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# Preoperative Symptoms and Feasibility of Minimally Invasive Resection for Congenital Pulmonary Airway Malformation: A Multicenter Retrospective Study from the East Asia Pediatric Surgery Research Consortium

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# Preoperative Symptoms and Feasibility of Minimally Invasive Resection for Congenital Pulmonary Airway Malformation: A Multicenter Retrospective Study from the East Asia Pediatric Surgery Research Consortium


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**Abstract**

**Purpose:** Congenital pulmonary airway malformation (CPAM) has heterogeneous clinical presentations. We investigated whether preoperative symptomatic status is associated with postoperative outcomes and whether it affects the feasibility of thoracoscopic resection.

**Methods:** We retrospectively reviewed patients who underwent CPAM resection at four institutions between 2005 and 2024. Patients were classified as symptomatic (respiratory failure and/or pulmonary infection) or asymptomatic. The surgical approach, conversion to thoracotomy, postoperative complications, and long-term musculoskeletal outcomes were compared.

**Results:** Among 293 patients, 89 (30.4%) were symptomatic. Postoperative complications were more frequent in symptomatic patients than in asymptomatic patients (23.6% vs. 10.2%, $p$=0.002), with air leakage being the most frequent complication (12.4% vs. 3.4%). Thoracoscopic resection was performed less frequently in symptomatic patients (64.0% vs. 93.6%, $p$<0.001), whereas conversion rates were comparable (10.5% vs. 6.8%, $p$=0.31). Symptomatic status was independently associated with postoperative complications (OR 2.42, 95% CI 1.05–5.44, $p$=0.034), with no significant interaction with surgical approach ($p$=0.64). Long-term musculoskeletal outcomes were comparable between the approaches in symptomatic patients.

**Conclusion:** Preoperative symptoms are associated with increased postoperative morbidity but do not preclude thoracoscopic resection. Symptomatic status is useful for risk stratification but does not preclude a minimally invasive approach.

**Key words:** Congenital pulmonary airway malformation, Thoracoscopic surgery, minimal invasive surgery, lobectomy, thoracoscopy, pediatric surgery, multicenter study

## Introduction

Congenital pulmonary airway malformation (CPAM) is a rare congenital lung disease characterized by abnormal airway development and cystic lesions of the lung [1]. With advances in prenatal imaging, particularly ultrasonography, an increasing number of cases are diagnosed before birth, allowing for early evaluation and planned surgical management [1].

Surgical resection is generally recommended to prevent complications such as recurrent infection, respiratory distress, and potential malignant transformation. Traditionally, open thoracotomy has been the standard approach for the treatment of CPAM. Over the past two decades, thoracoscopic surgery has been increasingly adopted in pediatric thoracic surgery owing to advances in surgical techniques and instrumentation[2]. Thoracoscopic resection offers several potential advantages, including reduced surgical trauma, faster postoperative recovery, and improved cosmetic outcomes, and is now widely considered a feasible alternative to open surgery[2, 3]. Despite these advantages, several important issues remain unresolved. In particular, thoracoscopic surgery can be technically challenging in small infants and in patients with severe inflammation or infection. In addition, the optimal timing of surgery and the indications for thoracoscopic approaches, especially in symptomatic patients, remain controversial [3, 4]. Furthermore, concerns persist regarding postoperative complications and long-term outcomes, including the potential impact on chest wall development and musculoskeletal deformities [5–7].

This study aimed to evaluate the clinical characteristics and surgical outcomes in patients with CPAM, with a particular focus on symptomatic status and surgical approach. We also assessed the safety and feasibility of thoracoscopic surgery in comparison to open surgery, including its impact on perioperative and long-term outcomes.

## Methods

### *Study design and patients*

This retrospective study included patients who underwent surgical resection for CPAM at four institutions (Kagoshima University, The University of Hong Kong, Nagoya University Graduate School of Medicine, and Juntendo University School of Medicine) between 2005 and 2024. A total of 295 patients were identified and included in the analysis. The number of cases at each facility is summarized in Table 1. All procedures were performed either by attending surgeons at each institution or by fellows under the direct supervision of an attending surgeon. Thoracoscopic and open resections were performed according to institutional practice and surgeon preference. The bronchus was divided using either a stapling device or surgical clips, depending on patient size and institutional practice.

**Table 1**

Patients were further divided into symptomatic and asymptomatic groups according to the presence of preoperative symptoms, including pulmonary infection and respiratory compromise. Pneumonia was defined as the presence of a new pulmonary infiltrate or consolidation on chest radiography or computed tomography, together with the requirement for antibiotic therapy. Respiratory compromise was defined as the requirement for any respiratory intervention, such as supplemental oxygen, CPAP, noninvasive positive pressure ventilation, or invasive mechanical ventilation. The indications for surgery were determined based on institutional practice and clinical presentation.

