Original Article

# Factors influencing the length of stay (LOS) undergoing robot-assisted thoracoscopic lung surgery in the setting of enhanced recovery after surgery (ERAS) protocol for pediatric patients: a retrospective study

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**Background:** A prolonged length of stay (LOS) after surgery may result in higher hospital costs and hospital-acquired complications. This study aims to identify the risk factors associated with a prolonged hospital stay after robot-assisted thoracoscopic lung surgery for pediatric patients in the context of enhanced recovery after surgery.

**Methods:** The data for this retrospective study were collected from pediatric patients undergoing robot-assisted thoracoscopic lung surgery. Patients were divided into two subgroups based on median postoperative LOS (Group I: LOS > median 5 days and Group II: LOS ≤ median 5 days). Logistic regression analysis was used to identify the potential factors associated with increased LOS.

**Results:** This study included 241 patients, 71 (29.46%) with an LOS of >5 days. The proportion of older children was significantly higher in Group I than that in Group II (P=0.004). Patients in Group I were more likely to experience a longer duration of anesthesia and surgery (P<0.001). They also had significantly higher rates of pneumonia, pleural effusion, and liver function damage (P<0.05). Several factors were identified to be associated with an increased LOS after robot-assisted thoracoscopic lung surgery: age >6 years [odds ratio (OR) =3.214, 95% confidence interval (CI): 1.464–7.502, P=0.004], surgery duration >100 min (OR =2.138, 95% CI: 1.296–4.387, P=0.005), intra-albumin (OR =13.778, 95% CI: 1.470–129.116, P=0.022), and blood loss >5 mL (OR =2.184, 95% CI: 1.082–4.409, P=0.029).

**Conclusions:** The results revealed that older age, longer surgery duration, use of intra-albumin, and more blood loss predict longer postoperative hospital stay in pediatric patients with congenital lung lesions after robot-assisted thoracoscopic lung surgery.

**Keywords:** Length of stay (LOS); robot-assisted thoracoscopic lung surgery; enhanced recovery after surgery (ERAS); risk factors; pediatric

Submitted Oct 13, 2023. Accepted for publication Jan 12, 2024. Published online Feb 21, 2024.
doi: 10.21037/jtd-23-1585
**View this article at:** https://dx.doi.org/10.21037/jtd-23-1585

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## Introduction

Intrapulmonary cysts are among the most frequently observed pulmonary pathological findings in an active pediatric surgical pathology service. The current incidence of congenital cystic lung disease ranges from 1/2,500 to 1/8,000 and includes congenital cystic adenomatoid malformations pulmonary sequestrations, congenital lobar emphysema, and bronchogenic cysts (1). Surgical excision is the primary treatment option. With technological advancements in minimally invasive surgery, many centers consider video-assisted thoracoscopic surgery (VATS) as the preferred method for performing cystic resections and lobectomies in children (2). With the advent of surgical robots, robot-assisted thoracoscopic surgery (RATS) has become the main surgical approach for lung resection in children with congenital cystic lesions of the lung at our institution. RATS is safe and effective in children (3). Despite the paucity of conclusive evidence demonstrating the advantages of RATS over VATS, robot-assisted minimally invasive surgery has relative advantages, such as improved hand-eye coordination, suturing skills, dexterity, and precise dissection (4). It is possible to improve perioperative outcomes.

Enhanced recovery after surgery (ERAS) is an evidence-based multimodal protocol for the perioperative care of surgical patients that involves a team of surgeons, anesthesiologists, nurses, an ERAS coordinator, and staff from units throughout the hospital stay (5). In recent years, significant advancements in ERAS strategies have improved the prognosis in almost all major adult surgical specialties, including thoracic surgery (6-9), leading to the gradual application of ERAS in pediatric surgery (10-13). Despite the progress of minimally invasive thoracoscopy and the application of ERAS strategies at our institution, the length of hospital stays for children after robotic lung resection varies significantly. Moreover, the factors influencing enhanced recovery after lung surgery in children remain poorly understood. This study aimed to identify risk factors associated with increased length of stay (LOS) after lung surgery in children with ERAS strategy and robot-assisted thoracoscopic application. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1585/rc).

