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Risk factors for postoperative pulmonary complications in neonates: a retrospective cohort study

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ABSTRACT

Objective Postoperative pulmonary complications (PPCs) are an important quality indicator and are associated with significantly increased mortality in infants. The objective of this study was to identify risk factors for PPCs in neonates undergoing non-cardiothoracic surgery.

Methods In this retrospective study, all neonates who underwent non-cardiothoracic surgery in a children's hospital from October 2020 to September 2022 were included for analysis. Demographic data and perioperative variables were obtained. The primary outcome was the occurrence of PPCs. Univariate analysis and multivariable logistic regression analysis were used to investigate the effect of patient-related factors on the occurrence of PPCs.

Results Totally, 867 neonatal surgery patients met the inclusion criteria in this study, among which 35.3% (306/867) patients experienced pulmonary complications within 1 week postoperatively. The PPCs observed in this study were 51 exacerbations of pre-existing pneumonia, 198 new patchy shadows, 123 new pulmonary atelectasis, 10 new pneumothorax, and 6 new pleural effusion. Patients were divided into two groups: PPCs (n=306) and non-PPCs (n=561). The multivariate stepwise logistic regression analysis revealed five independent risk factors for PPCs: corrected gestational age (OR=0.938; 95% CI 0.890 to 0.988), preoperative pneumonia (OR=2.139; 95% CI 1.033 to 4.426), length of surgery (> 60 min) (OR=1.699; 95% CI 1.134 to 2.548), preoperative mechanical ventilation (OR=1.857; 95% CI 1.169 to 2.951), and intraoperative albumin infusion (OR=1.456; 95% CI 1.041 to 2.036) in neonates undergoing non-cardiothoracic surgery.

Conclusion Identifying risk factors for neonatal PPCs will allow for the identification of patients who are at higher risk and intervention for any modifiable risk factors identified.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Pulmonary complications are one of the most common complications after surgery and are well studied in adults and pediatrics but seldom in neonates.
⇒ There is a correlation between postoperative pulmonary complications (PPCs) and increased postoperative mortality.
⇒ There is currently no standard definition of PPCs, although they include a different range of respiratory-related complications.

WHAT THIS STUDY ADDS

⇒ Definitions of PPCs in neonates might include exacerbation of pre-existing pneumonia, new patchy shadows, new pulmonary atelectasis, new pneumothorax, or new pleural effusion.
⇒ This study identified five risk factors for PPCs in neonates: corrected gestational age, preoperative machine ventilation, preoperative pneumonia, length of surgery (>60 min), and intraoperative albumin infusion.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

⇒ Risk factors for PPCs can be identified and optimized to improve prognosis in neonates by anesthesiologists, neonatologists, and surgeons.
⇒ A standardized definition of PPCs can improve the homogeneity of related studies.

INTRODUCTIONS

Postoperative pulmonary complications (PPCs) are broadly defined as complications of surgery affecting the respiratory system.[1] PPCs are related to postoperative morbidity, mortality, longer length of hospital stay, and higher cost.[1–3] PPCs have been studied extensively in adults. The reported incidence of PPCs varies from 1% to 70% depending on the definitions, and there is high heterogeneity among surgical populations,[1 3–7] with the incidence of PPCs in abdominal and thoracic surgeries ranging from 14.5% to 70%.[3 4 8] Among patients with PPCs, the mortality was as high as 1.7%–30%,[1 3 7 8] while it was 0.2%–0.5% in patients without PPCs.

Several perioperative risk factors for PPCs have been reported, such as age, smoking, comorbidity, surgical site, length of surgery, anesthesia, and analgesia.[2 3] However, existing studies have not utilized a standard definition for PPCs; therefore, a wide range of PPCs were included in existing studies.[1] To establish consistency in reporting research outcomes, the European Perioperative Clinic Outcome taskforce and the Standardized Endpoints in Perioperative Medicine Initiative reduced the main PPCs to atelectasis, acute respiratory

distress syndrome, pneumonia, and aspiration.[9 10] However, whether this definition can be applied to pediatrics, infants or neonates has not been confirmed. Moreover, studies on pediatric respiratory complications have mainly focused on perioperative rather than perioperative period.[11–14] The incidence of unexpected respiratory complications was 3% after tonsillectomy or adenotonsillectomy.[15] Postoperative respiratory failure occurred in 1.8% infants.[16] An evaluation of postoperative complications in extremely low birthweight infants with patent ductus arteriosus found that pneumothorax and pulmonary hemorrhage were the main complications in 50% of children.[17] The risk factors and corresponding interventions of PPCs for infants or neonates are still unknown.