### *Data collection*

Clinical data were retrospectively collected from medical records, including patient demographics (sex, birth weight), perioperative variables (age, body weight, and height at operation), prenatal diagnosis, surgical approach (open vs. thoracoscopic), type of surgical

procedure, intraoperative blood loss, and postoperative length of stay. Patients were classified according to CPAM subtype (types 1–4 and others) based on pathological findings.

Postoperative outcomes included conversion to thoracotomy and postoperative complications. Long-term complications, including chest wall deformity (pectus excavatum and thoracic deformity), scoliosis, and respiratory compromise, were also evaluated based on the available medical records and imaging findings at the latest follow-up. Follow-up intervals were not standardized across institutions because of the retrospective multicenter design.

A multivariate logistic regression analysis was performed to identify independent risk factors for postoperative complications. The variables included in the model were preoperative symptomatic status, age at surgery, CPAM type (type 1 as the reference), surgical approach (thoracoscopic vs. open), and surgical timing (emergent vs. elective). The results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). An interaction term between symptomatic status and surgical approach was additionally included to evaluate whether the effect of surgical approach differed according to preoperative symptoms.

***Statistical analysis***

Continuous variables are presented as the mean ± standard deviation or median (interquartile range), as appropriate. Comparisons of continuous variables were performed using Student's t-test or Mann–Whitney U test, depending on the distribution of the data. Categorical variables are presented as number (%) and were compared using Fisher's exact test. All tests were two-sided, and p values $< 0.05$ were considered statistically significant. Statistical analyses were performed using R (version R 4.6.1, The R Foundation software program for Statistical Computing, Vienna, Austria).

### *Ethical approval*

This study was performed in accordance with the Ethical Guidelines for Medical and Health Research Involving Human Subjects of the Ministry of Health, Labour and Welfare of Japan in 2014 and was in compliance with the 1964 Declaration of Helsinki, revised in 2013. This study was approved by the local ethics committee of our institution (registration number: 250311).

## Results

### *Patient characteristics and clinical outcomes stratified according to the type of CPAM*

Table 2 summarizes the patient characteristics according to the type of CPAM. A total of 293 patients were included in this study, with CPAM type 1 (134/293, 45.4%) and type 2 (144/293, 48.8%) accounting for the majority of cases. Other subtypes were relatively rare, including type 3 (13/293, 4.4%) and type 4 (2/293, 0.7%). The male-to-female ratio was comparable across all groups, with no apparent sex predominance. Birth weight was also similar among the groups, ranging from 2803.9 ± 529.1 g in type 3 to 3093 ± 529.1 g in type 4, with no significant differences observed ($p$ = 0.180). The age at operation varied among subtypes, with a statistically significant difference observed (overall: 279 [98–641] days, $p$ = 0.041). Similarly, body weight at the time of surgery was comparable across CPAM types ($p$ = 0.052), whereas height at surgery showed a statistically significant difference among groups ($p$ = 0.047). A prenatal diagnosis was achieved in the majority of cases (240/293, 81.9%), with particularly high detection rates in type 2 (128/144, 88.9%) and type 1 (101/134, 75.4%) ($p$ = 0.029). Regarding preoperative clinical status, respiratory compromise was more frequently observed in type 1 (26/134, 19.4%) compared with other subtypes ($p$ = 0.048), whereas a history of

**Table 2**

infection did not significantly differ among groups ($p = 0.12$). The proportion of elective versus emergent surgery was comparable across CPAM types ($p = 0.10$).

Surgical outcomes and long-term complications are summarized in Table 3. The overall rate of thoracoscopic surgery was 69.6% (204/293) and did not differ significantly among groups, although a trend toward variation was observed ($p = 0.09$). The type of resection was comparable across CPAM subtypes ($p = 0.52$–$0.91$), with lobectomy being the most frequently performed procedure (257/293, 87.1%). Intraoperative blood loss was low and similar among groups (overall median 6 mL [IQR 1–30], $p = 0.228$). In contrast, postoperative length of stay differed significantly among subtypes ($p = 0.011$), being longest in type 4 (11 days [7–15]) and shortest in type 2 (6 days [4–10]). Regarding postoperative complications, significant differences were observed in air leakage (18/293, 6.1%; $p = 0.041$), residual lesions (15/293, 5.1%; $p = 0.031$), and reoperation rates (18/293, 6.1%; $p = 0.022$). These complications tended to be more frequent in types 3 and 4; however, the small sample size in these subgroups should be considered when interpreting these findings. Other complications were rare and did not differ significantly among groups.

**Table 3**

Long-term complications were infrequent and showed no significant differences across CPAM subtypes.