### Highlight box

**Key findings**

- Age >6 years, surgery time >100 min, use of intra-albumin, and blood loss >5 mL were associated with longer hospital stay after robot-assisted thoracoscopic lung surgery in children with congenital lung lesions.

**What is known and what is new?**

- It is well known that many studies have identified the factors affecting enhanced recovery after thoracic surgery in adults, such as early removal of chest tubes, postoperative analgesia, and patient compliance with enhanced recovery after surgery, etc.
- Our study explored the risk factors affecting enhanced recovery after robot-assisted lung surgery in pediatric patients.

**What is the implication, and what should change now?**

- The preoperative condition and the choice of operation time of children with congenital pulmonary lesions have an important influence on the operation process and the enhanced recovery of patients after surgery.

## Methods

### *Study design and patients*

This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Children's Hospital of Zhejiang University (No. 2022-IRB-272) and individual consent for this retrospective analysis was waived. Detailed information about all consecutive patients preoperatively diagnosed with the congenital pulmonary cystic disease and undergoing robot-assisted thoracoscopic lung surgery was collected through the electronic anesthesia system (Medical system, Suzhou, China) and electronic medical records (Ewell, Hangzhou, China). The exclusion criteria were as follows: (I) acute infection and inflammation with a body temperature above 38 ℃; (II) symptoms of tachypnea, cyanosis, or respiratory distress before surgery; (III) cardiovascular or cerebrovascular diseases, abnormal liver or kidney function, and other diseases; and (IV) conversion to thoracotomy. Moreover, patients who underwent non-lung surgery simultaneously were excluded to maintain cohort homogeneity. The study included 241 pediatric patients who underwent robot-assisted thoracoscopic lung surgery between May 2020 and December 2022.

The primary outcome of this study was the postoperative LOS. LOS was defined as the number of nights spent in the hospital after surgery. LOS was dichotomized into two subgroups by performing a median split: the Group I and Group II. A LOS greater than the median was considered prolonged and included in Group I. LOS not exceeding the median was included in Group II. We identified potential risk factors associated with prolonged LOS by utilizing the electronic anesthesia system and electronic medical records.

### *Anesthesia and surgery procedures*

The patient received routine intravenous induction, tracheal intubation for general anesthesia combined with regional anesthesia, and one-lung ventilation as much as possible. Subsequently an invasive arteriovenous puncture was performed, and arterial blood gases were monitored intraoperatively. Postoperatively, anesthetic resuscitation was performed, and the tracheal tube was removed early.

All procedures were performed by the same surgeon using the Da Vinci Xi robotic surgery system. Each patient was positioned in the lateral decubitus position with the lesion side facing upward, and a pad was placed to widen the intercostal space slightly. Four incisions were made: an observation port (8 mm) was created in the fourth intercostal space at the midaxillary line, two operation ports (8 mm) were created in the sixth intercostal space at the midclavicular line, and the seventh intercostal space at the subscapular line; one assistant port (5 mm) was created in the fifth intercostal space at the anterior axillary line. If one-lung ventilation failed, carbon dioxide ($CO_2$) pressure was maintained at 6–8 mmHg to create an artificial pneumothorax (14). All surgeries are consistently performed by the same experienced chief surgeon and his surgical team. Anesthesia is administered by an anesthesiologist who is qualified as an attending physician or higher.

### *ERAS protocol*

The evidence-based ERAS principles were implemented in pediatric patients who were admitted to the hospital. Preoperative: children of appropriate age and their parents received preoperative education. Sedation was administered 30 minutes before surgery to reduce preoperative anxiety. Prolonged fasting was avoided by allowing oral clear liquids (<5 mL/kg) up to 2 hours before surgery. Antibiotic prophylaxis was also provided. Intraoperative: standardized anesthesia was used, and regional anesthesia was employed to reduce the use of opioids. The tracheal catheter was removed early. Goal-directed fluid therapy was implemented to prevent salt and water overload. Vasoactive drugs were applied appropriately. Routine temperature monitoring was conducted to prevent and reduce hypothermia. Intravenous administration of ondansetron and dexamethasone was performed to prevent nausea and vomiting. In cases where the operation time exceeded 3 hours, additional antibiotics were administered. Postoperative: analgesic management, included the use of ropivacaine for local anesthesia of the incision and administration of ibuprofen suppositories. Catheterization and drainage tubes were either avoided or removed early. Early enteral nutrition and mobilization were encouraged.

