Editorial

Thoracoscopic resection of congenital pulmonary airway malformations: timing and technical aspects

Francesco Macchini

Department of Pediatric Surgery, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy

Correspondence to: Francesco Macchini, MD, PhD. Department of Pediatric Surgery, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Via Francesco Sforza 35, 20122 Milan, Italy. Email: francesco.macchini@policlinico.mi.it.

Provenance and Peer Review: This article was commissioned by the editorial office, *Journal of Thoracic Disease*. The article did not undergo external peer review.

Comment on: Ito A, Takao M, Shimamoto A, *et al.* Introduction of thoracoscopic surgery for congenital pulmonary airway malformation in infants: review of 13 consecutive surgical cases. J Thorac Dis 2019;11:5079-86.

Submitted Feb 21, 2020. Accepted for publication Mar 20, 2020.

doi: 10.21037/jtd.2020.03.109

View this article at: http://dx.doi.org/10.21037/jtd.2020.03.109

In a recent publication of this Journal, Ito *et al.* (1) report the experience of their center on the complete video-assisted thoracic surgery (C-VATS) approach to congenital pulmonary airway malformations (CPAM) in neonates and infants, especially focusing their attention on the optimal timing of surgical intervention.

Indeed, the topic is very current. However, many aspects of the treatment of CPAM are still matter debated among experts.

Incidence of CPAM

CPAM represent the great majority of congenital lung malformations (CLM) and are characterized by an abnormal proliferation of the terminal respiratory structures that induces the formation of a mass of pulmonary tissue and the abnormal development of alveoli (2). The true incidence is still unclear: while in past years it was estimated 1:11,000–35,000 live births, currently it seems around 1:7,200.

This increase in incidence may be explained by improved prenatal ultrasound techniques, greater availability of prenatal therapies and procedures to treat fetal complications, and improvement in neonatal intensive cares (3).

Current therapeutics

Ultrasound currently offers a high level of sensitivity in fetal diagnosis of CPAM. Furthermore, the concomitant measure of the cystic pulmonary airway malformation volume ratio (CVR) may predict the risk of the most severe complication, represented by fetal hydrops.

Fetal therapy gained significant importance in the last decade allowing treating with high success-rate hydrops, condition that exposes the fetus to a high risk of mortality. Current prenatal treatments are: systemic corticosteroid therapy for microcystic CPAM, single-needle thoracentesis, thoraco-amniotic shunts, open fetal resection or ex-utero intrapartum therapy (EXIT) resection (4).

In patients with a prenatal suspicion of CPAM, a chest computed tomography (CT) scan is the gold standard both for diagnosis and for the lesion's location in relation to critical structures (5).

Post-natal management significantly improved in the last years and the treatment strategies for CPAM are selected according to the presence or absence of symptoms at birth.

In the group of symptomatic newborns (25% of cases), presenting with respiratory distress and mass effect, no concerns are raised about prompt surgical indication.

In asymptomatic patients (75%), there is little controversy about the surgical resection, being infections and malignancy the main indications for surgery (2).

There are other aspects that may justify a surgical approach of all asymptomatic CPAM: the risk of pneumothorax, the potential for compensatory lung re-growth following early resection, a reduction in postoperative complications following elective surgery and the lack of non-invasive standardized long-term follow-up programs of conservative management.

Concerning the risk of malignancy, an incidence of 4% of pleuropulmonary blastoma (PPB) among apparently benign lung lesions has been observed, while occasional findings of bronchioalveolar carcinoma has been reported (6).

It seems that PPB is a distinct pathological entity and does not represent the malignant transformation of CPAM. However no clinical or radiological markers exist to differentiate CPAM from PPB and it is well known that delayed recognition or partially resection of PPB significantly worsen the prognosis (7,8).

As for infections and pneumothorax, it has been estimated that 3–9.2% of CPAM will become symptomatic (2,9). The incidence of significant infections is reported up to 30% (10).

It has also been reported that previous pneumonia may represent a risk factor for conversion of thoracoscopy to thoracotomy (11). Furthermore, it has been also outlined that 50% of CLM resected after the age of 6 months has evidence of chronic infection at histological examination (12). Finally, symptomatic patients have a greater than twofold increase in risk of postoperative complications compared with asymptomatic patients, supporting the advantages of elective surgery (13,14).

Another important advantage of a surgical approach to asymptomatic CPAM is the potential compensatory lung growth when resection is performed in early life. There is some evidence that supports the practice of early resection based on the possibility of compensatory lung growth (4). Although there are reports of cases of spontaneous disappearance of CPAM in the neonatal period, this observation appears to be more likely due fact that some pulmonary lesions may become undetectable on prenatal ultrasound follow-up and postnatal chest X-ray (15).

