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Thoracoscopic repair of neonatal congenital diaphragmatic hernia

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Purpose: To describe the surgical technique and criteria for neonatal congenital diaphragmatic hernia (CDH) repair. Methods: CDH repairs were carried out by a thoracoscopic approach between February 2013 and April 2014. Preoperatively, the neonates were stabilized with high-frequency oscillatory ventilation and nitric oxide inhalation. They had no associated cardiac anomalies. Confirmation of the appropriateness of thoracoscopic repair was determined based on the patient's stability in the decubitus position and no clinical signs of pulmonary hypertension. The operation was carried out with one optical and two operating trocars. The hernia defect was closed by interrupted nonabsorbable sutures. The more lateral portion of the defect was repaired with a U-shaped stitch using a laparoscopic percutaneous extraperitoneal closure needle. Results: Three neonates underwent repair via thoracoscopy. Two patients underwent primary CDH repair, and conversion to laparotomy was required in the other because of a large diaphragmatic defect. There was no intraoperative cardiorespiratory instability or postoperative complications. Conclusions: Thoracoscopic repair of neonatal CDH is a feasible and safe procedure for the patients who have respiratory stability in the decubitus position, no pulmonary hypertension and no intra-thoracic liver herniation.

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Introduction

The first laparoscopic repair of congenital diaphragmatic hernia (CDH) was reported in 1995 for a 6-month-old infant[1], and the first thoracoscopic repair was reported in 2001 for a 9-month-old infant[2]. Since then, the indications for minimally invasive surgery (MIS) for the repair of CDH have widened to include neonates. However, the criteria for MIS for neonatal CDH repair are still obscure, and a higher hernia recurrence rate than with traditional open repair has been reported in many institutions.

In this report, our criteria and technique to ensure successful neonatal CDH repair are described.

Patients and methods

Between February 2013 and April 2014, three neonates with CDH underwent thoracoscopic operation in our institution. The profiles of the patients are listed in the table. They had no severe associated cardiac anomalies.

The patients were managed in the neonatal intensive care unit after birth. They were intubated and ventilated with high-frequency oscillatory (HFO) ventilation. Nitric oxide (NO) inhalation was used in accordance with the patient's respiratory condition. For 48 hours after birth, the patient's cardiorespiratory condition was monitored by echocardiograpy and transcutaneous oximetry.

When the patient's stability in the decubitus position was confirmed, and there were no clinical signs of pulmonary hypertension such as dominant right–to-left shunt and tricuspid regurgitation by echocardiography, the patient was transported to the operating room. When patients did not satisfy these criteria, conventional open surgical repairs were performed.

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Table 1. Patient characteristics

	Case 1	Case 2	Case 3
Gender	Male	Female	Female
GA at diagnosis (weeks)	31	21	32
Side	Left	Left	Left
Birth weight (g)	2580	2840	3286
GA at birth	37w4d	38w5d	37w0d
APGAR (1min/5min)	8 / 9	3 / 8	2/7
SpO_2 (upper limb/lower limb)	100% / 83%	100% / 88%	100% / 84%
Use of HFOV	Yes	Yes	Yes
Use of NO inhalation	Yes	Yes	Yes
Intra-thoracic stomach at X-ray	No	Yes	Yes
Intra-thoracic stomach at MRI	No	Yes	Yes
Intra-thoracic liver at MRI	No	No	No
Day at operation (days)	2	2	3
Surgical approach	Thoracoscopy	Thoracoscopy	Thoracoscopic ↓ Laparotomy
Operative time (mins)	113	115	115
Use of patch	No	No	Yes
Extubation (days after operation)	7	6	16
Oral feeding (days after operation)	8	7	16
Hospital stay (days)	22	28	42

In the operative room, the patient with left CDH was placed in the right lateral decubitus position. A 5-mm trocar was introduced at the midaxillary line in the fourth intercostal space for a thoracoscope. A second 3-mm trocar was placed in the fifth intercostal space just below the left nipple line, and the third 3-mm trocar was placed in the sixth intercostal line just below the scapula. Carbon dioxide insufflation was started at a pressure of 4 mmHg in the thoracic cavity. The herniated organs were reduced into the abdominal cavity by the intrathoracic pressure and manipulation with thoracoscopic instruments. The loose portion of the hernia defect was primarily repaired with nonabsorbable (coated braided polyester) interrupted sutures (Fig. 1). The more lateral portion of the defect, where a lateral diaphragmatic leaf was lacking, was sewn to the thoracic wall with a U-shaped stitch using an LPEC (laparoscopic percutaneous extraperitoneal closure) needle (Fig. 2). After the diaphragmatic repair, the three trocars were removed.