### *Postoperative management*

Postoperatively, we measured respiratory rate, heart rate, blood pressure, and oxygen saturation. After returning to the ward from the intensive care unit (ICU) or post-anesthesia care unit (PACU), routine blood tests, blood biochemistry, chest radiography, and B-mode ultrasonography were performed. We adhered to the principle of multimodal analgesia to manage postoperative pain. Patients were encouraged to start walking as early as possible after surgery. The changes of hemoglobin were analyzed by blood routine examination before and after operation. Temperature ≥38 ℃ within 3 days postoperatively was defined as fever. Postoperative pulmonary complications (PPCs) included perioperative bronchospasm, pulmonary atelectasis, pleural effusion, pneumothorax, and pneumonia. Pleural effusion was categorized into ≤2 and >2 cm according to the size of the liquid echogenic zone on postoperative chest ultrasound. Pneumothorax was categorized into two subgroups: thoracentesis and no-thoracentesis. The diagnosis of pneumonia and atelectasis is based on postoperative chest X-ray findings and the patient's corresponding respiratory symptoms. The criteria for chest tube removal were as follows: X-ray chest plain film revealed that the remaining lungs were completely re-expanded, and there was no apparent air leak or active bleeding; B-ultrasound revealed that the pleural effusion was less than 2 cm, and total drainage was less than 50 mL in 24 hours. The patient discharge criteria were: normal vital signs, no complications requiring in-hospital treatment, no residual abundant pleural effusion, and normal inflammatory marker levels.

### *Data collection and statistical analyses*

Risk factors influencing LOS in this study were divided into patient- and procedure-related risk factors. Patient-related risk factors included age, gender, weight, body mass index (BMI), infection status, and the American Society

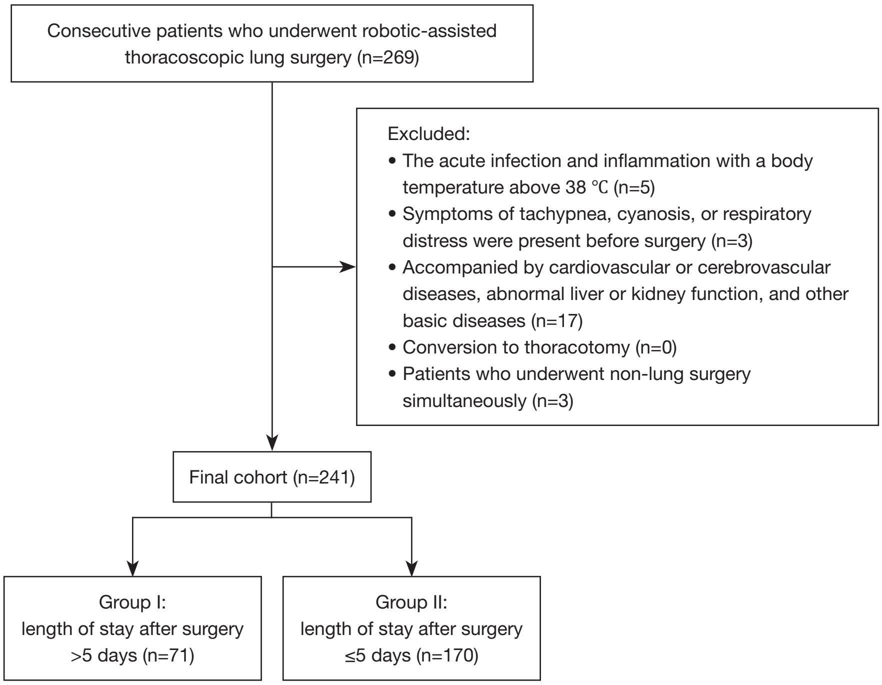


**Figure 1** Flowchart of included patients.

of Anesthesiologists (ASA) status class. Procedure-related risk factors included the surgical approach, surgery time, pathological type, anesthesia method, anesthetist seniority, anesthesia duration, one-lung ventilation, mechanical ventilation mode and duration, arterial blood gas analysis, estimated blood loss, and infusion and transfusion volumes. Postoperative complications were retrospectively recorded in the both subgroups.

