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Factors associated with chest tube duration in neonatal pneumothorax requiring tube thoracostomy

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Abstract

Objectives: This study aimed to evaluate the clinical and radiologic characteristics of neonates with pneumothorax (PNX) requiring tube thoracostomy and to identify factors independently associated with chest tube duration.

Patients and Methods: In this retrospective single-center study, neonates who underwent tube thoracostomy for PNX between January 2020 and January 2026 were evaluated. Radiologic and follow-up variables, including PNX size, persistent air leak, and early lung re-expansion, were reviewed. The primary outcome was chest tube duration. Factors associated with duration were analyzed using univariable tests and a multivariable linear regression model.

Results: Fifty-eight neonates (38 males, 20 females; median gestational age: 37 weeks; interquartile range [IQR], 31-39) were included. Among 55 survivors, the median chest tube duration was six days (IQR, 4 to 12). Longer chest tube duration was associated with larger PNX size (p = 0.020), persistent air leak ≥ 72 h (16.5 *vs.* 5.0 days, $p < 0.001$), and absence of early lung re-expansion (9.0 *vs.* 5.5 days, $p = 0.033$), whereas timing of onset, mediastinal shift, and laterality were not. In multivariable analysis, only persistent air leak remained independently associated with prolonged duration, whereas PNX size and early lung re-expansion were no longer significant after adjustment.

Conclusion: Drainage duration appears to depend more on post-procedural resolution dynamics than on baseline presentation features. Persistent air leak and the absence of early lung re-expansion are best regarded as markers of unresolved PNX rather than independent determinants and may help identify infants likely to require prolonged drainage. These findings should be interpreted cautiously given the observational design.

Keywords: Chest tube duration, intensive care, neonatal, newborn, pneumothorax, thoracostomy.

Neonatal pneumothorax (PNX) remains an important cause of acute respiratory compromise in the neonatal intensive care unit (NICU), especially in infants with fragile lungs, underlying pulmonary disease, or exposure to positive-pressure ventilation.[1] It is most commonly observed during the neonatal period, most notably within the first 72 h after birth.[2] Depending on clinical and radiographic severity, management ranges from conservative follow-up to urgent pleural decompression and tube thoracostomy.[3] While the existing literature has largely addressed incidence, risk factors, and treatment approaches, less is known about the factors associated with chest tube duration once drainage has been initiated. Given that prolonged drainage may increase treatment burden and tube-related complications, defining predictors of chest tube duration may have practical value for clinical monitoring and management. Therefore, this study aimed to evaluate neonates with PNX

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treated with tube thoracostomy and to identify the factors associated with chest tube duration.

PATIENTS AND METHODS

This retrospective observational study was conducted in the NICU of University of Health Sciences, İzmir Dr. Behçet Uz Children's Diseases and Surgery Training and Research Hospital, a tertiary referral center, between January 2020 and January 2026. Infants diagnosed with neonatal PNX who required tube thoracostomy during their NICU admission were included in this study. Exclusion criteria comprised neonates managed conservatively without chest tube drainage, as well as those with esophageal atresia, congenital diaphragmatic hernia, pleural effusion, or a history of cardiac or thoracic surgery. Written informed consent was obtained from the parents and/or legal guardians of the participating patients. The study protocol was approved by the University of Health Sciences, İzmir Dr. Behçet Uz Children's Diseases and Surgery Training and Research Hospital Non-Interventional Research Ethics Committee (Date: March 12, 2026, Approval no. GOA-298, Decision no. 2026/05-16). The research was conducted in accordance with the principles outlined in the Declaration of Helsinki, and the manuscript was prepared following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Data collection and definitions

Demographic, perinatal, maternal, clinical, radiologic, treatment-related, and outcome data were extracted retrospectively from electronic medical records, bedside charts, radiographic records, and procedure notes. Recorded variables included sex, gestational age, birth weight, delivery mode, small for gestational age (SGA) status, maternal diabetes mellitus, cardiac abnormality, resuscitation at birth, intubation, surfactant therapy, postnatal age at PNX diagnosis, primary clinical diagnosis, radiographic PNX characteristics, chest tube size, suction use, tube malposition, chest tube revision, early lung re-expansion, persistent air leak, recurrence after tube removal, in-hospital mortality, and chest tube duration. Maternal diabetes mellitus included both gestational and pregestational diabetes. Maternal comorbidities other than diabetes were reviewed during chart abstraction but were not analyzed separately due to marked heterogeneity and low individual frequencies.

