respiratory distress syndrome. Patients stay in the hospital for 3.75 days (average, 2-6 IQR).

The conversation rate to open were 2.6%. The converted procedure was an oesophageal atresia repair due to a severe desaturation. The intraoperative complication rate was 8% and the overall complication rate was 42%. The complications included intraoperative bleeding of a branch of pulmonary artery, intraoperative perforation of the upper oesophageal pouch, intraoperative severe desaturation, oesophageal anastomosis leak, oesophageal anastomotic stenosis, tracheomalacia, and respiratory distress syndrome.

Two patients underwent a second surgery, both due to an oesophageal anastomosis major leak. One case was an oesophageal atresia long gap B type. 6 days after primary anastomosis was performed, the patient showed signs and symptoms of hydropneumothorax. This patient underwent thoracotomy, and an oesophagostomy was performed. 25 days after the second surgery the patient dead due to sepsis.

Table 1 summarizes main findings.

	Overall **38**	**AE** **20**	**CDH** **5**	**Eventratio** **2**	**CPAM** **11**
Birth weight gr; media IQR	2689 (850-4010)	2466 (850-3995)	2762 (2100-3425)	-	3419 (3000-4010)
Gestational age weeks; media (IQR)	36.7 (27-41)	36.8 (27-41)	32 (30-34)	-	38.6 (38-40)
Age at surgery days; media (IQR)	66 (2-316)	12.8 (2-108)	2.3 (2-3)	237.5 (190 -285)	160.25 (11-316)
Weight at surgery gr; media (IQR)	2658 (1240-4900)	2645 (1240-4900)	2762 (2100-3425)	-	-
Operative time minutes; media (IQR)	131 (70-254)	131 (70-254)	-	-	133 (75-219)
Intraoperative complications n (%)	3 (8)	2 (10)	0	0	1 (9)
Postoperative complications n (%)	13 (34)	10 (50)	1 (20)	0	2 (18)
Conversations n (%)	1 (2.6)	1 (5)	0	0	0
Length of stay days; media (IQR)	19.7 (2-94)	27.4 (9-94)	26 (7-45)	-	3.75 (2-6)
Re-do surgery n (%)	2 (5)	2 (10)	0	0	0
Deaths n (%)	1 (2.6)	1 (5)	0	0	0

Table 1.

5. DISCUSSION

The author reported the experience of the Paediatric Surgery team of Braga Hospital performing thoracoscopic procedures in neonates and infants. Although the previous studies suggested that MIS in children of this age was safe for selected patients, the low power of the studies made this argument less convincing.

MIS have a shorter and simpler postoperative course, better cometic results, more rapid recovery, and lower postoperative pain. Neonates, however, have distinct physiologic and anatomic characteristics that increase the rate of surgical complications (1).

Neonatal ventilatory limitations, particularly the small airway calibre and the important instrumental deadspace could explain the markedly perturbed gas exchanges. The peritoneal and pleural absorption surface per unit of weight is high in newborns. The low quantity of peritoneal fat and the slight distance between vessels and the serous surface increase the permeability of the peritoneum to CO2. This is 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 CO2 arterial pressure and low pH (16,17). Despite a low compliance in the neonatal myocardia, a low functional reserve, and heightened sensitivity to changes in systolic pressure and telediastolic volume, the hemodynamic tolerance of insufflation in small infants is overall acceptable. 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. 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 (15,18,19).

Anaesthetic techniques have been developed and continue to evolve to allow safe MIS in neonates. Hypercapnia is invariable due to the use of CO2 in achieving pneumoperitoneum or pneumothorax. In order to alleviate hypercapnia, various authors suggest hyperventilation, increase in minute volume and limiting of the intrabdominal pressures. Of more concern is perhaps an increased frequency of anaesthetic ‘‘events’’ during surgery, such as desaturation (despite 100% oxygen), transient hypotension requiring volume expansion, hypercapnia, hypothermia, and metabolic acidosis. To overcome these “events”, some authors have proposed one-lung ventilation for thoracoscopy in small infants to avoid pressure in the chest from insufflation (16). 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. 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, anaesthetic incidents, temporary interruption of insufflation, and delayed extubation. The best strategy to minimize intraoperative hypercapnia and acidosis would be to use

CO2 insufflation at very low pressures, possibly insufflating only at the beginning of the operation (17).