### *Statistical analysis*

The collected data were compiled in an Excel spreadsheet (Microsoft, Redmond, WA, USA) and analyzed using SPSS Version 22.0 (IBM, Armonk, NY, USA). Data with a normal distribution were expressed as mean ± standard deviation (SD), and group differences were determined using Student's *t*-test. While data with an abnormal distribution were expressed as the median and interquartile range (IQR), and differences between groups were detected using the Mann-Whitney test. Categorical variables were expressed as frequencies and percentages and compared using Pearson's $\chi^2$ or Fisher's exact tests. A forward stepwise logistic regression analysis was used to identify independent variables associated with prolonged LOS. The results were presented as odds ratios (ORs) and 95% confidence intervals (95% CIs). All P values were bilaterally distributed, and P<0.05 was considered statistically significant.

## Results

### *Patient-related risk factors*

This study included 241 patients treated between May 2020 and December 2022 (*Figure 1*). The median LOS for the entire cohort was 5 days (IQR, 4–6 days). A total of 71 (29.46%) patients had LOS >5 days. The median LOS for the Group I and Group II was 8 days (IQR, 6–8 days) and 5 days (IQR, 4–6 days), respectively. The age distribution of the children in the two subgroups was statistically different (P=0.004) (*Table 1*). Although the number of children aged 1 month to 1 year was similar in both subgroups, the proportion of older children gradually decreased in the Group II while increasing in the Group I. Similarly, the weight of patients in the Group I was significantly higher than that in the Group II (16.94±15.77 *vs.* 11.97±5.74 kg, P=0.012). However, no other patient-related factors were significantly associated with prolonged LOS.

### *Procedure-related risk factors*

Procedure-related risk factors associated with increased

 

**Table 1** Patient-related risk factors associated with increased LOS after surgery

| Characters | Group I (n=71) | Group II (n=170) | P value |
|---|---|---|---|
| Age | | | 0.004 |
| >1 month, ≤1 year | 35 (49.30) | 86 (50.59) | |
| >1 year, ≤3 years | 10 (14.08) | 50 (29.41) | |
| >3 years, ≤6 years | 10 (14.08) | 20 (11.76) | |
| >6 years | 16 (22.54) | 14 (8.24) | |
| Gender, male | 41 (57.75) | 93 (54.71) | 0.665 |
| Weight (kg) | 16.94±15.77 | 11.97±5.74 | 0.012 |
| BMI (kg/m$^2$) | 16.26±3.07 | 16.44±2.33 | 0.644 |
| ASA | | | 0.537 |
| I | 22 (30.99) | 46 (27.06) | |
| II | 49 (69.01) | 124 (72.94) | |
| Diagnosis | | | 0.889 |
| CCAM | 45 (63.38) | 112 (65.88) | |
| PS | 21 (29.58) | 49 (28.82) | |
| CLE | 4 (5.63) | 7 (4.12) | |
| Bronchogenic cyst | 0 (0) | 1 (0.59) | |
| Pulmonary blastoma | 1 (1.41) | 1 (0.59) | |
| Preoperative pulmonary infection | 5 (7.04) | 6 (3.53) | 0.234 |

Data are presented as n (%) or mean ± standard deviation. Group I: LOS after surgery >5 days; Group II: LOS after surgery ≤5 days. LOS, length of stay; BMI, body mass index; ASA, American Society of Anesthesiologists; CCAM, congenital cystic adenomatoid malformations; PS, pulmonary sequestration; CLE, congenital lobar emphysema.

LOS are shown in *Table 2*. Patients in the Group I were more likely to experience longer periods of anesthesia [181 (IQR, 157–215) *vs.* 160 (IQR, 134.75–181) min, P<0.001], surgery [108 (IQR, 85–127) *vs.* 86 (IQR, 70.75–108) min, P<0.001], and one-lung ventilation [106 (IQR, 74–132.75) *vs.* 89 (IQR, 90–109) min, P=0.003] compared to the Group II. They frequently received postoperative transfusion [4 (5.63%) *vs.* 1 (0.59%), P=0.027]. Moreover, the two subgroups were statistically different in terms of bronchial blocker use [27 (38.03%) *vs.* 40 (23.53%), P=0.021], intraoperative albumin level [5 (7.04%) *vs.* 1 (0.59%), P=0.013], and estimated blood loss [2 (IQR, 2–5) *vs.* 2 (IQR, 2–2) mL, P=0.002]. In the Group I, 35 patients (49.30%) had chest tubes, significantly higher than in the Group II (P=0.035). Furthermore, the duration of chest intubation differed significantly between the two subgroups (P=0.001). The LOS was not affected by intraoperative complications, extubation complications, and anesthetist seniority (P>0.05).