***Comparison between symptomatic and asymptomatic patients***

Table 4 shows the comparison between symptomatic and asymptomatic patients. A total of 89 symptomatic and 204 asymptomatic patients were included in this study. Prenatal diagnosis was significantly more frequent in asymptomatic cases than in symptomatic cases (190/204 [93.1%] vs. 52/89 [58.4%], $p < 0.001$). Preoperative symptoms in the symptomatic group included pulmonary infection in 47 patients (52.8%) and respiratory compromise in 42 patients (47.2%). Patients in the symptomatic group underwent surgery at a significantly younger age

**Table 4**

than those in the asymptomatic group (median 131 [ 8–762] vs. 310 [180–627] days, $p = 0.003$). Emergent surgery was performed more frequently in symptomatic patients than in asymptomatic patients (28/89 [31.5%] vs. 1/204 [0.5%], $p < 0.001$). Regarding surgical procedures, lobectomy was more frequently performed in symptomatic patients ($p = 0.017$). The thoracoscopic approach was more frequently utilized in asymptomatic patients than in symptomatic patients (191/204 [93.6%] vs. 57/89 [64.0%], $p < 0.001$). Notably, however, the rate of conversion to thoracotomy was comparable between the two groups (6/57 (10.5%) vs 13/191 (6.8%), $p = 0.31$). Postoperative complications occurred more frequently in symptomatic patients than in asymptomatic patients (21/89 [23.6%] vs. 21/204 [10.2%], $p = 0.002$). Among these, air leakage was more common in symptomatic cases (11/89 [12.4%] vs. 7/204 [3.4%]), whereas other complications, including atelectasis, hemorrhage, pulmonary hypertension, residual lesions, and reoperation, were infrequent and showed no significant differences between the groups.

***Long-term outcomes according to surgical procedure in symptomatic patients***

**Table 5**

Table 5 shows the surgical procedures and long-term outcomes according to the surgical approach in symptomatic patients. Elective surgery was performed more frequently in the thoracoscopic group than in the open surgery group (44/57 [77.2%] vs. 16/32 [50.0%], p = 0.011), whereas emergency surgery was more frequent in the open surgery group (16/32 [50.0%] vs. 13/57 [22.8%]). With regard to the surgical procedures, single lobectomy was the most frequently performed procedure in both groups (open: 27/32 [84.4%]; thoracoscopic: 46/57 [80.7%]), followed by segmentectomy (4/32 [12.5%] vs. 4/57 [7.0%]). Less commonly performed procedures included partial resection (0/32 [0.0%] vs. 2/57 [3.5%]), multiple lobectomies (0/32 [0.0%] vs. 3/57 [5.3%]), and pneumonectomy (0/32 [0.0%] vs. 1/57 [1.8%]). The distribution of surgical procedures was comparable between the two groups (all $p > 0.05$).

In terms of long-term outcomes, pectus excavatum was observed in 4 patients in each group (4/32 [12.5%] vs. 4/57 [7.0%]), and thoracic deformity was noted in 4 patients in the open group and 3 patients in the thoracoscopic group (12.5% vs. 5.3%). Scoliosis occurred in 3 patients (9.4%) in the open group and 2 patients (3.5%) in the thoracoscopic group, while respiratory compromise was identified in one patient (3.1%) in the open group and in none of the thoracoscopic cases. Rib fusion was not observed in either group. Overall, the incidence of long-term complications was comparable between the two groups, with no statistically significant differences observed.

***Multivariable analysis for postoperative complications***

In the multivariable analysis, preoperative symptomatic status was independently associated with postoperative complications (OR 2.42, 95% CI 1.05–5.44, $p = 0.034$). CPAM type 3/4 showed a trend toward increased risk compared with type 1 (OR 3.38, 95% CI 0.93–11.2, $p = 0.051$), although this did not reach statistical significance. Age at surgery, thoracoscopic approach, and emergent surgery were not significantly associated with postoperative complications (Table 6, Fig. 1).

**Table 6**

**Fig.1**

Figure 2 shows the predicted probability of postoperative complications according to symptomatic status and surgical approach. Symptomatic patients had a higher predicted risk of complications than asymptomatic patients across both surgical approaches. The multivariable analysis identified symptomatic presentation as the sole independent predictor, and no significant interaction was observed between symptomatic status and surgical approach (interaction $p = 0.64$).

**Fig.2**

## Discussion

CPAM has traditionally been managed by open thoracotomy; however, thoracoscopic surgery has been increasingly adopted. Thoracoscopy, particularly thoracoscopic lobectomy, is one of the most technically demanding minimally invasive procedures in the pediatric population. It can be especially challenging in small infants and patients with prior inflammation or infection. In addition, the indications for thoracoscopic surgery and its impact on perioperative and long-term outcomes remain areas of active investigation [4].