Zani et al. reported that neonates undergoing thoracoscopy develop intraoperative acidosis and hypercapnia regardless of the approach used. However, this phenomenon is more severe during thoracoscopic repair. Although the finding of acidosis is concerning, the authors found no association of intraoperative acidosis with any other postoperative outcome of immediate interest. The effects of acidosis and hypercapnia on cerebral development are unknown but maintaining adequate arterial oxygenation could be key to prevent damage. These findings have made surgeons and anaesthetists aware of the occurrence of intraoperative acidosis and hypercapnia, prompting the surgeons to use low insufflation settings and the anaesthetists to meticulously check neonatal physiology intraoperatively (20). Moreover, two reports by Stolwijk showed no difference between the open and thoracoscopic group regarding hypercapnia, acidosis, and cerebral perfusion. They did use average pressure of 5 mmHg, and that could explain the results (21,22).

Although advancements in technique and instrumentation in paediatric endoscopic surgery have allowed significantly more complex and delicate procedures to be performed even in small neonates, it is still unclear which types of thoracoscopic operations should be recommended as standard procedures (1,23).

However, some authors have established recommendations and some standards for pulmonary resection, oesophageal atresia repair and congenital diaphragmatic hernia. Therefore, we selected these procedures for evaluation (13).

Oesophageal atresia thoracoscopic repair was first reported in 1999 in a 2-month-old infant with pure oesophageal atresia. Since then, techniques have evolved further and have been widespread adopted (11). Nevertheless, oesophageal atresia repair remains a challenging procedure. Nonetheless complications seem comparable to the open alternative with an anastomotic leak rate of less than 10% and a postoperative mortality rate of 3% (24,25). An important putative advantage for MIS in the management of this condition is the avoidance of chest wall deformity and cosmetic results. This would be significant if confirmed on long-term follow-up studies as some open series have reported the incidence of chest wall deformity to be as high as 25–30% (26,27,28). Ure and colleagues recently reported their experience of thoracoscopic oesophageal atresia repair, using selective criteria. These criteria appear very reasonable and should serve as a guide for the use of the thoracoscopic approach for those who may not be as experienced with this technique as others. A better case is a baby who is 3–3.5 kg and has no other anomalies with the oesophageal segments close together as noted by chest radiograph and bronchoscopy. The suggestion is that the surgeon starts thoracoscopically and proceeds as far as he/ she is comfortable (29).

The first report of thoracoscopic diaphragmatic hernia repair was in 2001. This procedure has been performed by both the laparoscopic and thoracoscopic routes. With increasing experience, thoracoscopy was shown to be superior to the laparoscopic approach as the insufflation of the CO2 in the thoracic cavity supported the reduction of the abdominal organs (13). Compared with open surgery, thoracoscopic repair for CDH is potentially associated with fewer postoperative ventilator days and possibly less use of analgesics. On the other hand, the artificial

pneumoperitoneum (or pneumothorax) needed for MIS negatively affects hemodynamic. Multiple studies show a higher recurrence rate associated with thoracoscopic repair due to learning curve, limited workspace, and the use of a patch (30). Furthermore, the surgical difference between open and thoracoscopic repair is that the rim of diaphragm is mostly adhered to the dorsal pleuroperitoneal canal and preparation from thoracic side is challenging. Although several series emphasize the good feasibility of the thoracoscopic approach for CDH, the heterogenous selection criteria of the appropriate patients and the long-term outcome compared to open surgery are still a matter of discussion (11,13). Costerus et al. emphasized the needs of criteria to select patient for thoracoscopic repair. Based on their experience they suggested criteria such as PEEP of 2–5 cm and in addition FiO2\50 % with a SpO2 between 85 and 95 % (31).