This retrospective study aimed to summarise the characteristics of common neonatal PPCs in a single center and to investigate the incidence of neonatal PPCs and its potential perioperative risk factors.

MATERIALS AND METHODS

Patients and data collection

The medical records of neonates who underwent non-cardiac surgery and non-thoracic surgery in our hospital between October 2020 and September 2022 were retrospectively analyzed. All non-cardiac and non-thoracic operations performed in neonates under general anesthesia were eligible for inclusion. The exclusion criteria were as follows: (1) No preoperative or postoperative chest X-ray/CT within 48 hours; (2) Missing data; (3) Reoperation related to a previous surgical complication; (4) Death within 48 hours after surgery; and (5) Needed mechanical ventilation for surgical or cardiovascular reasons within 48 hours after surgery.

Demographic data, disease category of PPCs and preoperative, intraoperative and postoperative variables were obtained. Demographic data included age, corrected gestational age, sex, body weight, and premature delivery. Preoperative variables included American Society of Anesthesiologists physical status classification system, respiratory disease, congenital heart disease, preoperative anemia (<120 g/L), preoperative severe anemia (<90 g/L), preoperative sepsis, corticosteroids, mechanical ventilation, vasoactive infusions, transfusion, acidosis (pH<7.35), hyperlactemia, hypercapnia (>50 mm Hg), prolonged prothrombin time/activated partial thromboplastin time, thrombocytopenia, and hematocrit. Intraoperative variables included endoscopy, type of surgery, site of surgery, emergency surgery, intraoperative input, albumin infusion, transfusion, urine, blood loss, acidosis (pH<7.35), hyperlactemia (lactic acid >2.0 mmol/L), hypercapnia ($PaCO_2$>50 mm Hg), anemia (<120 g/L), severe anemia (<90 g/L), hyperkalemia (>5.5 mmol/L), hypoglycemia (<2.2 mmol/L), hypotension, hypoxemia, and hypothermia. Other postoperative variables included time of mechanical ventilation, length of intensive care unit stay, length of postoperative hospital stay, long-term postoperative respiratory complications, bronchopulmonary dysplasia, pulmonary atelectasis, acute lung injury, acute kidney injury, cardiac insufficiency, acidosis (pH<7.35), hyperlactemia (lactic acid >2.0 mmol/L), severe hyperlactemia (>5.0 mmol/L), hypercapnia ($PaCO_2$>50 mm Hg), thrombocytopenia (<100×10^9/L), anemia (<120 g/L), severe anemia (<90 g/L), hypoproteinemia, surgical site infection, postoperative hemorrhage, deep venous thrombosis, transfusion in intensive care unit, unplanned intubation, unplanned surgery, and mortality within 30 days postoperatively.

The definition of PPCs

PPCs are currently not clearly defined in neonates. We referred to the definition of Jammer *et al*.[18] All the included patients were divided into two groups according to whether they had PPCs or not: the PPCs group and the non-PPCs group. As regards PPCs, these are: (1) Pneumonia, defined as at least three of the following criteria are present: new or changed sputum, new or changed lung opacities, fever, leukocyte count >12×10^9 after surgery; (2) Acute respiratory failure, defined as postoperative PaO_2<8 kPa (60 mm Hg) on room air, a PaO_2:FiO_2 ratio <40 kPa (300 mm Hg) or arterial oxyhaemoglobin saturation measured with pulse oximetry <90% and requiring oxygen therapy; (3) Pleural effusion, defined as presence of displacement of adjacent anatomical structures or (in supine position) a hazy opacity in one hemithorax with preserved vascular shadows; (4) Atelectasis, defined as presence of lung opacification with a shift of the mediastinum, hilum or hemidiaphragm towards the affected area; (5) Bronchospasm, defined as presence of newly detected expiratory wheezing treated with bronchodilators.