This multicenter study systematically evaluated the clinical characteristics and surgical outcomes of patients with CPAM, with a particular focus on symptomatic status and surgical approach. The main findings of this study are as follows: (1) thoracoscopic surgery was more frequently performed in asymptomatic patients, whereas open surgery was more commonly selected in symptomatic cases; (2) despite differences in surgical approach, the rate of conversion to thoracotomy was comparable between symptomatic and asymptomatic patients; (3) long-term outcomes, including thoracic deformity and scoliosis, were comparable between thoracoscopic and open approaches, suggesting that thoracoscopic surgery does not increase the risk of adverse musculoskeletal sequelae; and (4) postoperative complications were significantly more frequent in symptomatic patients, and the multivariable analysis confirmed that symptomatic presentation remained the only independent predictor of postoperative complications, indicating that preoperative clinical status strongly influences perioperative outcomes.

An additional important finding of this study is the markedly higher prenatal diagnosis rate in asymptomatic patients compared with symptomatic patients. A prenatal diagnosis allows for early evaluation and planned surgical intervention, which may contribute to improved perioperative outcomes and a lower likelihood of emergent surgery. In contrast, symptomatic patients often present with infection or respiratory compromise, necessitating

earlier and sometimes emergent intervention. This difference in clinical presentation may partly explain the observed disparities in surgical timing and postoperative complications between the two groups.

Consistent with this, symptomatic patients underwent surgery at a significantly younger age than asymptomatic patients, with a higher proportion of emergent procedures. These findings suggest that disease severity and clinical presentation strongly influence the timing of surgical intervention. Although early surgery may be unavoidable in symptomatic patients, careful consideration should be given to the optimal timing of surgery to balance the risks of infection, technical difficulty, and postoperative complications.

Postoperative complications remain an important concern in the surgical management of CPAM, particularly in the context of thoracoscopic approaches [8–10]. In the present study, the overall incidence of postoperative complications was significantly higher in symptomatic patients than in asymptomatic patients, suggesting that preoperative clinical status has a substantial impact on perioperative outcomes. Among the observed complications, air leakage was the most common, occurring more frequently in symptomatic patients. This finding is consistent with previous reports indicating that inflammation and infection may increase tissue fragility and impair postoperative healing [5, 11]. However, most complications were minor and could be managed conservatively without the need for invasive interventions. Other complications, including atelectasis, hemorrhage, pulmonary hypertension, and residual lesions, were relatively infrequent and showed no significant differences between groups. These findings are in line with prior studies demonstrating that thoracoscopic resection of congenital lung lesions is associated with acceptable morbidity rates [3, 4]. Although symptomatic patients were at an increased risk of postoperative complications, the safety profile of thoracoscopic surgery remained favorable, with most complications being manageable and non-life threatening.

Conversion to thoracotomy remains a critical concern in thoracoscopic resection for CPAM, as it reflects intraoperative technical difficulty and may be associated with increased perioperative morbidity. Several studies have identified pulmonary infection, severe inflammation, and dense pleural adhesions as key risk factors for conversion, all of which can obscure anatomical planes, compromise visualization, and hinder safe dissection [4, 9–14]. Pulmonary infection has been consistently reported as a major determinant of conversion. Inflammatory changes and adhesions associated with infection can distort normal anatomy and increase tissue fragility, thereby making thoracoscopic dissection more challenging and increasing the likelihood of conversion to thoracotomy [4, 10–14]. These observations underscore the technical limitations of thoracoscopic surgery in symptomatic patients. However, in the present study, the rate of conversion to thoracotomy was comparable between symptomatic and asymptomatic patients, suggesting that thoracoscopic surgery can be performed safely when appropriate expertise and perioperative management are ensured. These results further highlight the importance of surgical experience, careful patient selection, and optimal timing of intervention. In selected cases, even patients with symptomatic disease may be suitable candidates for thoracoscopic resection without an increased risk of conversion. These findings may also reflect differences in surgical expertise and institutional practices across centers.

In the multivariate analysis, CPAM type 3/4 showed a nonsignificant trend toward increased postoperative complications (OR 3.38, 95% CI 0.93–11.21, p=0.051). However, this finding should be interpreted with caution because only a small number of patients had type 3 or type 4 lesions. CPAM subtypes differ in their histopathological and clinical characteristics, and type 3 lesions, in particular, may present as large, predominantly solid lesions associated with respiratory compromise [15–17]. Nevertheless, given the limited number of type 3/4 cases in the present cohort, meaningful subtype-specific conclusions regarding postoperative

outcomes cannot be drawn. Larger studies are needed to clarify whether histopathological subtype is independently associated with postoperative outcomes.