As mentioned before, the first significant us in children of thoracoscopy was recorded in later 1970s when Rodger reported his experience using this procedure for evaluation of intrathoracic lesions, small biopsies, and limited pleural debridement (32). In the last decade, thoracoscopic lung biopsy, decortication, and bleb resection for pneumothorax has been shown to be so safe and effective that in many centres it has completely replaced open thoracotomy as the treatment of choice (33). Complete excision of congenital lung malformations remains the gold standard treatment (34). Thoracoscopic lobectomy in children for congenital cystic lung disease is now an accepted and well-described technique (35). Most authors agree on the relative merits of a thoracoscopic approach, including less pain, shorter hospital stay, and decreased long-term morbidity, including a decreased risk of chest wall deformity, shoulder girdle weakness, and scoliosis (36). Despite this general consensus, the adoption of this technique and surgeon comfort with the approach remains relatively low primarily because of the procedure is technically demanding and because most surgeons see a low volume of cases that results in a decreased familiarity with pulmonary anatomy (37). The advent of excellent 3-mm instrumentation and small scopes have made manoeuvring in the chest in the tiny ribspaces of neonates possible and more ergonomic. Rothenberg concluded that early resection is feasible, safe, and avoids the potential long-term complications such as infection and malignant transformation (34).

In order to showed evidence of the feasibility and safety of thoracoscopy, the authors compare their experience with the reports of the largest series describing thoracoscopic oesophageal atresia (28) and congenital diaphragmatic hernia repair (31), and pulmonary lobectomy in the literature (32). Our series showed comparable results in term of operative time, conversion rate, complications, mortality and length of stay. Thanks to that, we strongly believe that thoracoscopy should use as a gold standard in selected cases and be able to promptly convert when needed.

At the beginning the experience with MIS in infants was challenging mostly due to deficiencies in the equipment that was available. The process of creating the ideal instrument for the small infants too many years to refine and is still in evolution. Along with the evolution of the tools, the evolution of the CO2 insufflator was important. Nowadays, the development of a neonatal appropriate insufflator allows to alleviate the problem of overinsufflations (1).

MIS is not widely spread, and the reason is that endosurgery has a considerable learning curve. It has been stated that it takes more than one year for a senior paediatric surgeon to master laparoscopic surgery and that complications mainly occur in the first 60 cases. With increased experience there is a significant decrease in operating time, postoperative stay, and treatment failures (38).

Paediatric trainees continue to have limited exposure to advanced MIS procedures during their clinical training particularly for rare index cases, such as neonatal MIS. This makes it difficult for them to acquire the necessary skills to become competent and safe operators. For this reason, simulation in surgical training becomes an attractive modality for teaching technical and nontechnical skills in a way that does not pose a risk to the patient. Simulation offers an alternative to the traditional apprenticeship model of training, with its ethical constraints around trainees attaining skills on actual patients, the consequences of increased work hour restrictions, rising operating theatre costs. These factors often serve to deny trainees the opportunity of being the primary surgeon for these rare and complex procedures. Ideally, simulation should allow the operative steps of neonatal MIS to be practiced in a deliberate, repetitive, and participatory fashion, with a validated model that can tolerate and correct performance errors. Similarly, it should be able to demonstrate when the required skills have been acquired with a degree of reliability. Simulators designed to the same scale as neonates are needed to replicate the smaller surgical spaces available for neonatal thoracoscopic procedures. Access to simulator should be mandatory during paediatric training, allowing trainees to quickly acquire skills to perfume a safe neonatal MIS (39).

6. CONCLUSIONS

Recently, the feasibility of minimally invasive surgery in the neonate has been demonstrated for a variety of indications. With modern equipment, it appears that there is no minimum age or weight criteria for laparoscopic or thoracoscopic interventions and there is increasing popularity for neonatal minimally invasive surgery in the paediatric surgical community (12). The focus of the academic work has shifted from the feasibility to the potential advantage or disadvantage of minimally invasive surgery in neonates and there is an increasing number of studies that include follow-up observations, comparisons with historic controls, matched control cases and prospective randomized trials (13). However, evidence for the benefit of minimally invasive surgery in the neonatal age group is still limited. There is a demand for prospective multicentre study and prospective database in paediatric MIS to evaluate not the feasibility but evidence of clinical benefit.