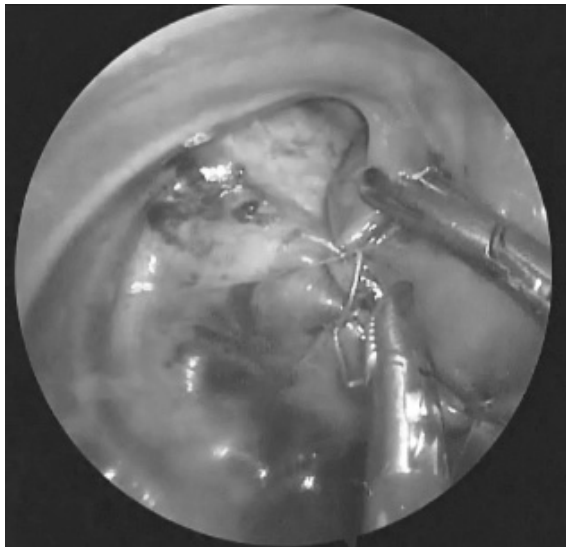

Figure 1 Laparoscopic view of repairing the left diaphragmatic defect.
Mediastinal side of the defect was repaired by the interrupted absorbable sutures.

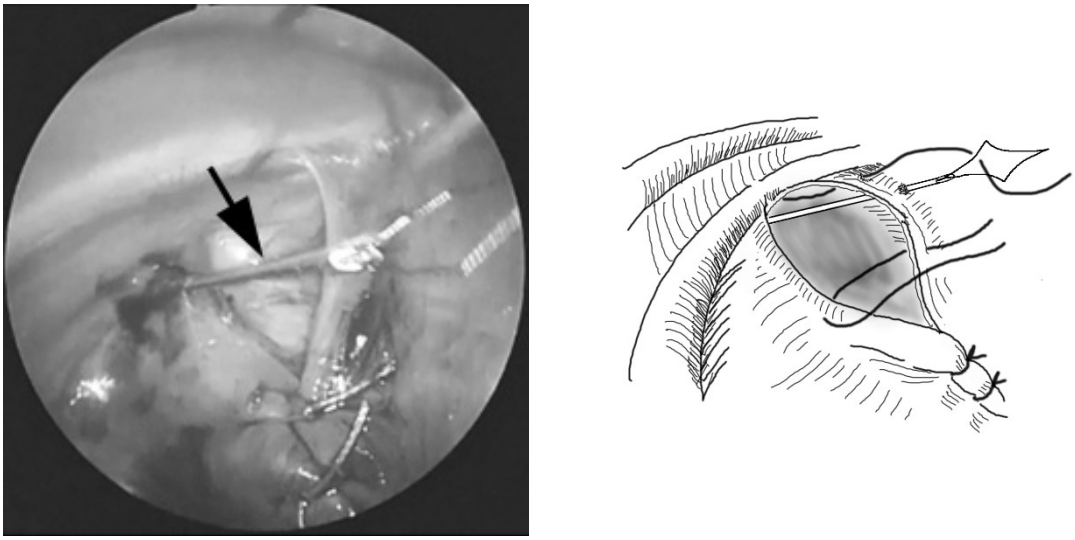

Figure 2 Laparoscopic view and the schema. The lateral defect where the diaphragmatic leaf was widely lack was closed by the U-shaped sutures with the extracorporeal LPEC needle (black arrow) punctures.

Results

The diagnosis of left CDH was made on routine prenatal ultrasonography at 21, 31, and 32 weeks' gestational age, respectively. Prenatal MRI showed the intra-thoracic stomach in cases 2 and 3, but no intra-thoracic liver in any of them. NO inhalation was used in all patients. Operative time was 113, 115, and 115 minutes for cases 1, 2, and 3, respectively. During the surgical operation, vital signs and respiratory function were stable, and there were no increases in end-tidal PCO_2. Of the 2 patients who successfully underwent a diaphragmatic hernia repair by the thoracoscopic approach, the reduction of the hernia contents into the abdominal cavity did not require much time. A hernia sac was not present in either patient. The diaphragmatic defect was directly sutured without any prosthetic patches. There were no operative or postoperative complications. Extubation was performed 6 and 7 days after operation in the thoracoscopic approach group, and the patients resumed oral intake on the 7th and 8th postoperative days, respectively. In case 3, there were difficulties reducing the spleen and the intestines because of a wide diaphragmatic defect. The presence of this wide diaphragmatic defect was not precisely diagnosed before operation. Conversion to laparotomy was required, and the diaphragmatic defect was repaired with a patch. This case required postoperative ventilator support for 16 days. All patient clinical conditions and chest X-rays were normal at 6 months after operation.