Thoracoscopic surgery offers several advantages over open thoracotomy in the management of CPAM, particularly in terms of reduced surgical invasiveness and improved postoperative recovery. Previous studies have demonstrated that thoracoscopic approaches are associated with decreased postoperative pain, shorter length of stay, and faster return to normal activity compared with open procedures [3, 4, 18, 19]. In addition to these short-term benefits, thoracoscopic surgery may also provide favorable long-term outcomes. In particular, preservation of chest wall integrity has been associated with a reduced risk of musculoskeletal deformities, including scoliosis and thoracic asymmetry [5–7]. A recent study from Hong Kong demonstrated that patients undergoing thoracoscopic resection had a better postoperative pulmonary function than those treated with open thoracotomy, suggesting a potential long-term functional advantage of minimally invasive approaches [18]. Furthermore, the superior cosmetic outcomes associated with thoracoscopic surgery represent an important consideration in pediatric patients. Smaller incisions and avoidance of thoracotomy may contribute to an improved quality of life and patient satisfaction [6].

This study has several limitations. First, its retrospective design may have introduced selection bias, particularly in the choice of surgical approach and the classification of symptomatic and asymptomatic patients. Symptomatic patients were more likely to undergo open surgery, which may have influenced the observed differences in postoperative outcomes. Second, this was a multicenter study involving four institutions. Although this enhances the generalizability of the findings, variations in surgical techniques, perioperative management, and institutional preferences among centers may have introduced heterogeneity and influenced the outcomes. In particular, differences in surgeon experience and indications for thoracoscopic surgery may have affected the selection of surgical approach and perioperative results. Third,

although the overall sample size was relatively large, the number of patients in certain subgroups, particularly less common CPAM subtypes and specific surgical procedures, was limited, which may have reduced the statistical power to detect differences. In addition, the CPAM subtype was determined based on postoperative pathological findings, and reliable preoperative classification of CPAM subtype was not possible. Therefore, differences in age at operation according to CPAM subtype should be interpreted cautiously. Surgical timing was likely determined by clinical factors, such as prenatal diagnosis, symptoms, lesion size, respiratory status, history of infection, and institutional practice, rather than by the CPAM subtype itself. Finally, the duration of follow-up may not have been sufficient to fully evaluate long-term outcomes, particularly musculoskeletal deformities such as scoliosis, which may develop over time.

**Conclusion**

Thoracoscopic surgery is a safe and feasible approach for the management of CPAM, providing comparable surgical and long-term outcomes to open surgery. Although symptomatic patients were associated with a higher incidence of postoperative complications, the rate of conversion to thoracotomy remained comparable, suggesting that thoracoscopic surgery can be performed safely even in selected symptomatic cases. Careful patient selection and appropriate timing of surgery are essential to optimize outcomes, particularly in patients with preoperative symptoms.

## Declarations

### Competing interests

The authors did not receive support from any organization for the submitted work.

### Ethics approval

This study was performed in accordance with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Kagoshima University ( June 9, 2026 /No. 250311).

### Consent to publish

Informed consent was obtained from all individual participants included in the study.

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**Legend for Figure/Tables**

**Table1** **Number of cases at each facility**

**Table2** **Patient characteristics according to type of CPAM**

**Table3** **Surgical outcomes according to type of CPAM**

**Table 4** **Clinical characteristics and surgical outcomes according to symptomatic status in patients with CPAM**

**Table 5** **The long-term outcomes according to surgical procedure in symptomatic patients**

**Table 6** **Multivariable analysis for postoperative complications**

**Figure 1** **Multivariable analysis of risk factors for postoperative complications**

Multivariable analysis of risk factors for postoperative complications

**Figure 2** **Predicted probability of postoperative complications according to symptomatic status and surgical approach**

Predicted probabilities of postoperative complications based on a multivariable logistic regression model stratified by symptomatic status and surgical approach. The model was adjusted for age at surgery and CPAM type. Error bars represent 95% confidence intervals. No significant

interaction was observed between symptomatic status and surgical approach (interaction $p = 0.64$).

**Table 1. Number of cases at each facility**

| | Hong Kong | Juntendo | Kagoshima | Nagoya | Total |
|---|---|---|---|---|---|
| **CPAM type** | | | | | |
| **Type 1** | 36 | 33 | 13 | 52 | 134 |
| **Type 2** | 48 | 33 | 13 | 50 | 144 |
| **Type 3** | 4 | 5 | 0 | 4 | 13 |
| **Type 4** | 0 | 2 | 0 | 0 | 2 |
| **Total** | 88 | 73 | 26 | 106 | 293 |