Statistical analysis

Data are presented as mean±SD and median (range) for normally distributed and non-normally distributed continuous variables, respectively, and counts (percentage) for categorical variables. Comparisons between the two groups were performed using the unpaired two-tailed Student's t-test or the Mann–Whitney U test for continuous variables and the χ^2 test for categorical variables. Logistic regression analysis was used to identify risk factors for PPCs. The variables with a value of p<0.01 were enrolled in this regression model. A value of p<0.05 was considered statistically significant. All the statistical analyses were performed via the IBM Statistical Package for the Social Sciences V.23.0.

RESULTS

General characteristics

The incidence of PPCs was 35.3% (306 of 867) in all neonates, which is verified by chest radiograph. These included exacerbation of pre-existing pneumonia (51 cases), new patchy shadow (198 cases), new pulmonary atelectasis (123 cases), new pneumothorax (10 cases),

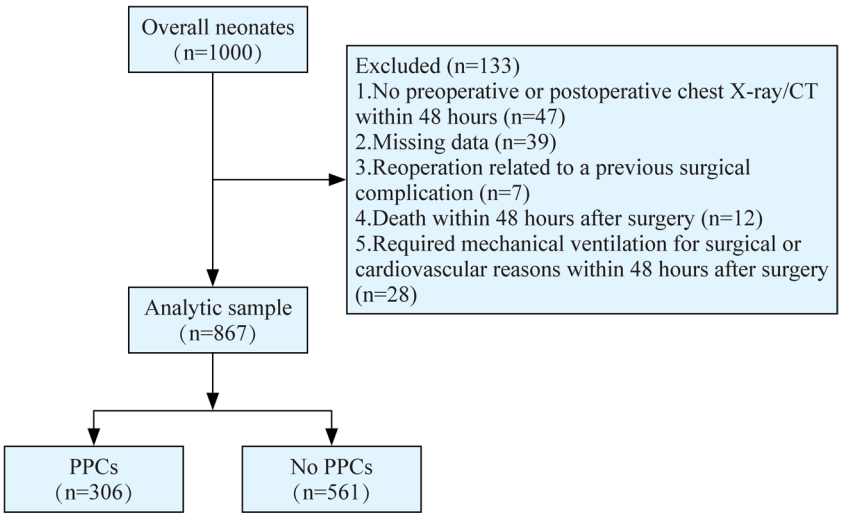

Figure 1 Strategies for enrollment and analysis. PPCs, postoperative pulmonary complications.

new pleural effusion (6 cases), and bronchospasm (0 cases) (figure 1).

Identifying risk factors for PPCs

Patients in the PPCs group had a smaller corrected gestational age (p<0.001) and weight (p<0.001) than those in the non-PPCs group (table 1). Patients in the PPCs group had a higher proportion of respiratory failure, neonatal respiratory distress syndrome, pneumonia, pulmonary surfactant performed, mechanical ventilation, and hematocrit (all p<0.01), and patents in the non-PPCs group had a higher proportion of premature delivery, oxygen inhalation, and acidosis (pH<7.35) (all p<0.01) (table 1). Lower albumin infusion, higher transfusion rate, smaller blood loss, higher incidence of acidosis (pH<7.35), hypercapnia ($PaCO_2$>50 mm Hg) and severe anemia (<90 g/L) were found in the PPCs group compared with the non-PPCs group (all p<0.05) (table 2). Mechanical ventilation, length of intensive care unit stay, length of postoperative hospital stay, bronchopulmonary dysplasia, acidosis (pH<7.35), severe hyperlactemia (>5.0 mmol/L), anemia (<120 g/L), severe anemia (<90 g/L), transfusion in the intensive care unit and unplanned intubation were all significantly different between the two groups (all p<0.01) (table 3).

Valid risk factors for PPCs

Multivariable regression analysis identified five independent risk factors, which included smaller corrected gestational age (p=0.016), use of preoperative mechanical ventilation (p=0.009), preoperative pneumonia (p=0.04), length of surgery >60 min (p=0.01), and intraoperative albumin infusion (p=0.028) (table 4).

DISCUSSION

In this retrospective study, we defined PPCs as respiratory-related complications, including new or progressed pneumonia, atelectasis, pneumothorax, and respiratory failure requiring mechanical ventilation 1 week after the operation. We found that the incidence of PPCs was 35.3% in neonates. By logistic regression analysis, five risk factors for PPCs were found, including corrected gestational age, preoperative mechanical ventilation, preoperative pneumonia, length of surgery (>60 min), and intraoperative albumin infusion.