Elective surgery is reported as safe by many experienced groups (16,17). Complications occur in <5% of asymptomatic infants, the majority of which can be usually conservatively managed.

At present time, standardized programs to follow-up non-operated patients are lacking. Some groups suggest to perform at least three thoracic CT-scan during childhood while nothing is written about adulthood (2). This approach seems currently not safe and significantly invasive from a radiological point of view.

Analysis of the commented article

Regarding the recently published article titled "*Introduction of thoracoscopic surgery for congenital pulmonary airway malformation in infants: review of 13 consecutive surgical cases*" by Ito *et al.* (1), especially focused on the optimal timing and technique of surgical intervention for CPAM, some points deserve to be deepened.

Thirteen patients were treated for CPAM in a 10 years period in a single center. A comparison on patient backgrounds and operation data between the thoracotomy Group (nine patients) and the C-VATS Group (four patients) was done. In particular, age and height/weight at intervention, operative time, blood loss, postoperative day of drain removal, and length of hospital stay after surgery were analyzed. C-VATS was performed using 3 mm instruments and a 5 mm rigid endoscope. Intraoperative differential ventilation was preferred, especially during the thoracoscopic approach.

Mean age and weight at surgery were 2 years 3 months and 12.2 kg. No statistically significant differences were observed between the thoracotomy Group and C-VATS group for all of the studied variables, except for the body weight, that was significantly higher in C-VATS group.

Authors concluded recommending performing C-VATS lobectomy for asymptomatic CPAM in patients older than 18 months or with weigh more than 10 kg (1).

Current management of CPAM

Regarding treatment of asymptomatic CPAM, two items are still matter of discussion among experts: the best timing of surgery and the type of surgical approach.

Concerning the optimal timing for resection, a wide variation of opinions still exists among pediatric surgeons. Two of the previously cited factors consistent with elective surgery of CPAM must point to the best strategy: the compensatory lung growth after pulmonary resection and the attempt to prevent inflammation. Again, the possibility of compensatory lung growth has been described especially when surgery is performed before 2 years of age (4,18).

Different groups report the safety of performing elective surgery in early childhood. It seems that early intervention might avoid the inflammatory changes associated with both clinical and subclinical infections. Furthermore, surgery can be more challenging once the child has already suffered a clinical chest infection (19). In fact, experts report that it is very difficult to approach the interlobar pulmonary artery and bronchi when not perfectly visible due to severe adhesions or absent fissure (20).

In summary, as outlined in a review from the American Pediatric Surgery Association (APSA): while there is little

evidence to mandate an operation at a defined time in the first year of life, current available data would suggest that early (<6 months of age) surgery allows for ease of operative intervention, adequate recovery, and a reasonable time for compensatory lung growth while avoiding the potential infectious complications associated with the conservative management (4).

As regards the surgical approach, lobectomy historically represents the treatment of choice for CPAM confined to a single lobe. Recently, lung sparing resections (LSR), such as segmentectomy and wedge or other non-anatomic resections, have been proposed (21). The aim of LSR is to preserve the most of the lung tissue. It has been employed initially in multilobar lesions and then progressively extended by some groups to most of the cases, in particular to the smallest and most peripheral lesions.

One of the main limiting factors of partial lobar resection is the higher risk of post-operative complications and of an incomplete removal of the lesion (21). Thus, lobectomy still represents the standard treatment for CPAM, limiting the indications to LSR to multilobar involvement or very limited and peripheral malformations (10). In most cases, non-anatomic resections seem unsatisfactory, as some of the disease is microscopic and not grossly visible, making complete resection difficult. An anatomic segmental resection is applicable only when preoperative imaging and gross findings at the time of surgery strongly suggest that the disease is limited to a single segment. In fact, based on the embryologic development of the lung, it is reasonable to assume that CPAM and broncho-pulmonary malformations are defects of lung bud development that, in only in a limited number of cases, may be limited to an anatomic segment (10).

In the last decades minimally invasive techniques significantly developed, extending to infancy and childhood. This progress is mainly due to the introduction of specific devices for the management of little spaces and little anatomical structures. In particular, thoracoscopy now represents a well-established approach for infants and children and it is considered by most thoracic surgeons as the best choice for lung resections. In fact, it allows to reduce pain and morbidity and to avoid the long-term consequences of a thoracotomy in an infant or a small child (16).

In a publication by one of the groups with the wider experience in pediatric thoracoscopy, the safety and effectiveness of thoracoscopic lobectomy in patients weighing less than 10 kg and aged less than 3 months are well described (19).

