Pediatric thoracoscopic repair of congenital diaphragmatic hernias

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Abstract: Congenital diaphragmatic hernia (CDH) is a rare congenital disease requiring neonatal surgical treatment. The traditional surgical management of CDH consists of diaphragmatic repair by laparotomy. Thoracoscopic repair techniques have been well described for CDH with late presentation. Nevertheless, its feasibility for CDH treatment in neonates emerged only the past few years because the use of thoracoscopy with carbon dioxide insufflation remains controversial in these patients more vulnerable to hypothermia and acidosis. However, we think that thoracoscopy can be safely used to repair CDH in selected patients and the major limiting factor is pulmonary hypoplasia. Some patients should be excluded based on their higher potential need for patch closure with its technical difficulty and increased operative time. The close collaboration between pediatric surgeon, anesthetist and neonatologist is essential. We discuss here the patient selection criteria, expose the pre- and post-operative management, the procedure steps; regarding to our experience we deliver some tips to achieve the safest surgical procedure for the pediatric patient.

Keywords: Congenital diaphragmatic hernia (CDH); thoracoscopy; neonatal surgery

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Introduction

The traditional surgical management of congenital diaphragmatic hernia (CDH) consists of open repair by laparotomy. The use of minimally invasive techniques in pediatric surgery has been increasing in the last decade (1-3). MIS for CDH repair includes laparoscopic and thoracoscopic repair techniques and has been well described for CDH with late presentation (2,4,5). Nevertheless, its feasibility for CDH treatment in neonates emerged only the past few years because these patients are more vulnerable to hypothermia and acidosis caused by carbon dioxide insufflation (1,2,6-14).

General advantages of MIS include less pain, faster recovery, shorter hospitalization and better cosmetic results (1,11,14). Thoracoscopy for CDH can also bring a potential decrease in the occurrence of small bowel occlusion (15) and decreased thoracic deformity (2). However, thoracoscopic repair have been associated with higher recurrence rates (1,2,14,15).

Therefore, it is important to determine which neonates with CDH can benefit of MIS repair without adverse effects (2). Regarding to our experience we deliver some tips to achieve the safest surgical procedure for the pediatric patient.

Patient selection

Many studies comparing thoracoscopic *vs.* open repair are retrospective and non-randomized control trials (3). In consequence the two types of surgery can still not be validly compared. However, thoracoscopy may be risky in neonates with also higher recurrence rates (1-3). Bishay *et al.* proved

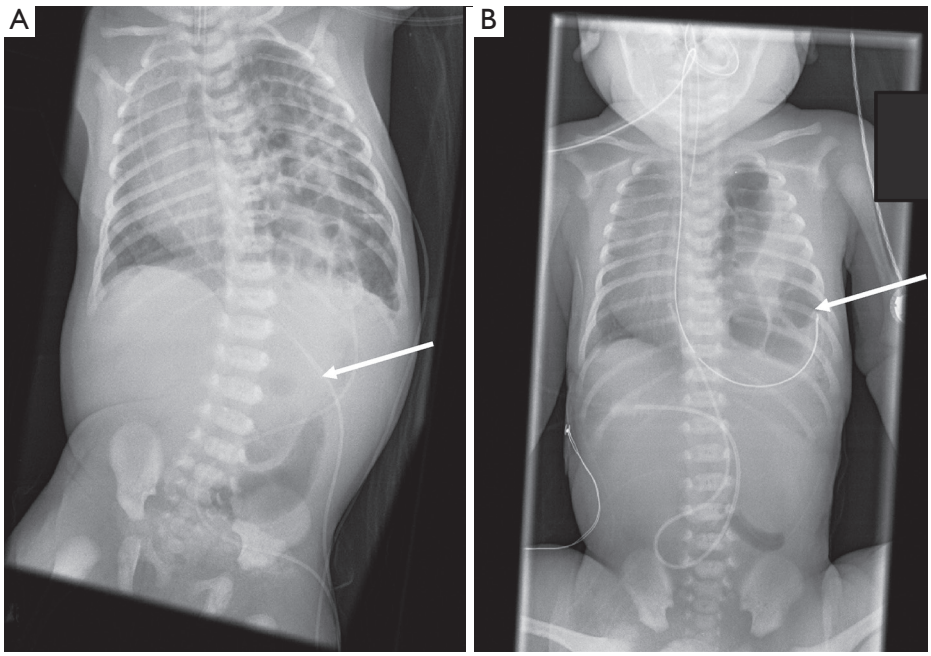

Figure 1 Initial X-ray of 2 patients with left CDH, arrow = end of the nasogastric tube. (A) Intra-abdominal stomach, defect size type A repaired thoracoscopically; (B) intra-thoracic stomach, defect size type C repaired with a patch inserted by laparotomy.