Neonates are susceptible to PPCs because of their unique respiratory and physiological characteristics. The immature respiratory system results in irregular and periodic breathing patterns in preterm and term infants.[19] A highly compliant and compressible intrathoracic airway may lead to expiratory airway collapse.[20] Moreover, reduced pulmonary elastic recoil and closing pressure near or below functional residual capacity (FRC) results in an increased risk of FRC loss. In addition, fewer type I muscle fibers, higher wall compliance and horizontal ribs result in reduced efficiency of respiratory muscle. In particular, anesthesia and surgical interventions can easily disturb the delicate balance between closing volume and FRC, resulting in respiratory deterioration.[21] Meanwhile, mechanical ventilation and oxygen toxicity can lead to bronchopulmonary dysplasia, significant impairment of lung function, reactive airway disease, or exercise intolerance. Over time, these patients may develop asthma or chronic obstructive pulmonary disease, pulmonary vascular disease, and pulmonary hypertension.[22]

We adopted Jammer *et al*'s definition of PPCs according to the clinical experience of anesthesiologists, neonatologists, neonatal surgeons, and critical care physicians in our center.[18] In fact, pneumonia, respiratory failure, pleural effusion, and pulmonary atelectasis found in this study fulfilled this definition. However, Jammer *et al*'s definition encompassed perioperative respiratory-related events, such as bronchospasm, which did not affect prognosis and did not apply to PPCs. At the same time, bronchospasm was not detected or not observed in this study. Moreover, there were 10 cases of pneumothorax in this study, which was also associated with the respiratory system and may affect the prognosis. Therefore, it was added to

Table 1 Basic characteristics and preoperative factors in patients with and without PPCs

	PPCs (n=306)	Non-PPCs (n=561)	P value
Age, day‡	6 (2–14)	6 (2–13)	0.631
CGA, week‡	38(34–40)	39(37–41)	<0.001
Gender, male*	161 (52.6)	316 (56.3)	0.294
Weight†	2.59±0.86	2.92±0.78	<0.001
Premature delivery*	151 (49.3)	176 (31.4)	<0.001
ASA*			0.001
I	19 (6.2)	52 (9.2)	
II	223 (72.9)	445 (79.3)	
III	58 (19.0)	57 (10.2)	
≥IV	6 (2.0)	7 (1.2)	
Respiratory disease			
Respiratory failure*	67 (21.9)	59 (10.5)	<0.001
NRDS*	58 (19)	42 (7.5)	<0.001
Wet lung*	1 (0.3)	12 (2.1)	0.071
Pneumonia*	23 (7.5)	19 (3.4)	0.007
BPD*	7 (2.3)	5 (0.9)	0.168
Asphyxia*	8 (2.6)	19 (3.4)	0.531
Pneumothorax*	0 (0.0)	3 (0.5)	0.2
CHD*	218 (71.2)	389 (69.3)	0.559
ASD/PFO*	210 (68.6)	376 (67.0)	0.63
PDA*	107 (35.0)	186 (33.2)	0.59
VSD*	20 (6.5)	19 (3.4)	0.033
PAH*	50 (16.3)	79 (14.1)	0.372
Heart failure*	3 (1.0)	3 (0.5)	0.431
Preoperative anemia (<120 g/L)*	79 (25.8)	103 (18.4)	0.008
Preoperative Severe anemia (<90g/L)*	16 (5.2)	18 (3.2)	0.136
Preoperative sepsis*	13 (4.2)	17 (3.0)	0.348
Preoperative therapy			
PS*	50 (16.3)	45 (8.0)	<0.001
Corticosteroids*	8 (2.6)	9 (1.6)	0.305
Mechanical Ventilation*	87 (28.4)	68 (12.1)	<0.001
O_2 inhalation*	131 (42.8)	146 (26.0)	<0.001
Vasoactive drug*	26 (8.5)	25 (4.5)	0.016
Transfusion*	37 (12.1)	48 (8.6)	0.094
Preoperative lab			
Acidosis (pH<7.35)*	92 (30.1)	122 (21.7)	0.005
Hyperlactemia*	189 (61.8)	363 (64.7)	0.503
Hypercapnia (>50 mm Hg)*	27 (8.8)	29 (5.2)	0.033
Prolonged PT/APTT*	228 (74.5)	401 (71.5)	0.22
Thrombocytopenia*	13 (4.2)	23 (4.1)	0.931
Hematocrit†	44.15±10.68	46.66±10.19	0.001