### *Multifactor analysis*

The relevant independent factors for increased LOS were evaluated using binary logistic regression. The following four factors were identified to be associated with a prolonged LOS after robot-assisted thoracoscopic lung surgery in children (*Table 3*): age >6 years (OR =3.214, 95% CI: 1.464–7.502, P=0.004), surgery time >100 min (OR =2.138, 95% CI: 1.296–4.387, P=0.005), intra-albumin (OR =13.778, 95% CI: 1.470–129.116, P=0.022), and blood loss >5 mL (OR =2.184, 95% CI: 1.082–4.409, P=0.029).

### *Comparison of postoperative complications and costs*

The postoperative complications of the two subgroups are shown in *Table 4*. There was a significant difference in the incidence of pleural effusion between the two subgroups (P<0.001). The incidence of pleural effusion in the Group

**Table 2** Procedure-related risk factors associated with an increased LOS after surgery

| Variables | Group I (n=71) | Group II (n=170) | P value |
|---|---|---|---|
| Preoperative sedation | 34 (47.89) | 99 (58.24) | 0.141 |
| Surgery time (min) | 108 [85–127] | 86 [70.75–108] | <0.001 |
| Surgery method | | | 0.647 |
| Pulmonary lobectomy | 35 (49.30) | 75 (44.12) | |
| Pulmonary segmentectomy | 36 (50.70) | 92 (54.12) | |
| Pulmonary mass resection | 0 (0) | 2 (1.18) | |
| Pulmonary wedge resection | 0 (0) | 1 (0.59) | |
| Pathology | | | 0.503 |
| Benign | 70 (98.59) | 169 (99.41) | |
| Malignancy | 1 (1.41) | 1 (0.59) | |
| Anesthesia time (min) | 181 [157–215] | 160 [134.75–181] | <0.001 |
| Anesthesia procedure | | | 0.673 |
| TIVA | 21 (29.58) | 55 (32.35) | |
| Combined intravenous-inhalational general anesthesia | 50 (70.42) | 115 (67.65) | |
| OLV | 68 (95.77) | 162 (95.29) | 0.871 |
| OLV time (min) | 106 [74–132.75] | 89 [70–109] | 0.003 |
| Bronchial blocker | 27 (38.03) | 40 (23.53) | 0.021 |
| Protective ventilation strategy | 16 (22.54) | 25 (14.71) | 0.140 |
| Intraoperative complication | | | |
| Hypercapnia | 22 (30.99) | 60 (35.29) | 0.520 |
| Hyperlactatemia | 2 (2.82) | 1 (0.59) | 0.169 |
| Acidosis | 43 (60.56) | 115 (67.65) | 0.091 |
| Hypotension | 2 (2.82) | 5 (2.94) | 0.958 |
| Hypoxemia | 11 (15.49) | 28 (16.47) | 0.851 |
| Hypothermia | 28 (39.44) | 77 (45.29) | 0.403 |
| Intraoperative transfusion | 2 (2.82) | 0 (0) | 0.086 |
| Intraoperative albumin | 5 (7.04) | 1 (0.59) | 0.013 |
| Intraoperative vasoactive drugs | 2 (2.82) | 0 (0) | 0.086 |
| Infusion volume (mL) | 300 [200–500] | 250 [150–350] | <0.001 |
| Estimated blood loss (mL) | 2 [2–5] | 2 [2–2] | 0.002 |
| Urine (mL) | 100 [50–200] | 90 [30–150] | 0.127 |
| Place of extubation | | | 0.164 |
| Operating room | 51 (71.83) | 108 (63.53) | |
| PACU | 12 (16.90) | 48 (28.24) | |
| ICU | 8 (11.27) | 14 (8.24) | |

**Table 2** (*continued*)

 