Discussion

MIS for common surgical diseases in children provides faster recovery, less pain, and shortens the hospital stay. However, MIS for neonatal CDH could precipitate complications of respiratory acidosis, pulmonary hypertension, and even a high mortality because of the patients' vulnerable cardiovascular status and pulmonary hypoplasia. A large diaphragmatic defect that needs a prosthetic patch for closure has a high recurrence rate after hernia repair.

MIS cannot be performed for all neonates with CDH. A large diaphragmatic defect and pulmonary hypoplasia are keys to the success of MIS repair of neonatal CDH. Each institution has its own preoperative criteria for selecting MIS for neonatal CDH. Yang et al. selected patients based on the anatomical position of the stomach on the initial X-ray[3]. Okazaki et al. proposed physiological criteria using cardiac stability in the preoperative decubitus position[4]. During the thoracoscopic procedure, the patients are placed in the decubitus position. Changing the body positon form the supine to the decubitus is a risk for developing respiratory and cardiovascular instability. Ferreira et al. mentioned that the limiting factor for thoracoscopic CDH repair is persistent pulmonary hypertension of the newborn (PPNH), and the best indicator for PPHN is the oxygenation index[5]. At the moment, there are no implicit criteria that could anticipate the possibility and the success of an MIS repair. Our criteria for thoracoscopic repair of CDH are respiratory stability in the preoperative decubitus position, no evidence of pulmonary hypertension and no herniation of the liver in

the thoracic cavity regardless of using NO. Presence of the liver in the thoracic cavity increases the probability of a large diaphragmatic defect. Use of a prosthetic patch to close a large diaphragmatic defect has a high risk of recurrence and requires a longer operative time. Zamakhshary et al. reported that initial arterial PCO_2 >34 mmHg and preoperative HFO are the predictors of the need for patch closure of a large diaphragmatic defect[6]. A meta-analysis by Lansdale et al. in 2010 reported a higher recurrence rate and longer operation time in the endosurgical operation group for CDH, but no statistically significant difference in survival[7]. Despite the unstable respiratory and cardiovascular condition with CDH, a long operation is unwise for a large diaphragmatic defect with a patch.

Both the thoracoscopic and the laparoscopic approaches have been used to repair CDH in the pediatric population. However, two major drawbacks have been described in the laparoscopic procedures[3,8,9]. One is the difficulty of bringing the spleen back into the abdominal cavity. The other is the difficulty of suturing the diaphragmatic defect because the operative view is blocked with relocation of the herniated organs from the thoracic cavity. With the thoracoscopic approach, one can directly and visually confirm the herniated organs and can gently push the organs back into the abdominal cavity. One can repair the diaphragmatic defect without any obstacles after bringing back the herniated organs. In addition, once the abdominal organs are reduced back into the abdomen, CO_2 insufflation is no longer required, which lowers the inspiratory pressure. The disadvantage of the thoracoscopic approach is that one cannot observe the abdominal organs from the chest.

Recurrences are higher after thoracoscopic CDH repair than after laparoscopic repair[10]. The posterolateral border of the diaphragmatic defect in CDH is usually very hypoplastic, and the operator must suture the diaphragm to the chest wall or use a patch. The laparoscopic procedure allows controllability, because the trocars are inserted through the extensible abdominal wall. However, the trocars that are fixed on the thorax give limited controllability with the thoracoscopic procedure, and the hernia closures near the posterolateral border are physically difficult and insecure with only intracorporeal suturing. Shalaby et al. reported that a Reverdin needle assisted extracorporeal suturing[11]. Arca et al. used extracorporeal procedures and a stitch placed around a rib[9]. We repaired the most lateral diaphragmatic defect with U-shaped extracorporeal sutures and an LPEC needle.

Conclusion

Thoracoscopic repair of neonatal CDH is a feasible and safe procedure in selected patients. The current criteria for thoracoscopic repair of neonatal CDH are respiratory stability in the decubitus position, no evidence of pulmonary hypertension and no intra-thoracic liver herniation; the presence of pulmonary hypertension or intra-thoracic liver herniation suggests a large diaphragmatic defect requiring patch closure. Advances of MIS for CDH repair could improve survival outcomes of CDH.

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