Continued

Table 1 Continued

	PPCs (n=306)	Non-PPCs (n=561)	P value

Data are presented as n (%), mean±SD or median (range).
*Values pf p obtained by χ^2 test.
†Values of p obtained by t test.
‡Value of p obtained by Mann–Whitney U test.
ASA, American Society of Anesthesiologists; ASD/PFO, atrial septal defects/patent foramen ovale; BPD, bronchopulmonary dysplasia; CGA, corrected gestational age; CHD, congenital heart disease; NRDS, neonatal respiratory distress syndrome; PAH, pulmonary arterial hypertension; PDA, patent ductus arteriosus; PPC, postoperative pulmonary complication; PS, pulmonary surfactant; PT/APTT, prothrombin time/activated partial thromboplastin time; VSD, ventricular septal defect.

the PPCs. As mentioned, although reported definitions of PPCs were varied, all were within the range of complications of surgery affecting the respiratory system.[1] The most common PPCs included pneumonia or progression of pneumonia, atelectasis, pneumothorax, and respiratory failure in this study. Hence, these PPCs might be included as the definition in neonates.

The maturity of the respiratory system is critical in the development of PPCs. The development of respiratory control, airway tracts, pulmonary alveoli, and capillaries starts early in gestation but continues for weeks or months after term birth. It is generally accepted that lung development starts at 3–4 weeks of gestation and comprises six different stages. The alveolar stage and microvascular maturation are from 36 weeks of gestation to 2–3 years of age.[23] During these two stages, alveoli are formed by the saccules being subdivided incompletely into smaller units and subsequently undergo more restructuring known as macrovascular maturation. In this study, the subjects were all neonates with a corrected gestational age between 34 weeks and 41 weeks. Deficiency of sufficient lung function contributes to the increased incidence of PPCs.

Neonatal pneumonia is a major cause of morbidity and mortality worldwide.[24 25] The newborn lung is susceptible to bacterial and viral infections, which can inactivate existing surfactants and damage type II pneumocytes, preventing replenishment.[26] The risk factors for neonatal pneumonia include immature innate and adaptive immunity, maternal systemic infections (eg, TORCH), perinatal infections (eg, chorioamnionitis), and postnatal factors (eg, prematurity, low birth weight, length of mechanical ventilation).[26] The majority of neonates with surgical therapies may receive general anesthesia with endotracheal intubation, which increases the opportunity to damage pulmonary tracts and disseminate potential pathogens from the oropharyngeal mucosa to the lower respiratory tract. For patients with pneumonia before surgery, intubation with anesthetics may increase new bacterial or viral infections, impair mucociliary clearance of debris, and cause atelectasis, emphysema, desaturation, and pneumothorax resulting from heterogeneous ventilation and increased inflammatory cell secretions. Preoperative pneumonia was observed as a risk factor for

Table 2 Intraoperative factors in patients with and without PPCs

	PPCs (n=306)	Non-PPCs (n=561)	P value
Endoscopic*	74 (24.2)	133 (23.7)	0.875
Type of surgery, n (%)			0.937
General surgery*	263 (85.9)	477 (85.0)	
ENT*	6 (2.0)	8 (1.4)	
Urology*	4 (1.3)	10 (1.8)	
Neurosurgery*	32 (10.5)	64 (11.4)	
Other*	1 (0.3)	2 (0.4)	
Site of surgery, n (%)			0.833
Head and neck*	38 (12.4)	73 (13.0)	
Abdomen*	267 (87.3)	487 (86.8)	
Others*	1 (0.3)	1 (0.2)	
Emergency surgery*	234 (76.5)	454 (80.9)	0.121
Intraoperative input, ml†	70(50–100)	60(40–100)	0.01
ALB infusion*	133 (43.5)	159 (28.3)	<0.001
Transfusion*	70 (22.9)	86 (15.3)	0.005
Blood loss, mL†	3 (2–5)	2 (1–5)	<0.001
Urine, mL†	10(5–15)	10(5–15)	0.789
Intraoperative complications			
Acidosis (pH<7.35)*	148 (48.4)	190 (33.9)	0.001
Hyperlactemia (lac >2.0 mmol/L)*	98 (32.0)	124 (22.1)	0.015
Hypercapnia ($PaCO_2$ >50 mm Hg)*	75 (24.5)	72 (12.8)	<0.001
Anemia (<120 g/L)*	111 (36.3)	143 (25.5)	0.011
Severe anemia (<90 g/L)*	32 (10.5)	28 (5.0)	0.008
Hyperkalemia (>5.5 mmol/L)*	8 (2.6)	3 (0.5)	0.034
Hypoglycemia (<2.2 mmol/L)*	16 (5.2)	22 (3.9)	0.561
Hypotension*	108 (35.3)	162 (28.9)	0.051
Hypoxemia*	40 (13.1)	66 (11.8)	0.574
Hypothermia*	236 (77.1)	414 (73.8)	0.563