arterial blood gas changes during thoracoscopic repair of CDH, but this study was based on only five patients (16). A larger study group related the development of intraoperative acidosis and hypercapnia regardless the approach used. However, this is more severe during thoracoscopic repair (17). The effect of this intraoperative hypercapnia and acidosis on the patients' neurodevelopment remains unknown. Therefore, selection criteria for thoracoscopic repair are mandatory (2).

In a retrospective multicenter study, we described 5 risk factors for failure (need for conversion or major complications) of thoracoscopic primary repair: four of them are related to physiological parameters, in relation to the severity of pulmonary hypertension; the last criterion is the intra-thoracic position of the stomach at X-ray (14). In several centers, thoracoscopic repair is only done when the patient is cardiovascular and pulmonary stable, that is to say, when he can be moved to the operating theatre.

Some patients should be excluded based on their higher potential need for patch closure with its technical difficulty and increased surgery time (1). MIS repair should be proposed to patients with low risk (size A and B) defects, following the Congenital Diaphragmatic Hernia Study Group staging system (15). Defect size is difficult to predict pre-operatively, but can be extrapolated regarding to the position of the stomach on initial radiography. In fact, the intra-abdominal presence of the stomach suggests an intact esophageal hiatus and therefore a smaller defect with presence of a posterior diaphragmatic rim (14) (*Figure 1*).

Finally, the selection criteria for thoracoscopic CDH repair in neonates depends on each institution's experience and larger prospective clinical trials are necessary to evaluate this technique in neonates (2,3).

Pre-operative preparation

Operating techniques, such as the coelioscopic approach, require equipment quite difficult to mobilize and are therefore less feasible in intensive care unit; so that the possibility of transporting children towards the operating room establishes in itself a selection criterion of MIS (6).

As for open surgery, the thoracoscopic approach requires a general anesthesia with tracheal intubation; a selective intubation is nevertheless not required (12). The patient should be manually ventilated or in conventional mode with limited pressures of insufflation to avoid any pulmonary barotrauma. They are monitored in a conventional way and a good venous access is essential. A nasogastric tube is necessary to reduce the stomach size and will help in post-operative until the transit recovery. No antibioprophylaxie

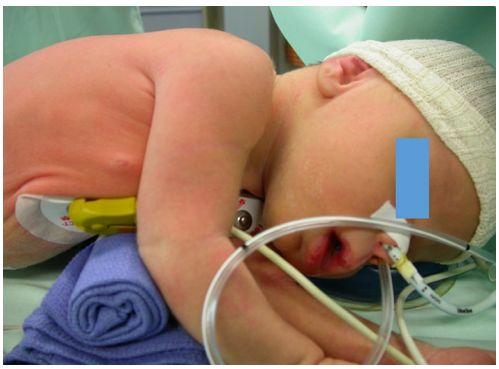

Figure 2 Patient installation for the thoracoscopic repair of a right CDH. CDH, congenital diaphragmatic hernia.

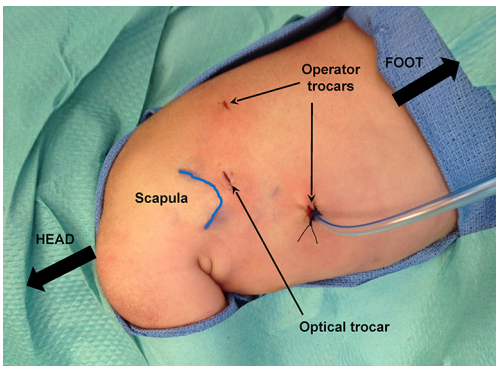

Figure 3 Positioning of the trocars for the thoracoscopic approach in a left CDH. CDH, congenital diaphragmatic hernia.

is mandatory.