7. REFERENCES

1. Martin Lacher, Joachim F. Kuebler, Jens Dingemann, Benno M. Ure. Minimal invasive surgery in the newborn: Current status and evidence. Seminars in Pediatric surgery 2014;23:249-256
2. Aayed R. Al-Qahtani, Hamdi Almaramhi. Minimal access surgery in neonates and infants. J Pediatr Surg 2006;41:910-913
3. Georgeson KE, Owings E. Advances in minimally invasive surgery in children. Am J Surg 2000;180:362 – 4
4. Todd A. Ponsky Æ Steven S. Rothenberg. Minimally invasive surgery in infants less than 5 kg: experience of 649 cases. Surg Endosc (2008) 22:2214–2219
5. Joachim F. Kuebler, Benno M. Ure. Minimally invasive surgery in the neonate. Seminars in Fetal & Neonatal Medicine 16 (2011) 151e15
6. N. Scott Adzick, Micheal L. Nance. Pediatric Surgery. The New England J of Medicine 2000;342:1651-1657
7. Keith E. Georgeson and Daniel J. Robertson. Minimally Invasive Surgery in the Neonate: Review of Current Evidence. Seminars in Perinatology 2004;28:212-220
8. Anthony M Firilas, Richard J Jackson, and Samuel D Smith. Minimally Invasive Surgery: The Pediatric Surgery Experience. J Am Coll Surg 1998;186:542-544
9. Jeffrey L. Zitsman. Current Concepts in Minimal Access Surgery for Children. Pediatrics 2003;111: 1239-1252
10. Chandrasen K. Sinha, Saravanakumar Paramalingam, Shailesh Patel, Mark Davenport, Niyi Ade-Ajay. Feasibility of complex minimally invasive surgery in neonates. Pediatr Surg Int (2009) 25:217–221
11. Mark Davenport, Steven S. Rothenberg, David C.G. Crabbe, Mark L. Wulkan. The great debate: open or thoracoscopic repair for oesophageal atresia or diaphragmatic hernia. J Pediatr Surg 2015;50:240-246
12. Rothenberg SS, Chang JH, Bealer JF. Experience with minimally invasive surgery in infants. Am J Surg 1998;176:654 – 8
13. B. M. Ure, A. I. Schmidt, N.K. Jesh. Thoracoscopic Surgery in Infants and Children. Eur J Pediatr Surg 2005;15:314-318
14. Bradley M. Rodgers. Pediatric Thoracoscopy: Where Have We Come and What Have We Learned? Ann Thorac Surg 1993;56:704-707
15. Nicolas Kalfa, Hossein Allal, Olivier Raux et al. Tolerance of Laparoscopy and Thoracoscopy in Neonates. Pediatrics 2005;116:785-791
16. Joseph D. Tobias. Anaesthesia for minimally invasive surgery in children. Best practice & Research 2002;16:115-130

