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An Optimum Animal Model for Neonatal Thoracoscopy

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Abstract

Purpose: This study attempted to define an optimum animal model for neonatal thoracoscopy.
Materials and Methods: Seven rabbits and three 5–7-kg piglets were subjected to thoracoscopy by three pediatric surgeons. The outcome for the successful completion of esophageal anastomosis and additional procedures, including diaphragmatic plication and lung biopsy, were noted.
Results: Whereas esophageal anastomosis could be accomplished in all piglets, it could be achieved in only 1 rabbit. Additional procedures were possible in 2 piglets and no rabbits. Anesthetic complications were seen in 4 rabbits and 1 piglet.
Conclusion: Our findings suggest that the piglet may be the optimum animal model for replicating neonatal thoracoscopy. The fragility of the rabbit, coupled with a limited intrathoracic working space, limits its use for thoracoscopy.

Introduction

MINIMALLY INVASIVE SURGERY (MIS) was successfully used for thoracoscopic work in infants by the mid-1990s.[1] By the turn of the century, successful repair of esophageal atresia (EA) and tracheoesophageal fistula (TEF) had been described.[2,3] Whereas adequate thoracic surgery can be done by the open route, the musculoskeletal sequelae of a thoracotomy is of some concern.[4] Recent successful reports of large series of neonates and children undergoing thoracoscopic surgeries make a case for advocating thoracoscopic MIS as the preferred approach in children.[5,6] However, in view of the limited numbers of patients available for thoracic procedures in most centers, alternate training models need to be available. Though the rabbit and the piglet models have been reported for neonatal thoracoscopic work by various researchers, there is no conclusive evidence in the literature as to which model is better suited for replicating neonatal thoracoscopy.[7–12] In this paper, we present our experience, detailing the search for an optimum animal model for neonatal thoracoscopic surgery.

Materials and Methods

Study design

The study was approved by the Scientific Advisory Committee and the Animal Ethics Committee of our hospital. Measures were taken to fully comply with the Australian Code of Practice for the care and use of animals for scientific purposes (2004). Seven New Zealand white rabbits (weight, 3–3.5 kg) and 3 pigs (weight, 5–7 kg) were sanctioned for the comparative study. The endpoint of the study was the successful completion of the intended thoracoscopic surgery (i.e., esophageal transection and repair, diaphragmatic plication, and lung biopsy). Surgery was done over a period of 6 months by three pediatric surgeons familiar with thoracoscopy. Outcomes were noted and the animal models compared.

Anesthesia

For the rabbit, anesthesia was induced with an intramuscular (i.m.) mixture of ketamine HCl (50 mg/kg) and xylazine (5 mg/kg). Intubation was performed by doing a tracheotomy in the supine position and passing an endotracheal (ET) tube over a 3-mm endoscope and guiding it visually into the left main bronchus to allow for the selective ventilation of the left lung, as previously described.[12] It is to be noted that in a rabbit, the trachea is very mobile and is easily displaced by neck extension and manipulation. Supine positioning with no extension and superficial dissection 1.5 cm below the lower border of the cricoid cartilage will facilitate an easy localization of the trachea. The tube was also anchored with sutures to the skin at the tracheotomy site. Following intubation, anesthesia was maintained with inhalant 3% isoflurane.

The piglets were administered an i.m. dose of 0.04 mg/kg of atropine, 4.4 mg/kg of Zolatil® (Virbac-Milperra, Sydney,

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Australia), 2.2 mg/kg of xylazine, and 2.0 mg/kg of azaperone for premedication. Following the local application of lignocaine on the larynx, endotracheal intubation was performed and inhalant anesthesia maintained through a T-piece with 2% isoflurane. An orogastric tube of 8 Fr was passed after intubation for both animals.

Port placement

Both animals were placed in the semiprone position, with the right side elevated at 30–45°. The port positioning and setup is shown in Figure 1 and were primarily placed for the purpose of esophageal repair. The surgeon and the assistant were placed anterior to the animal and the screen was positioned posteriorly. A semiprone position helps the lung to fall away and expose the mediastinum. These port placements correspond to the midaxillary line for the camera port and the posterior axillary line for the working ports.

All 3 piglets were operated upon by using the above setup. The surface landmarks for the ports in a 5-kg piglet were: working ports 10 cm anterior to the spine at a level 1 cm inferior to the tip of the scapula (port B) and 3 cm superior to the costal margin (port C). Port A served as the camera port for a 5-mm, 0-degree telescope and was placed 1.5 cm anterior to, and midway between, the two ports (Fig. 1). The fourth port was placed level with port A, 5 cm anterior to the spine, and served as the working port along with port A for diaphragmatic plication and lung biopsy. For a larger piglet, the surface landmarks varied, but the relative positions of the ports remained the same.