**Table 2** (*continued*)

| Variables | Group I (n=71) | Group II (n=170) | P value |
|---|---|---|---|
| Extubation time (min) | 17 [10–30] | 23.5 [14–33] | 0.161 |
| Extubation complication | | | |
| Oxygen desaturation | 7 (9.86) | 8 (4.71) | 0.224 |
| Airway spasm | 3 (4.23) | 5 (2.94) | 0.612 |
| Unplanned re-intubation | 1 (1.41) | 1 (0.59) | 0.522 |
| Unplanned admission to ICU | 2 (2.82) | 3 (1.76) | 0.633 |
| Anesthetist seniority | | | 0.960 |
| Senior (years of work >10 years) | 57 (80.28) | 136 (80.0) | |
| Junior (years of work ≤10 years) | 14 (19.72) | 34 (20.0) | |
| Postoperative destination | | | 0.309 |
| PACU | 48 (67.61) | 131 (77.06) | |
| ICU | 8 (11.27) | 14 (8.24) | |
| Ward | 15 (21.13) | 25 (14.71) | |
| Length of PACU (min) | 56 [38–73] | 59 [46–79] | 0.114 |
| Length of ICU (day) | 1 [1–1] | 1 [1–1] | – |
| Duration of machine ventilation (h) | 3 [3–4.5] | 2.5 [2–4] | 0.267 |
| Chest tube | 35 (49.30) | 59 (34.71) | 0.035 |
| Duration of the chest tube (day) | 2 [1–3] | 1 [1–2] | 0.001 |
| Postoperative transfusion | 4 (5.63) | 1 (0.59) | 0.027 |

Discrete data are expressed as numbers with percentages; continuous data are expressed as median (interquartile range). Group I: LOS after surgery >5 days; Group II: LOS after surgery ≤5 days. LOS, length of stay; TIVA, total intravenous anesthesia; OLV, one-lung ventilation; PACU, post-anesthesia care unit; ICU, intensive care unit.

II was generally lower than that in the Group I, and most of them were mild. The Group II had a significantly lower incidence of pneumonia [6 (3.53%) *vs.* 13 (18.31%), P<0.001] and liver function damage [16 (9.41%) *vs.* 14 (19.72%), P=0.027] compared to the Group I. Surgical resection was not associated with any mortality in the study. In terms of hospitalization costs, the Group II was significantly lower than the Group I [74,407.62 (IQR, 70,671.25–80,187.35) *vs.* 71,078.52 (IQR, 66,084.55–75,504.20), P<0.001].

## Discussion

In our study, there were still many patients with postoperative hospital stays greater than 5 days, indicating a lack of enhanced recovery. Furthermore, numerous factors correlated with prolonged postoperative hospital stay were identified. Specifically, older age, longer surgery duration, intra-albumin use, and higher blood loss were significantly associated with an increased LOS following robotic-assisted thoracoscopic lung surgery in pediatric patients.

A significant predictor of LOS among the risk factors identified in this study was age >6 years. The timing of surgery in asymptomatic congenital cystic lung patients remains controversial. Patients are often not diagnosed with cystic lung disease until they display symptoms of pneumonia or an occasional chest X-ray reveals the lesion in childhood or later. Asymptomatic lung lesions can become infected, undergo malignant degeneration, or cause hemoptysis (15), pneumothorax, or hemothorax (16). In this study, two patients were pathologically diagnosed with pulmonary blastoma after surgery. One study investigating the timing of surgery from birth to early childhood concluded that surgery was safe for all age groups. However,

 

**Table 3** Logistic regression results for prolonged LOS

| Variables | B | OR | 95% CI | P value |
|---|---|---|---|---|
| Age >6 years | 1.198 | 3.214 | 1.464–7.502 | 0.004 |
| Surgery time >100 min | 0.869 | 2.138 | 1.296–4.387 | 0.005 |
| Intra-albumin | 2.623 | 13.778 | 1.470–129.116 | 0.022 |
| Blood loss >5 mL | 0.781 | 2.184 | 1.082–4.409 | 0.029 |

LOS, length of stay; OR, odds ratio; CI, confidence interval.