Small for gestational age was defined as birth weight below the 10th percentile for gestational age. Cardiac abnormality was defined as clinically relevant echocardiographic abnormalities other than isolated patent foramen ovale (PFO) and/or isolated patent ductus arteriosus (PDA), given that isolated PFO and PDA may represent physiological neonatal findings. Pneumothorax occurring within the first three postnatal days was classified as early PNX, whereas cases diagnosed after day three were classified as late PNX. Persistent air leak was defined a priori as persistent air leak lasting ≥ 72 h after chest tube placement, in line with prior PNX literature.[4] In our institutional practice, the first follow-up chest radiograph is obtained 4 to 6 h after tube thoracostomy in clinically stable neonates. Early lung re-expansion was defined as complete radiographic resolution of the PNX on this first follow-up radiograph. Tube malposition was defined as radiographic evidence of incorrect chest tube placement requiring clinical reassessment, repositioning, or revision. Chest tube revision was defined as any repeat procedural intervention involving repositioning or replacement of the tube after initial insertion. No patient required insertion of a second chest tube on the same side.

Radiologic and chest tube management

All chest radiographs obtained at the time of PNX diagnosis were reviewed retrospectively. All radiographic evaluations were performed by two independent clinicians; however, interobserver agreement was not formally quantified. Pneumothorax width was measured on anteroposterior chest radiographs as the maximal interpleural distance and recorded in millimeters for descriptive analysis. Additionally, PNX size was classified semiquantitatively on chest radiographs according to predefined criteria based on the estimated extent of pleural air and degree of lung collapse: small (< 20% of the hemithorax with minimal lung collapse), moderate (approximately 20% to 40% of the hemithorax with partial lung collapse), and large (> 40% of the hemithorax or near-total lung collapse).[5,6] Pneumothorax localization was categorized as apical, lateral, or diffuse. Laterality was recorded as right, left, or bilateral. Mediastinal shift and

subcutaneous emphysema were recorded as present or absent based on chest radiographic findings. Since retrospective radiographic size measurements based on thoracic ratios may be affected by projection, patient positioning, and mediastinal shift, semiquantitative radiographic classification was used for categorical analyses.

Chest tube size (French; Fr) and the use of negative-pressure suction were recorded. Chest tube size was excluded from comparative statistical analyses, given that size selection was primarily guided by patient weight and operator preference rather than standardized clinical criteria, and multiple tube sizes were utilized in select patients undergoing revision procedures. After chest tube insertion, a control chest radiograph was routinely obtained within the first 4 to 6 h. If a large residual PNX persisted, repeat radiographic evaluation was performed approximately 6 h later. Chest tube removal was considered after disappearance of oscillation in the drainage chamber and cessation of air leak. Once complete radiographic resolution was achieved, the tube was clamped for 12 to 24 h, and a follow-up chest radiograph was obtained. The tube was removed if no residual or recurrent PNX was present; otherwise, the clamp was released, and drainage was continued.

Patients were monitored until discharge from the NICU. Therefore, recurrence following chest tube removal was assessed only during the NICU hospitalization period, and post-discharge outcomes were not available. The primary outcome of the study was chest tube duration, defined as the number of days from tube insertion to tube removal. Since the timing of chest tube removal is partly guided by clinician-dependent decision-making, chest tube duration represents a semi-objective outcome. Three infants who died prior to chest tube removal were excluded from duration analyses. Secondary descriptive outcomes included early lung re-expansion, persistent air leak, tube malposition, chest tube revision, recurrence after tube removal, and in-hospital mortality.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as median and interquartile range (IQR), whereas categorical variables were presented as number and percentage. For analyses of factors associated with chest tube duration, nonparametric tests were used as duration data were not normally distributed. Comparisons between two groups were performed using the Mann-Whitney U test, and comparisons across three or more groups were performed using the Kruskal-Wallis test, as appropriate. The following variables were evaluated in relation to chest tube duration: timing of PNX onset (early *vs.* late), PNX size category, persistent air leak ≥ 72 h, early lung re-expansion, mediastinal shift, and PNX laterality (unilateral *vs.* bilateral). In addition, perinatal and clinical factors known to be associated with neonatal PNX were tested for association with chest tube duration, including prematurity, low birth weight, resuscitation at birth, intubation, surfactant therapy, mode of delivery, and primary diagnostic category. To assess whether the factors associated with duration were independent of one another, a multivariable linear regression model was fitted on log-transformed chest tube duration; variables associated with duration at $p < 0.10$ in univariable analysis (PNX size, persistent air leak ≥ 72 h, and early lung re-expansion) were entered into the model, and multicollinearity was assessed using variance inflation factors. Given that persistent air leak is itself an indication to maintain chest drainage and is therefore conceptually intertwined with the outcome, a sensitivity analysis was performed in which persistent air leak was excluded from the model, and the robustness of the model was further examined with a gamma generalized linear model (log link). A two-sided p-value < 0.05 was considered statistically significant.