Technically, early thoracoscopy is currently feasible and safe mainly due to the following reasons. As extensively described, the standardized technique for infants is exclusively thoracoscopic. Some groups reported their experience with the VATS approach (22) but it presents some limitations in infancy. First of all, VATS is strictly dependent on differential lung ventilation using double-lumen tube or bronchial blockers, which it is not applicable to small infants. On the contrary, thoracoscopy is performed inflating the chest with CO_2 inducing lung collapse with the patient in lateral decubitus position. When possible, single-lung ventilation, obtained by mainstem intubation of the contralateral side, is preferred. However, in cases where single-lung ventilation cannot be achieved, tracheal intubation and CO_2 insufflation may result effective anyway (5,15).

Furthermore, using the thoracoscopic approach no mini-thoracotomy is required, whereas it is needed in VATS: two 3 mm and one 5 mm trocars are usually enough, only occasionally a fourth trocar is placed if added retraction is necessary (17).

Still, CLM thoracoscopic resection remains a challenging procedure, due to the difficulties of fitting instruments in the small chest of neonates and infants.

However, the recent introduction of instruments suitable for children, such as a 3-mm vessel sealing device and a 5-mm linear stapler from JustRight® (Bolder Surgical), represents an important step forward for the safety and feasibility of thoracoscopic surgery in early infancy. With only 10 mm of jaw length, compared with the 20 mm of traditional tools, and a curved Maryland-style jaw design, dissecting anatomical structures is easier and quicker and does not risk the sealing being compromised. The reduced dimensions of these instruments occupy less of the surgical field, allowing better visualization (23).

The last concern in using a thoracoscopic approach in early infancy is represented by the effects of capnothorax on cerebral and somatic oxygenation. In fact, CO_2 absorption has been related to respiratory acidosis, hypercapnia and hemodynamic alterations in different procedures (24,25). Up to now, no studies about the potential modifications of cerebral oxygenation during the thoracoscopic resection of CPAM in infancy are reported.

Personal experience

In our Pediatric Surgery Department, a pediatric multistep thoracoscopic training was concluded in 2014. According

to our training program, the techniques recommended by Prof. Rothenberg in his last publications were selected as procedures of choice (10,16,19). Since then, 32 thoracoscopic resections of CLM were performed in infants under 1 year of age, using a 3 mm camera, a 3 mm and a 5 mm trocars. Since 2018, when JustRight® instruments became available in our country, we started to use the new 3 mm sealer and 5 mm stapler. Lower lobectomies were performed in tracheal ventilation; for upper lobectomies a selective ventilation was preferred. No conversion neither major peri- and post-operative complications were recorded. Regarding CPAM resections, mean operative time was 148 (range, 85–240) minutes, chest drains were removed on average after 2.7 (range, 1–5) days and patients discharged after a mean of 4.5 (range, 4–7) days. In our series, a significant reduction of the operating time was observed since the introduction of the JustRight® miniaturized instruments and surgery resulted technically easier (23).

Finally, in our center data from cerebral and somatic near infrared spectroscopy (NIRS) recordings were collected intraoperatively in 13 patients operated on for CLM. Mean age at surgery was 8.3±6.2 (range, 4–25) months and mean weight 8.0±1.9 (range, 6.6–13.5) kg. In our preliminary experience no significant alteration in both standard monitoring and cerebral and somatic NIRS were recorded while performing thoracoscopic CLM resections. Furthermore, according to a recent publication, neurodevelopmental outcome after neonatal thoracoscopic surgery seems favourable within the first 24 months (24). Accordingly, thoracoscopy with CO_2 inflation seems safe in infancy and childhood.

Conclusion and suggestions for future direction

In conclusion, the following algorithm should be kept in mind when approaching a CPAM. The surgical management in neonates and infants is consensual for symptomatic patients. For asymptomatic ones, elective surgery represents the current indication to avoid potential severe complications. Surgery should be programmed before 6 months of life, to prevent infections. Preoperative imaging should include a high-resolution CT scan. If the scan suggests that the disease is limited to a single anatomic segment or it is multilobar, then a lung-sparing procedure should be considered. Otherwise, lobectomy represents the universally accepted treatment for CPAM. Thoracoscopy with CO_2 inflation and single or double lung ventilation is the approach of choice for infants and children, reducing pain and morbidity and avoiding the long-term consequence of a thoracotomy. Thanks to the new miniaturized instruments, a better and safer management of the procedure in limited surgical fields on the little anatomical structures of infants is offered.

Further studies are advocated, especially focused on asymptomatic children, with the aim to find predisposing factors for complications, in order to characterize the sub-populations with absolute indication to surgery.

Acknowledgments

The author would like to thank Claudia Giavoli and Federico Villa for their scientific support and for the English language revision.
Funding: None.

Footnote

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jtd.2020.03.109). The author has no conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Macchini F. Thoracoscopic resection of congenital pulmonary airway malformations: timing and technical aspects. J Thorac Dis 2020;12(8):3944-3948. doi: 10.21037/jtd.2020.03.109