Three rabbits were initially operated on by using the above standard port placement shown in Figure 1.The surface landmarks for the ports with the above setup translates to the camera port (5-mm, 0-degree telescope) being placed 2.5 cm below, and anterior to, the scapular tip level and the two working ports at the scapular tip level, 2 rib spaces above and below the camera port. Having had limited success with the same, 2 rabbits were then operated on with a 30-degree, 3-mm camera at the midaxillary level looking down on the field and two working ports corresponding to the anterior axillary level, as previously described.[11] A further 2 rabbits were operated on by using more posterior ports, with the surgeon standing at the back of the animal (Fig. 2).

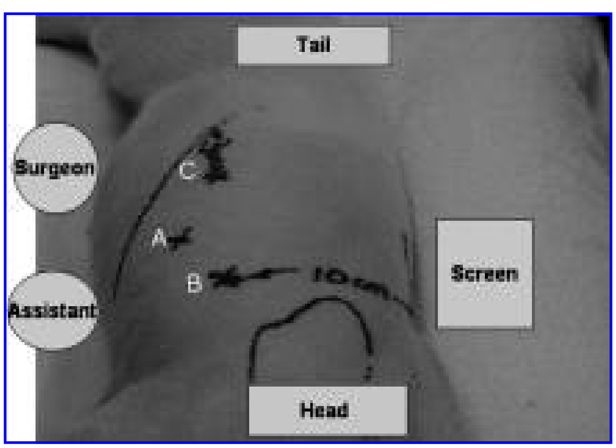

FIG. 1. Standard port placement and setup. (**A**) Camera port. (**B** and **C**) Two working ports.

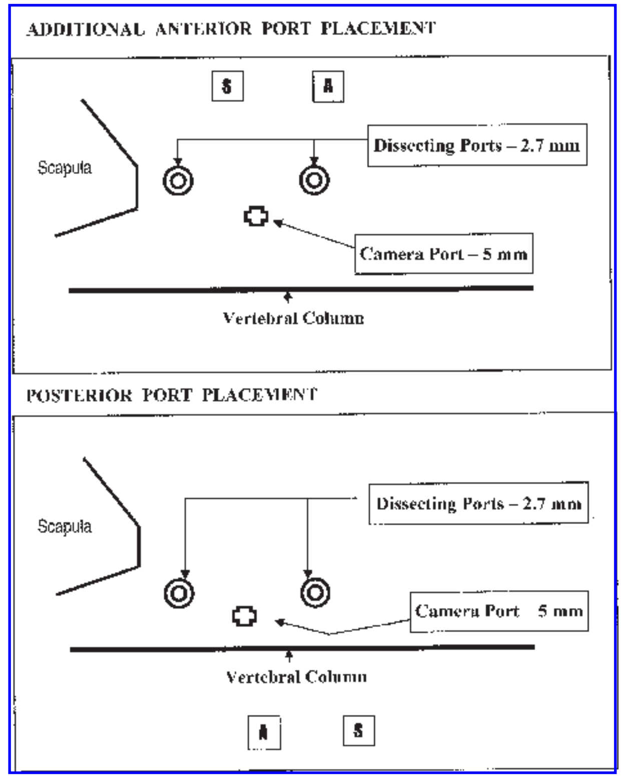

FIG. 2. Line diagram showing the additional port placements in the rabbit. S, surgeon; A, assistant.

Surgical procedure

Insufflation was provided at 4 mm Hg for the piglet and for the rabbit when selective bronchial intubation was not achieved. The surgery was performed using 5 mm instruments for the piglet and 5 mm or 2.7 mm instruments for the rabbit. The esophagus was identified with the aid of the orogastric tube and transected. Mobilization was avoided to reduce the tendency of the esophagus to retract back on transection. Suturing was done intracoporeally, using Ticron (nonabsorbable silicone-coated braided polyester) 5-0 sutures (Fig. 3). When access was limited, the esophagus was hitched up by using a stitch passed through the abdominal wall. Following esophageal repair, the diaphragm was plicated by using running sutures to simulate the repair of a diaphragmatic eventration (Fig. 4), after which a lung biopsy was performed. The animal was monitored and supported in accordance with standard guidelines and euthanized at the end of the procedure.