17. Mark Bishay, Luca Giacomello, Giuseppe Retrosi et al. Hypercapnia and Acidosis During Open and Thoracoscopic Repair of Congenital Diaphragmatic Hernia and Esophageal Atresia: results of a pilot randomized controlled tria. Annals of Surgery 2013;258:895-900)
18. Merrill Mchoney, Gordon Mackinlay, Fraser Murno et al. Effect of Patient Weight and Anesthetic Technique on CO2 Excretion During Thoracoscopy in Children Assessed by End-Tidal CO2. J Laparoend & Advanc Surg Tech 2008; 18:147-151
19. M. McHoney , S. Eaton , A. Pierro. Metabolic Response to Surgery in Infants and Children. Eur J Pediatr Surg 2009; 19: 275 – 285
20. Augusto Zani, Ruben Lamas-Pinheiro, Irene Paraboschi et al. Intraoperative acidosis and hypercapnia during thoracoscopic repair of congenital diaphragmatic hernia and esophageal atresia/tracheoesophageal fistula. Pediatric Anesthesia. 2017;27:841–848
21. Stolwijk L, Tytgat S, Keunen K, et al The Effects of CO2 insufflation of cerebral oxygenation in neonates during thoracoscopic repair of esophageal atresia. Presented at EUPSA annual congress, Dublin June 2014
22. Stolwijk L, Tytgat S, Keunen, et al The effects of CO2-insufflation with 5 and 10 mmHg during thoracoscopy on cerebral oxygenation and hemodynamics in PIGLETS. Presented IPEG, Edinburgh July 2014
23. Rothenberg SS. Thoracoscopy in infants and children; the state of the art. J Pediatr Surg 2005;40:303 – 6
24. Jason D. Fraser, Shawn D. St Peter. The Current Thoracoscopic Management of Esophageal Atresia. Eur J Pediatr Surg 2020;30:142-145
25. S. S. Rothenberg. Thoracoscopic repair of esophageal atresia and tracheoesophageal fistula in neonates, first decade's experience. Diseases of the Esophagus 2013;26:359–364
26. S. S. Rothenberg. Thoracoscopic repair of esophageal atresia and trachea-esophageal fistula in neonates: the current state of the art. Pediatr Surg Int 2014;30:979–98
27. George W. Holcomb III. Thoracoscopic surgery for esophageal atresia. Pediatr Surg Int 2017;33:475–481
28. Holcomb GW 3rd, Rothenberg SS, Bax KM et al. Thoracoscopic repair of esophageal atresia and tracheoesophageal fistula: a multi-institutional analysis. Ann Surg 2005;242:422–428
29. Dingemann C, Ure BM. Minimally invasive repair of esophageal atresia: an update. Eur J Pediatr Surg 2013;23:198–203
30. Anne Schneider, François Becmeur. Pediatric thoracoscopic repair of congenital diaphragmatic hernias. J Vis Surg 2018;4:43
31. Sophie Costerus, Katrin Zahn, Kees van de Ven et al. Thoracoscopic versus open repair of CDH in cardiovascular stable neonates. Surg Endosc 2016;30:2818–2824
32. Craig T. Albanese, Steven S. Rothenberg. Experience with 144 Consecutive Pediatric Thoracoscopic Lobectomies. Laparoend & Advanc Surg Tech 2007;17:339-341
33. Albanese CT, Sydorak RM, Tsao K, et al. Thoracoscopic lobectomy for prenatally diagnosed lung lesions. J Pediatr Surg 2003;38:553 – 5
34. Arnaud Bonnard. Thoracoscopic Lobectomy for Congenital Pulmonary Airway Malformation: Where Are We in 2019? Eur J Pediatr Surg 2020;30:146-149
35. Steven S. Rothenberg. Thoracoscopic Lobectomy in Infants and Children. Laparoend & Advanc Surg Tech 2021;31:1157-1161
36. Steven S. Rothenberg. Thoracoscopic Lobectomy in Infants and Children Utilizing a 5 mm Stapling Device. Laparoend & Advanc Surg Tech 2016;26:1036-1038
37. Steven S. Rothenberg. Experience With Thoracoscopic Lobectomy in Infants and Children. J Pediatr Surg 2003;28:102-104

38. Steven S. Rothenberg, Keith A. Kuenzler, William Middlesworth et al. Thoracoscopic Lobectomy in Infants Less Than 10 kg with Prenatally Diagnosed Cystic Lung Disease. Laparoend & Advanc Surg Tech 2011;21:181-184
39. V. Ibáñez Pradas, M. Couselo Jerez, M.E. Carazo Palacios. Thoracoscopic esophageal atresia repair: learning curve analysis using Clavien-Dindo surgical complication classification. Cir Pediatric 2021;33:166-171
40. David Nair, Jonathan M Wells, Nick Cook, Ash Moorhead, Spencer W Beasley. Critical design and validation considerations for the development of neonatal minimally invasive surgery simulators. J Pediatr Surg 2019;54:2448-2452