RESULTS

Patient characteristics

A total of 58 neonates (38 males, 20 females; median gestational age: 37 weeks; IQR, 31-39) who underwent tube thoracostomy for PNX were included in the study. The median birth weight of the cohort was 2780 g (IQR 1350 to 3100). Four infants (6.9%) were classified as SGA. Most deliveries occurred by cesarean section (82.8%), whereas 17.2% were vaginal births. Cardiac abnormalities were present in 21 patients (36.2%), excluding isolated PDA and PFO. Maternal diabetes mellitus was identified in 13 cases (22.4%).

At the time of PNX diagnosis, 11 infants (19.0%) had received delivery room resuscitation, 51 (87.9%)

required endotracheal intubation, and 26 (44.8%) had received surfactant therapy. The median postnatal age at PNX diagnosis was two days (IQR 1 to 4). Pneumothorax occurred within the first three postnatal days in 41 infants (70.7%), whereas 17 (29.3%) developed PNX later. The most common underlying diagnosis was respiratory distress syndrome (34.5%), followed by transient tachypnea of the newborn (27.6%) and pneumonia/sepsis (17.2%). Seven neonates (12.1%) were referred from outside centers with a diagnosis of PNX, as shown in Table 1.

Radiologic characteristics of pneumothorax

The median maximal PNX width measured on chest radiographs was 12 mm (IQR 8 to 18). Based on radiographic assessment, PNX size was classified as small in 12 patients (20.7%), moderate in 27 (46.6%), and large in 19 (32.8%). Diffuse PNX was the most common radiologic pattern (51.7%), followed by lateral (36.2%) and apical (12.1%) localization. Pneumothorax occurred more frequently on the right side (53.4%), while 31.0% were left-sided and 15.5% were bilateral. Mediastinal shift was identified in 18 patients (31.0%), and subcutaneous

TABLE 1
Baseline demographic, perinatal, and clinical characteristics of neonates with pneumothorax requiring tube thoracostomy (n = 58)

	n	%	Median	IQR
Demographic and perinatal characteristics				
Sex				
Male	38	65.5		
Female	20	34.5		
Gestational age (weeks)			37	31-39
< 32	13	22.4		
32-36	12	20.7		
≥ 37	33	56.9		
Birth weight (g)			2780	1350-3100
Delivery				
Vaginal	10	17.2		
Cesarean	48	82.8		
Small for gestational age	4	6.9		
Cardiac abnormality	21	36.2		
Maternal diabetes mellitus	13	22.4		
Clinical characteristics at PNX diagnosis				
Resuscitation at birth	11	19.0		
Intubation	51	87.9		
Surfactant therapy	26	44.8		
Postnatal age at PNX (days)			2	1-4
Early PNX (≤ 3 days)	41	70.7		
Late PNX (> 3 days)	17	29.3		
Primary diagnosis				
• Respiratory distress syndrome	20	34.5		
• Transient tachypnea of the newborn	16	27.6		
• Meconium aspiration syndrome	1	1.7		
• Pneumonia/sepsis	10	17.2		
• Referred PNX	7	12.1		
• Other	4	6.9		

IQR, interquartile range; PNX, pneumothorax. Maternal diabetes mellitus includes both gestational and pregestational diabetes. Pneumothorax occurring within the first three postnatal days was classified as early pneumothorax; cases diagnosed after day three were classified as late pneumothorax

emphysema was observed in eight patients (13.8%), as shown in Table 2.

Chest tube management and clinical outcomes

The vast majority of pneumothoraces occurred during mechanical ventilation (96.6%). Chest tube sizes ranged from 3 Fr to 20 Fr, with 12 Fr being the most commonly used size (48.3%), followed by 10 Fr and 16 Fr (each 17.2%). Suction was applied in 29 patients (50.0%) during chest tube management.

Early lung re-expansion within the first control radiograph after tube thoracostomy was observed in 38 patients (65.5%). Tube malposition occurred in 15 patients (25.9%). Chest tube revision was required in 14 patients (24.1%); 10 patients underwent one revision, whereas two patients each required two and three revisions. No patient required insertion of a second chest tube on the same side. Persistent air leak lasting ≥ 72 h occurred in 16 patients (27.6%). Pneumothorax recurrence after chest tube removal occurred in one patient (1.7%) during NICU hospitalization. Three patients (5.2%) died during hospitalization. Chest tube duration analysis was performed in the remaining 55 survivors after

TABLE 2
Radiologic characteristics of pneumothorax in neonates (n = 58)

	n	%	Median	IQR
Maximal PNX width (mm)			12	8-18
PNX size				
Small	12	20.7		
Moderate	27	46.6		
Large	19	32.8		
PNX localization				
Apical	7	12.1		
Lateral	21	36.2		
Diffuse	30	51.7		
PNX side				
Right	31	53.4		
Left	18	31.0		
Bilateral	9	15.5		
Mediastinal shift	18	31.0		
Subcutaneous emphysema	8	13.8		

IQR, interquartile range; PNX, pneumothorax.