**Table 2. Patient characteristics according to the type of CPAM**

| | Type 1 | Type 2 | Type 3 | Type 4 | Total | *p* value |
|---|---|---|---|---|---|---|
| **Number of cases, n (%)** | 134 (45.7) | 144 (49.1) | 13 (4.4) | 2 (0.7) | 293 (100) | N/A |
| **Sex (Male: Female)** | 68:66 | 65:79 | 5:8 | 1:1 | 139:154 | 0.320 |
| **Birth weight (g)** | 2926.7 ± 481.0 | 3040.9 ± 396.0 | 2803.9 ± 529.1 | 3093 ± 529.1 | 2961.0 ± 470.6 | 0.180 |
| **Age at surgery (days)** | 248 (54–764) | 307 (151–612) | 524 (197–592) | 264 (134–394) | 279 (98–641) | 0.041 |
| **Body weight at Surgery (g)** | 8160 (4458–11725) | 9000 (6800–10800) | 9290 (8000–9600) | 6400 (4750–8050) | 8720 (5600–11000) | 0.052 |
| **Height at surgery (cm)** | 70.5 (54.1–87.3) | 72.0 (64.5–83.0) | 77.0 (70.1–86.0) | 63.4 (56.2–70.6) | 72.8 (61.2–84.0) | 0.047 |
| **Prenatal diagnosis, n (%)** | 101(75.4) | 128 (88.9) | 10 (77.0) | 1 (50.0) | 240 (81.9) | 0.029 |
| **Preoperative symptoms, n (%)** | | | | | | |
| **Respiratory compromise** | 26 (19.4) | 13 (9.0) | 2 (15.4) | 1 (50.0) | 42 (14.3) | 0.048 |
| **History of infection** | 27 (20.1) | 17 (11.8) | 2 (15.4) | 1 (50.0) | 47 (15.9) | 0.12 |
| **Elective: emergent** | 116:18 | 134:10 | 12:1 | 1:1 | 263:30 | 0.10 |

**Table 3. Surgical outcomes according to the type of CPAM**

| | Type 1 n=134 | Type 2 n=144 | Type 3 n=13 | Type 4 n=2 | Total n=293 | *p* value |
|---|---|---|---|---|---|---|
| **Surgical approach (thoracoscopy)** | 86 (64.2) | 110 (76.4) | 7 (53.8) | 1 (50.0) | 204 (69.6) | 0.09 |
| **Performed surgery** | | | | | | |
| **Partial resection** | 3 (2.2) | 4 (2.8) | 1 (7.7) | 0 (0.0) | 8 (2.7) | 0.63 |
| **Segmentectomy** | 10 (7.4) | 8 (5.6) | 1 (7.7) | 0 (0.0) | 19 (6.4) | 0.78 |
| **Lobectomy** | 118 (88.1) | 126 (87.5) | 11 (84.6) | 2 (100) | 257 (87.1) | 0.91 |
| **Multiple lobectomy** | 1 (0.7) | 4 (2.8) | 0 (0.0) | 0 (0.0) | 5 (1.7) | 0.52 |
| **Pneumonectomy** | 0 (0.0) | 1 (0.7) | 0 (0.0) | 0 (0.0) | 1 (0.3) | 0.64 |
| **Other** | 2 (1.5) | 1 (0.7) | 0 (0.0) | 0 (0.0) | 3 (1.0) | 0.74 |
| **Blood loss (ml)** | 9 (2–40) | 5 (0–30) | 5 (1–30) | 5 (5–5) | 6 (1–30) | 0.228 |
| **Postoperative length of stay (days)** | 8 (5–14) | 6 (4–10) | 6 (4–8) | 11 (7–15) | 7 (4–11) | **0.011** |
| **Postoperative complications** | | | | | | |
| **Air leakage** | 10 (7.4) | 5 (3.4) | 3 (23.1) | 0 (0.0) | 18 (6.1) | 0.041 |
| **Atelectasis** | 0 (0.0) | 4 (2.8) | 0 (0.0) | 0 (0.0) | 4 (1.4) | 0.29 |
| **Hemorrhage** | 0 (0.0) | 2 (1.4) | 0 (0.0) | 0 (0.0) | 2 (0.7) | 0.56 |
| **Pulmonary hypertension** | 0 (0.0) | 1 (0.7) | 1 (7.7) | 0 (0.0) | 2 (0.7) | 0.18 |
| **Residual lesion** | 7 (5.2) | 5 (3.4) | 2 (15.4) | 1 (50.0) | 15 (5.1) | **0.031** |
| **Residual pulmonary ischemia** | 1 (0.7) | 2 (1.4) | 0 (0.0) | 0 (0.0) | 3 (1.0) | 0.81 |
| **Abscess** | 2 (1.5) | 1 (0.7) | 0 (0.0) | 0 (0.0) | 3 (1.0) | 0.74 |
| **Reoperation** | 11 (8.1) | 6 (4.1) | 0 (0.0) | 1 (50.0) | 18 (6.1) | **0.022** |
| **Long term complications** | | | | | | |
| **Rib fusion** | 0 (0.0) | 1 (0.7) | 0 (0.0) | 0 (0.0) | 1 (0.3) | 0.64 |
| **Pectus excavatum** | 8 (5.9) | 10 (6.9) | 2 (15.4) | 0 (0.0) | 20 (6.8) | 0.41 |
| **Thoracic deformity** | 6 (4.4) | 9 (6.2) | 1 (7.7) | 0 (0.0) | 16 (5.4) | 0.72 |
| **Scoliosis** | 1 (0.7) | 5 (3.4) | 0 (0.0) | 0 (0.0) | 6 (2.0) | 0.37 |