Data are presented as n (%) or mean±SD.
*Values of p obtained by χ^2 test.
†Value of p obtained by Mann–Whitney U test.
ALB, albumin; ENT, nose and throat.PPC, postoperative pulmonary complication;

PPCs in our study and should be considered in preoperative preparation but it may not always be feasible to postpone surgery in a neonate with pneumonia.

Preoperative mechanical ventilation can result from pulmonary or cardiac factors and can result in bronchopulmanary dysplasia. Regardless of the reason, ventilator-associated lung injuries cannot be avoided completely. Ventilator-associated pneumonia and ventilator-associated events should be considered.[27] The process of lung damage from mechanical ventilation is multifactorial and can be decreased by optimizing ventilation strategies.[21] For infants with bronchopulmonary dysplasia, small tidal volumes and/or inspired oxygen concentration less than 0.30 are necessary to get target: accept SpO_2 levels between 90% and 95% as well as arterial CO_2 levels of 55–65 mm Hg if a normal pH of 7.3–7.4 can be maintained.[22] Meanwhile, intrahospital transport of ventilated infants from the neonatal intensive care unit to the operating theater is associated with an increased risk of respiratory complications.[21] The operating site should be decided by anesthesiologists, neonatologists, and surgeons according to the pathophysiology at the time and equipment.

The length of surgery is an important risk factor for PPCs in neonates as well as adults.[3] In this study, surgical procedures lasting for more than 1 hour in neonates were associated with a greater risk of PPCs.[3] Surgery disturbs physiological homeostasis, contributing to systemic endocrine, inflammatory, and physiological responses, eventually resulting in an increased level of stress hormones, a promoted production of glucose and acute-phase proteins, and the release of inflammatory cytokines.[9 28 29]

Table 3 Postoperative factors in patients with and without PPCs

	PPCs (n=306)	Non-PPCs (n=561)	P value
Time of mechanical ventilation (hour)†	18.33 (9.44–46.25)	11.55 (7.19–19.72)	<0.001
Length of ICU stay (days)†	2.81 (0.92–19.90)	1.3 (0.77–3.93)	<0.001
Length of postoperative hospital stay (days)†	17.52 (10.52–38.33)	11.22 (7.23–20.81)	<0.001
Long-term postoperative respiratory complications			
BPD*	10 (3.3)	5 (0.9)	0.01
Pulmonary atelectasis*	2 (0.7)	0 (0.0)	0.124
Other postoperative complications			
ALI*	10 (3.3)	9 (1.6)	0.11
AKI*	5 (1.6)	10 (1.8)	0.845
Cardiac insufficiency*	1 (0.3)	1 (0.2)	0.803
Acidosis (pH<7.35)*	151 (49.3)	191 (34.0)	<0.001
Hyperlactemia (lac>2.0 mmol/L)*	189 (61.8)	363 (64.7)	0.503
Severe hyperlactemia (>5.0 mmol/L)*	18 (5.9)	12 (2.1)	0.005
Hypercapnia ($PaCO_2$>50 mm Hg)*	62 (20.3)	77 (13.7)	0.019
Thrombocytopenia (<100×10^9/L)*	30 (9.8)	42 (7.5)	0.333
Anemia (<120 g/L)*	121 (39.5)	143 (25.5)	<0.001
Severe anemia (<90 g/L)*	35 (11.4)	23 (4.1)	<0.001
Hypoproteinemia*	21 (6.9)	19 (3.4)	0.02
SSI*	8 (2.6)	12 (2.1)	0.656
Postoperative hemorrhage*	27 (8.8)	30 (5.3)	0.048
DVT*	3 (1.0)	7 (1.2)	0.725
Transfusion in ICU*	166 (54.2)	177 (31.)	<0.001
Unplanned intubation*	11 (3.6)	6 (1.1)	0.01
Unplanned surgery*	15 (4.9)	17 (3.0)	0.162
Mortality within postoperative 30 days*	20 (6.5)	17 (3.0)	0.015