Results

The comparison of outcome between the rabbit and the piglet is shown in Table 1. Visualization was limited in the rabbit, most likely because of a limited intrathoracic working space. In 2 rabbits, bleeding hindered visibility. Inadequate working space and limitation by the narrow intercostal spaces prevented successful esophageal anastomosis and ad-

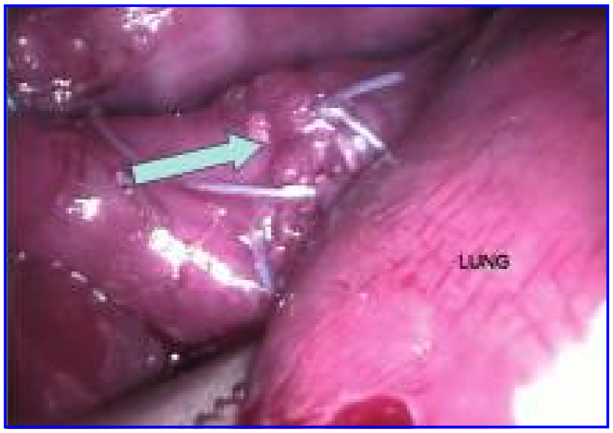

FIG. 3. Thoracoscopic view of esophageal anastomosis (arrow).

ditional procedures in the rabbits. Inadequacy of intrathoracic visualization was independent of port placement. The total operative time ranged from 145 to 210 minutes. Diaphragmatic plication and lung biopsy were performed in 2 piglets. An average of five and three sutures, respectively, were placed for the esophageal anastomosis and the diaphragmatic plication. All the procedures were completed through the right side. The aorta was seen to be in close proximity, even with a right thoracoscopic approach. Anesthetic complications encountered in the rabbits were inability to selectively intubate the bronchus in 2, bronchial perforation in 1, and unexplained hypoxia in 1. One piglet developed hypoxia after insufflation of the right hemithorax with CO_2. Procedures were attempted postmortem when an intraoperative death occurred.

Discussion

Despite early concerns about feasibility and safety, thoracoscopy in neonates has become established over the last 5 years. Since the initial description of the thoracoscopic repair of EA and TEF,[13] there have been other successful reports in larger numbers of patients.[2,3,5,14–16] Thoracoscopy has also

FIG. 4. Thoracoscopic view of the plicated diaphragm

TABLE 1. COMPARISON OF OUTCOME FOR THORACOSCOPY BETWEEN THE RABBIT AND PIG MODEL

Parameter	*Rabbit* (N = *7*)	*Pig* (N = *3*)
Adequate intrathoracic visualization	4	3
Esophageal anastomosis	1	3
Additional procedures (lung resection and diaphragmatic plication	0	2
Anesthetic complications	4	1
Intraoperative death	3	1

been successfully applied to lung resection and mediastinal lesions.[6,17] The acceptance of MIS for advanced thoracoscopic procedures also places a burden on training for pediatric surgeons. The limited patient numbers, and the complexity of these procedures, necessitates the development of alternate training models. *In vivo* training, using animal models, has been shown to be superior to *in vitro* trainers, as it closely simulates the live operating environment.[18]

The first step toward setting up an animal training lab is the choice of an appropriate animal model. Our study attempted to provide answers as to which model would be best suited to replicate neonatal thoracoscopy. Experimental thoracoscopic work has been previously described in human cadavers and rats.[19,20] However, the limited availability of cadavers and the small size of rats would preclude wide usage. Apart from use as an empyema animal model,[7] the rabbit has been advocated as the ideal animal model for thoracoscopic surgery in neonates by one research group.[11,12] Its intrathoracic volume of 250 mL, the small working space, and the fragility of the tissues have been cited as providing an ideal environment for simulating the newborn child. However, we could not replicate the results achieved by this group. Establishing and maintaining anesthesia in the rabbit was difficult. Limitation of intrathoracic working space due to the peculiar thoracic anatomy of a rapidly narrowing inlet made thoracoscopic work difficult. It could be argued that our limited experience with only 7 rabbits was contributory, but the very purpose of an animal lab is to provide an animal that will help establish the model with minimal difficulty and animal usage. Second, trainees who have limited experience should be able to learn the procedure in a workable model, rather than get frustrated with a model having a narrow margin for error.

The piglet has been used by a few investigators and advocated because of its close resemblance to humans.[8–10,21] Using piglets weighing 5–7 kg will adequately replicate the human neonatal anatomy for thoracoscopic work. An orogastric tube facilitates easy identification of the esophagus. Adequate space exists for intracorporeal knotting, and the intercostal spaces permit the entry of ports of various sizes. Additional surgical procedures can be performed to maximize the use of the animal for training purposes.

Conclusions

Our study could not replicate the success previously reported in a rabbit model for thoracoscopic work. We advocate the piglet model as the optimum animal model for neonatal thoracoscopy.

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