**Table 4** Hospitalization costs and postoperative complications of robot-assisted thoracoscopic lung surgery

| Variables | Group I (n=71) | Group II (n=170) | P value |
|---|---|---|---|
| Hospitalization costs (¥) | 74,407.62 (70,671.25–80,187.35) | 71,078.52 (66,084.55–75,504.20) | <0.001 |
| Fever | 20 (28.17) | 47 (27.65) | 0.934 |
| Atelectasis | 9 (12.68) | 11 (6.47) | 0.111 |
| Pneumonia | 13 (18.31) | 6 (3.53) | <0.001 |
| Pleural effusion | | | <0.001 |
| ≤2 cm* | 38 (53.52) | 121 (71.18) | |
| >2 cm* | 23 (32.39) | 11 (6.47) | |
| Contralateral pleural effusion (<2 cm*) | 21 (29.58) | 37 (21.76) | 0.196 |
| Pneumothorax | | | 0.217 |
| Thoracentesis | 25 (35.21) | 40 (23.53) | |
| No-thoracentesis | 7 (9.86) | 4 (2.35) | |
| Anemia | 33 (46.48) | 75 (44.72) | 0.737 |
| Liver function damage | 14 (19.72) | 16 (9.41) | 0.027 |
| Death | 0 (0) | 0 (0) | – |

Discrete data are expressed as numbers with percentages; continuous data are expressed as median (interquartile range). Group I: LOS after surgery >5 days; Group II: LOS after surgery ≤5 days. *, liquid anechoic area under chest ultrasound.

a higher risk of inflammatory sequelae was reported in older patients at the time of surgery (17). Another study from Australia showed that asymptomatic patients can undergo surgery between 3 and 9 months of age with good clinical outcomes and without the need for prolonged postoperative ventilation (18). Moreover, the authors reported that the risk of infective complications increases with age and thus recommend earlier excision. Some inflammatory responses may persist on histological examination for a long time before the onset of symptoms in asymptomatic patients (19). Sueyoshi *et al.* (20) discovered that delaying the resection until the child develops symptoms increases morbidity, demonstrating that all patients with postnatal diagnoses following pneumonia had a significantly longer duration of surgery and greater intraoperative blood loss. This is primarily due to adhesion at the lesion site and infection; surgery becomes more challenging in the later stages.

Intraoperative albumin administration is also a risk factor for enhanced recovery. The crystalloid has a distinct distribution phase, and excessive crystalloid infusion aggravates tissue edema, which is more pronounced in pulmonary resection (21). The occurrence of this adverse effect is dose-dependent. Numerous studies have demonstrated pathological changes in re-expansion pulmonary edema (REPE) after one-lung ventilation (22,23). Albumin, a colloid fluid commonly used in pediatric surgery, effectively increases colloid osmotic pressure and limits edema formation. Therefore, the crystalloids and infused albumin are decreased prophylactically in patients with severe disease and prolonged surgery.

In a retrospective study based on the National Surgical Quality Improvement Program (NSQIP) pediatric database, Mahida *et al.* analyzed information on all patients undergoing non-emergency lobectomy for congenital lung lesions and identified ASA grade ≥3 as a significant predictor of prolonged LOS, whereas the procedure type (open versus thoracoscopic) was not an independent risk factor for postoperative LOS >3 days (24). This study showed that the surgical approach had no significant impact on postoperative recovery; however, patients who received oxygen support before surgery and had other congenital anomalies or cardiac risk factors significantly affected postoperative recovery. In contrast, the patients included in our study for robot-assisted surgery had fewer comorbidities at baseline. In another retrospective study of adults, shorter hospital stay was found to be correlated not only with early removal of chest tubes and opioid cessation on day three but also with high ERAS compliance of patients (25). Although there were differences in the duration of chest tube use between the two subgroups in our study, the majority of patients in both groups had their chest tubes removed within 3 days. The use of opioids as postoperative analgesics remains limited among children. While previous foreign literature suggested that the expected LOS for patients undergoing lobectomy for a congenital pulmonary lesion was 3 days (26), our findings indicate that the LOS is a persistent variable influenced by multiple factors. In our cohort, the median LOS was 5 days, which also had the highest frequency. Therefore, we consider this grouping to be relatively reasonable.