**Table 4. Comparison between symptomatic and asymptomatic patients**

| | Symptomatic Cases n = 89 | Asymptomatic Cases n = 204 | *p* value |
|---|---|---|---|
| **Prenatal diagnosis, n (%)** | 52 (58.4) | 190 (93.1) | **< 0.001** |
| **Pulmonary infection, n (%)** | 47 (52.8) | 0 | - |
| **Respiratory compromise, n (%)** | 42 (47.2) | 0 | - |
| **CPAM type, n (%)** | | | **-** |
| **Type 1** | 53 (59.6) | 81 (39.8) | - |
| **Type 2** | 30 (33.7) | 114 (55.8) | - |
| **Type 3** | 4 (4.5) | 9 (4.4) | - |
| **Type 4** | 2 (2.2) | 0 (0.0) | - |
| **Age at surgery (days)** | 131 (8–762) | 310 (180–627) | **0.003** |
| **Surgical indication, n (%)** | | | **< 0.001** |
| **Elective** | 61 (68.5) | 203 (99.5) | - |
| **Emergent** | 28 (31.5) | 1 (0.5) | - |
| **Performed surgical procedure, n (%)** | | | **0.017** |
| **Lobectomy (single/multiple)** | 76 (85.4) | 153 (74.8) | - |
| **Segmentectomy** | 8 (9.0) | 46 (22.3) | - |
| **Wedge/partial/others** | 5 (5.6) | 5 (2.9) | - |
| **Thoracoscopic approach, n (%)** | 57 (64.0) | 191 (93.6) | **< 0.001** |
| **Conversion to thoracotomy, n (%)** | 6/57 (10.5) | 13/191 (6.8) | 0.31 |
| **Postoperative complication, n (%)** | 21 (23.6) | 21 (10.2) | **0.002** |
| **Air leakage, n (%)** | 11 (12.4) | 7 (3.4) | - |
| **Atelectasis, n (%)** | 1 (1.1) | 3 (1.5) | - |
| **Hemorrhage, n (%)** | 2 (2.2) | 0 | - |
| **Pulmonary hypertension, n (%)** | 2 (2.2) | 0 | - |
| **Residual lesion, n (%)** | 7 (7.9) | 8 (3.9) | - |
| **Residual pulmonary ischemia, n (%)** | 1 (1.1) | 2 (1.0) | - |
| **Abscess, n (%)** | 2 (2.2) | 1 (0.5) | - |

**Table 5. Long-term outcomes according to the surgical procedure in symptomatic patients**

| | Open Surgery n=32 | Thoracoscopy n=57 | *p* value |
|---|---|---|---|
| **Surgical timing** | | | |
| **Elective surgery, n (%)** | 16 (50.0) | 44 (77.2) | **0.011** |
| **Emergency surgery, n (%)** | 16 (50.0) | 13 (22.8) | |
| **Type of surgical procedure** | | | 0.534 |
| **Partial resection, n (%)** | 0 (0.0) | 2 (3.5) | 0.451 |
| **Segmentectomy, n (%)** | 4 (12.5) | 4 (7.0) | 0.778 |
| **Single lobectomy, n (%)** | 27 (84.4) | 46 (80.7) | 0.550 |
| **Multiple lobectomy, n (%)** | 0 (0.0) | 3 (5.3) | 1.000 |
| **Pneumonectomy, n (%)** | 0 (0.0) | 1 (1.8) | 1.000 |
| **Other, n (%)** | 1 (3.1) | 1 (1.8) | |
| **Long-term complications** | | | — |
| **Rib fusion, n (%)** | 0 (0.0) | 0 (0.0) | 0.451 |
| **Pectus excavatum, n (%)** | 4 (12.5) | 4 (7.0) | 0.246 |
| **Thoracic deformity, n (%)** | 4 (12.5) | 3 (5.3) | 0.346 |
| **Scoliosis, n (%)** | 3 (9.4) | 2 (3.5) | 0.360 |
| **Respiratory compromise, n (%)** | 1 (3.1) | 0 (0.0) | **0.011** |