Data are presented as n (%) or mean±SD.
*Values of p obtained by χ^2 test.
†Value of p obtained by Mann–Whitney U test.
AKI, acute kidney injury; ALI, acute lung injury; BPD, bronchopulmonary dysplasia; DVT, deep venous thrombosis; ICU, intensive care unit; PPC, postoperative pulmonary complication; SSI, surgical site infection.

These responses may last 3–5 days after surgery.[9] Hence, it is suggested that surgeons should try to perform a less ambitious and briefer procedure to reduce the incidence of PPCs, especially for high-risk neonates.

It is still controversial whether intraoperative albumin infusion is one of the risk factors for PPCs[30] in adults. However, in this study, intraoperative albumin infusion was identified as a risk factor for PPCs in neonates. Albumin can maintain oncotic pressure within the vascular compartment, bind several different endogenous and exogenous compounds as a depot and a carrier, and maintain acid–base balance as a plasma buffer.[31] Binding of compounds

Table 4 Multivariable analysis of the risk factors for perioperative pulmonary complications

	B	OR	95% CI	P value
CGA (week)	−0.064	0.938	0.890–0.988	0.016
Preoperative mechanical ventilation	0.619	1.857	1.169–2.951	0.009
Preoperative pneumonia	0.76	2.139	1.033–4.426	0.04
Length of surgery >60 min	0.53	1.699	1.134–2.548	0.01
Intraoperative ALB infusion	0.376	1.456	1.041–2.036	0.028

Values of p obtained by logistic regression ayalysis.
CGA, corrected gestational age; ALB, albumin.;

to albumin can decrease their toxicity (eg, unconjugated bilirubin) so that it is safe to use albumin in neonates.[31] Clinically, albumin is often used as a volume expander for various settings, including hypotension or hypovolemic shock, sepsis and so on.[32] Therefore, intraoperative albumin infusion may indicate unstable circulation and disturbed homeostasis. The critical systemic state may promote the occurrence of PPCs. Moreover, surgical stress and preoperative infections may lead to increased release of inflammatory factors, resulting in capillary endothelial cell damage and increased vascular permeability.[33] Infusion of albumin may increase the amount of albumin leaking into the tissue interstitium, leading to transfer intravascular liquids to the interstitium. Neonates, especially preterm infants, are not able to tolerate excessive fluid loads and are more sensitive to emergencies, making them more susceptible to vascular injury and increased vascular permeability to progressive generalized edema. Capillary leakage may promote the occurrence of PPCs.

There are still several limitations in this study. First, details of ventilation during operation are deficient. The model of ventilation selection is dependent on the site of surgery and basic lung disease, while tidal volume is adjusted by the partial pressure of carbon dioxide and changed by procedures. The fraction-inspired oxygen concentration is adjusted by the partial pressure of oxygen. For a respective study, we could not obtain complete information such as PEEP (Positive end expiratory pressure), driving pressure, tidal volume, compliance, and suction. However, an increase in driving pressure might be associated with more PPCs, which should be confirmed by more randomized controlled trials. Second, although we included a number of pulmonary complications, as a retrospective study, some were also missing, such as diaphragmatic dysfunction, bronchospasm, and pulmonary embolism. Therefore, the incidence of PPCs in this paper may be lower than the actual incidence.

Overall, PPCs might be defined as exacerbations of preexisting pneumonia, new patchy shadows, new pulmonary atelectasis, new pneumothorax, and new pleural effusion. Exploring the risk factors for PPCs might help to direct perioperative therapies to ameliorate outcomes in neonates. Optimized preoperative mechanical ventilation strategies, relief of pneumonia symptoms, reduction in surgical time, and compliance with indications for the use of albumin might help to reduce the incidence of PPCs.

Controlling the risk factors for PPCs in neonates and their effect on outcomes requires additional study.

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Patient consent for publication Not applicable.

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