For the thoracoscopic approach, the patient is placed in a right-side decubitus position for a left CDH, with a small block placed under the right hemithorax to rule out the intercostal spaces. The left upper limb is left free in the operative field not to interfere with the movements of the camera or instruments (*Figure 2*).

Equipment preference card

The coelioscopic instrumentation has to be adapted to the small size of the child: so we prefer a short instrumentation of coelioscopy of 3 or 5 mm. The instruments of 5 mm, less traumatizing for viscera, can be too long in a reduced workspace. The camera is of 5 mm (0° or 30°) allowing a sufficient light exposure. As for open surgery,

Figure 4 Thoracoscopic left CDH repair type A, using extracorporeal knots reinforced by a lateral absorbable pledget (18). CDH, congenital diaphragmatic hernia.
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the diaphragmatic defect will be closed with separated non absorbable points. Nevertheless, it is essential to plan a prosthetic replacement as well as a conventional instrumentation in case of conversion for a larger defect (13).

Procedure

The surgical team is positioned in front of the patient with the coelioscopic material behind the patient. The surgeon and his assistant are near the patient's head and the nurse on the foot.

The first trocar is placed under the scapula for camera placement. Two more operator trocars are introduced: one in the fifth intercostal space on the anterior axillary align and the other one in the fourth intercostal space between the optical trocar and the spine (*Figure 3*).

The insufflation of carbon dioxide will help to reduce the viscera herniated. Sometimes it will be sufficient, avoiding the use of traumatic instrumentation. Nevertheless, the reduction will be completed using coelioscopic grasper to reintroduce the viscera in the abdominal cavity. The spleen reduction can be difficult particularly with a smaller defect: a third trocar can be useful.

After the reduction, the defect size will be evaluated and classified (15). In presence of a hernia sac, there is no need for a resection (4,12): nevertheless, if a resection is required, it has to be performed carefully avoiding extensive coagulation, which can damage diaphragmatic innervation or vascularization.

In CDH without sac, it is recommended to dissect

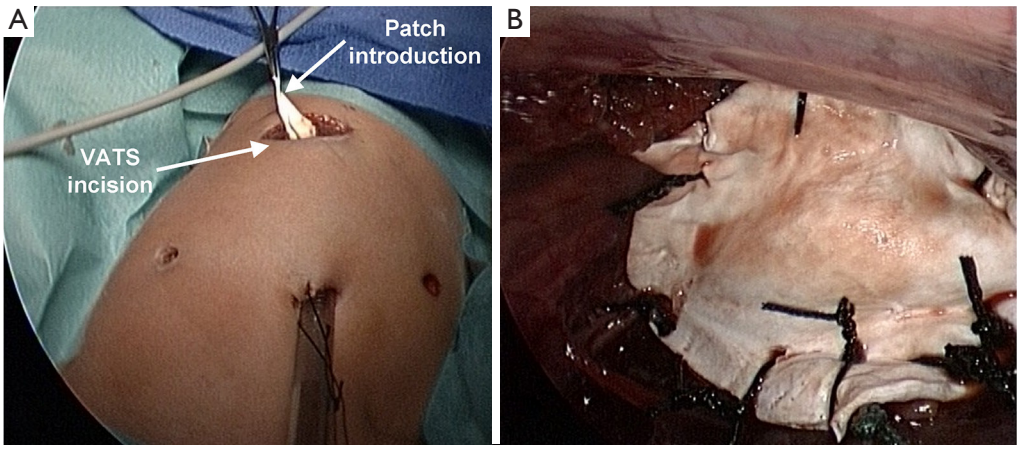

Figure 5 VATS approach for lateral prosthetic patch insertion in a left CDH. (A) Patch introduction after VATS incision; (B) intrathoracic view of the diaphragmatic repair after PTFE patch fixation. VATS, video-assisted thoracic surgery; CDH, congenital diaphragmatic hernia.

the posterior diaphragmatic rim and to test if primary closure is possible. Primary closure is performed using non-absorbable interrupted suture tied intracorporeally; extracorporeal knots can also be useful (*Figure 4*) (18).