**Table 6. Multivariable analysis for postoperative complications**

| Variable | Odds Ratio (OR) | 95% CI | *p* value |
|---|---|---|---|
| **Symptomatic (Yes vs. No)** | 2.42 | 1.05–5.44 | **0.034** |
| **Age at surgery (per day)** | 1.00 | 1.00–1.00 | 0.877 |
| **CPAM type** | | | |
| **Type 2 vs. Type 1** | 1.21 | 0.59–2.52 | 0.609 |
| **Type 3/4 vs. Type 1** | 3.38 | 0.93–11.2 | 0.051 |
| **Thoracoscopic approach (Yes vs. No)** | 1.27 | 0.52–3.36 | 0.611 |
| **Emergent surgery (Yes vs. No)** | 1.81 | 0.60–5.39 | 0.288 |

**Figure 1. Multivariable analysis of risk factors for postoperative complications**

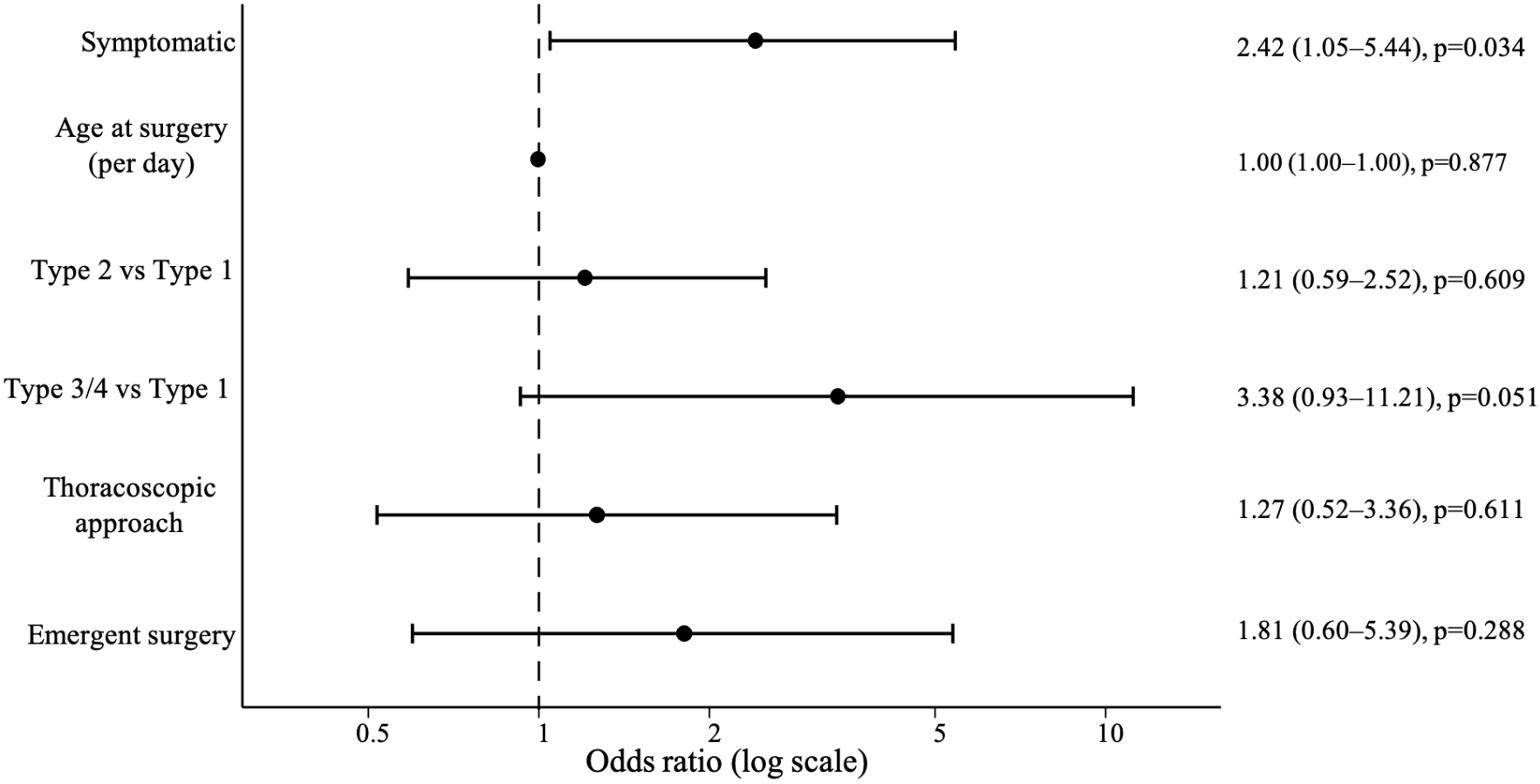

**Figure 2.** **Predicted probability of postoperative complications according to symptomatic status and surgical approach**