PPCs are considered to have a significant negative influence on recovery outcomes, increasing the risk of mortality (27). Theoretically, ERAS regimens integrating effective perioperative courses, including VATS and pain management, may improve postoperative recovery and reduce the occurrence of PPCs. However, patients undergoing VATS lobectomy are still at risk for developing PPCs. This can be seen in the complications of pneumonia and pleural effusion, which were significantly less frequent in the Group II. This trend was also seen in the other complications, although the difference was not significant, possibly due to the small sample size. Postoperative wound effusion and the high sensitivity of diagnostic B-ultrasound contribute to the higher incidence of postoperative pleural effusion. The high incidence of pneumothorax may be related to partial retention of gas during surgery, and this was more difficult to identify in our retrospective analysis. Therefore, we included cases with mild symptoms and classified the two complications. As can be seen from the *Table 4*, the number of mild cases between the two accounts for a larger proportion. In fact, this also shows that our ERAS strategy is effective and relatively reasonable. In terms of overall medical cost, there was a significant difference between the two groups, and although this is compounded realistically, it is a side note that the ERAS strategy also helped to reduce patient expenditures.

Moreover, our study revealed that the incidence of liver injury after thoracoscopic lung surgery was significantly higher (19.72%) in the Group I than in the Group II. This may be caused by shorter single lung ventilation time in Group II than in Group I. In an experimental study in rats, lung collapse and re-expansion during one-lung ventilation caused significant liver injury, which increased as occlusion duration increased (28). The cause of this second organ effect is unknown, but it has been suggested that inflammatory mediators released as a result of lung re-expansion injury activate endothelial cells to release reactive oxygen species/reactive nitrogen species (ROS/RNS), which can damage distal tissues (29). Similar to another study (30), mortality resulting directly from thoracotomy and resection is rare.

Our study identified several predictors of prolonged LOS after robot-assisted thoracoscopic lung surgery in children, and the results could contribute to choosing the surgery time. Neonatal surgical resection of symptomatic congenital lung lesions is clear; however, the timing of surgery for asymptomatic patients remains controversial. Although several studies have shown that surgery at 3–9 months of age is safe with good postoperative recovery (18), numerous patients are still treated after the onset of symptoms due to the fear of causing harm through surgery at this young age. Our study's recommendations for asymptomatic patients undergoing surgery at older ages (>6 years) may increase surgery time and intraoperative hemorrhage, as well as hinder postoperative enhanced recovery. Moreover, compensatory lung growth is thought to continue until the age of 6 to 8 years. Therefore, earlier surgery may allow for more compensatory lung growth (31).

This retrospective analysis has several limitations. First, it was a single-center cohort study that prospectively collected data for retrospective analysis. There may be selection bias and time-specific bias in this clinical trial, as we are in the midst of the coronavirus disease 2019 (COVID-19) pandemic from 2020 to 2022. Second, this retrospective study included a small sample size due to the limited number of patients undergoing robot-assisted thoracoscopic lung surgery at our center, which may have influenced our findings. Finally, despite the current implementation of various ERAS strategies at our center, variability and uncertainty in children's compliance to ERAS strategies can negatively impact post-operative recovery. This aspect must be improved in later stages. Therefore, a prospective study that includes all of these factors should be conducted in the future.

## Conclusions

Our results demonstrated that older age, longer surgical duration, intraoperative albumin use, and increased blood loss were associated with increased LOS in pediatric patients after robot-assisted thoracoscopic lung surgery. Overall, enhanced recovery after thoracoscopic lung surgery in children should be investigated and improved.

## Acknowledgments

*Funding:* This study was supported by the China Natural Science Foundation grant (No. 81601358).

## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1585/rc

*Data Sharing Statement:* Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1585/dss

*Peer Review File:* Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1585/prf

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1585/coif). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are 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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of Children's Hospital of Zhejiang University (No. 2022-IRB-272) and individual consent for this retrospective analysis was waived.



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**Cite this article as:** Fan J, Gao Y, Zhao J, Liang L, Jin Y, Jin H. Factors influencing the length of stay (LOS) undergoing robot-assisted thoracoscopic lung surgery in the setting of enhanced recovery after surgery (ERAS) protocol for pediatric patients: a retrospective study. J Thorac Dis 2024;16(2):1212-1222. doi: 10.21037/jtd-23-1585

 