In presence of a large diaphragmatic defect, it is assumed to prefer a prosthetic patch to repair the defect without tension. The material used for patch closure is in most cases polytetrafluoroethylene (PTFE, Gore-Tex Dual Mesh®) (Dualmesh® W.L. Gore and Associates, Flagstaff, AZ, USA). The prosthetic introduction will need a conversion by classical thoracotomy, or minimal thoracotomy with patch fixation by VATS (video-assisted thoracic surgery) (*Figure 5*). Some authors describe the possibility of introducing a patch rolled up through a trocar with complete fixation under thoracoscopy (19). As for the open surgery, it is recommended to reconstruct the diaphragmatic dome by setting up a slightly larger patch. The postero-lateral fixation can require anchoring on the costal periost or around a rib (rib-anchoring stitches).

After the diaphragmatic repair is achieved, a manual ventilation helps spread the compressed lung. Trocars are removed and closed. A thoracoscopic drain is inserted through one of the ports.

Role of team members

The child with CDH is very sensitive to the temperature variations and to the respiratory acidosis: the per-operative insufflation of carbon dioxide can cause an imbalance of these two conditions. The anesthetic team has a central role because they will have to adjust the ventilation to those specificities. On the one hand, they will have to increase the volumes and the respiratory pressures, while maintaining an adequate temperature. On the other hand, these increasing can have catastrophic consequences on hypoplasic lungs by the accentuation of the barotrauma.

An intermittent carbon dioxide insufflation reduces more the metabolic complications of the thoracoscopic approach. But the operating time is also a major variable in the physiopathological consequences: when the insertion of a prosthetic patch is required, the conversion should be preferred to avoid the increase of operating time (8,13). The operative success results from a closed collaboration between surgical and anesthetic team.

Post-operative management

The post-operative course will be managed initially in the intensive care unit. The patient will stay ventilated and sedated. The duration of artificial ventilation will depend on the severity of the pulmonary hypoplasia and pulmonary hypertension. The thoracoscopic drain will be removed quickly. MIS will allow faster recovery than open surgery (postoperative ventilation time, decreased use of narcotics, time for oral feeding, length of hospital stay) (1,2,14).

However, long-term follow-up with clinical and radiological examinations will be mandatory because of the higher recurrence rate. Actually, the trend is to long-term multidisciplinary evaluations until adulthood to identify overall and long-term rates of complications.

Tips, tricks and pitfalls

To avoid the use of a third operator trocar, it can be very useful to close the defect using extra-corporally tied sutures: with your right hand you will tighten the sutures, while the grasper placed in the left free hand will help to keep the viscera reduced in the abdominal cavity.

The insufflation of carbon dioxide is made with low pressures (4–6 mmHg) and with a minimal flow (max. 1.5 L/min). These low pressures of insufflation are enough to reduce the hypoplasic lung to obtain a sufficient workspace. During the reduction, the insufflation of carbon dioxide is necessary, and the ventilation must be monitored: any variation of the parameters requires a temporary stop of carbon dioxide insufflation. After the reduction, it is careful to stop the insufflation to reduce the risk of acidosis.

These concerns are essential, and some findings do not support the use of thoracoscopy with carbon dioxide insufflation and conventional ventilation for the repair of CDH, calling into question the safety of this practice. Nevertheless, neuromonitoring of the neonatal brain can provide information on neonatal cerebral oxygenation and estimate cerebral perfusion, which can be monitored non-invasively by near-infrared spectroscopy (NIRS). NIRS used during the surgery can measure the regional cerebral oxygen saturation: it can detect substantial changes in cerebral oxygenation in order to adjust by the anesthetist the respiratory and cardiovascular support if necessary (7,20).

Conclusions

MIS can be safely used to repair CDH. In the neonatal period, thoracoscopy can be achieved in selected patients and the major limiting factor is pulmonary hypoplasia. However, it should not be a loss of chance for the newborn. Some patients should be excluded based on their higher potential need for patch closure with its technical difficulty and increased operative time. The close collaboration between pediatric surgeon, anesthetist and neonatologist is mandatory.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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