TABLE 3
Chest tube management and clinical outcomes

	n	%	Median	IQR
Complete early lung re-expansion (first control radiograph)	38	65.5		
Persistent air leak ≥ 72 h	16	27.6		
Suction used	29	50.0		
Tube malposition	15	25.9		
Chest tube revision required	14	24.1		
PNX recurrence after tube removal	1	1.7		
In-hospital mortality	3	5.2		
Chest tube duration, days* (n = 55)			6	4-12

IQR, interquartile range; PNX, pneumothorax. * Calculated among survivors (n = 55) after excluding three infants who died prior to chest tube removal.

excluding patients who died before tube removal. Among survivors, the median chest tube duration was six days (IQR 4 to 12), as shown in Table 3.

Factors associated with chest tube duration

In univariable analyses, chest tube duration did not differ significantly according to timing of PNX onset (p = 0.346), mediastinal shift (p = 0.163), or PNX laterality (p = 0.630). In contrast, chest tube duration differed significantly according to PNX size (p = 0.020), with longer drainage duration observed in larger pneumothoraces.

Persistent air leak was strongly associated with prolonged chest tube duration. Infants with persistent air leak ≥ 72 h had a median chest tube duration of 16.5 days (IQR 11.8 to 18.3) compared with 5.0 days (IQR 3.5 to 7.0) in those without persistent air leak (p < 0.001). Likewise, the absence of early lung re-expansion was associated with significantly longer chest tube duration. Patients without early lung re-expansion had a median duration of 9.0 days (IQR 6.0 to 17.0) compared with 5.5 days (IQR 4.0 to 8.8) among those with early re-expansion (p = 0.033), as shown in Table 4.

In addition, none of the other perinatal or clinical factors examined was significantly associated with chest tube duration, including prematurity (p = 0.162), low birth weight (p = 0.191), resuscitation at birth (p = 0.882), intubation (p = 0.694), surfactant therapy (p = 0.061), cesarean delivery (p = 0.273), and primary diagnostic category (Kruskal-Wallis p = 0.348). Mechanical ventilation was in use in nearly all infants at the time of PNX and therefore could not be compared.

In the multivariable linear regression model, only persistent air leak ≥ 72 h remained independently associated with longer chest tube

TABLE 4
Factors associated with chest tube duration (univariable and multivariable analysis)

		Chest tube duration				
	n	Median	IQR	Adjusted ratio	95% CI	p
Timing of PNX (days)						
Early (≤ 3)	38	6	5-12			
Late (> 3)	17	5	3-13			
PNX size						
Small	12	4.5	2.8-6.0			
Moderate	26	6.5	5.0-14.5			
Large	17	7.0	5.0-14.0			
Persistent air leak ≥ 72 h						
Yes	16	16.5	11.8-18.3			
No	39	5.0	3.5-7.0			
Early lung re-expansion (first control radiograph)						
Yes	38	5.5	4.0-8.8			
No	17	9.0	6.0-17.0			
Mediastinal shift						
Yes	18	8.5	5.3-13.8			
No	37	6.0	4.0-11.0			
PNX laterality						
Bilateral	7	6.0	4.5-17.0			
Unilateral	48	6.0	4.0-11.3			
Multivariable analysis						
Persistent air leak ≥ 72 h				2.75	1.92-3.95	< 0.001
PNX size				1.21	0.97-1.51	0.095
Early lung re-expansion				1.14	0.79-1.65	0.487

IQR, interquartile range; PNX, pneumothorax; CI, confidence interval. Analyses were performed in the 55 survivors after excluding three patients who died during hospitalization. Univariable group comparisons used the Mann-Whitney U test or the Kruskal-Wallis test, as appropriate. The multivariable panel shows a multivariable linear regression on log-transformed chest tube duration; the adjusted ratio is exp(β), the multiplicative change in duration. Only persistent air leak remained independently associated with duration. In a sensitivity analysis excluding persistent air leak, pneumothorax size became significant (p = 0.042) while early lung re-expansion remained non-significant (p = 0.266); all variance inflation factors were < 1.4, and results were confirmed with a gamma generalized linear model.

TABLE 5

Perinatal and clinical factors associated with neonatal pneumothorax, tested for association with chest tube duration

	Chest tube duration (days)		
Factor	Median	IQR	*p*
Prematurity (< 37 weeks)			0.162
Yes	5.0	4.0-7.0	
No	7.0	5.0-13.0	
Low birth weight (< 2500 g)			0.191
Yes	5.5	4.0-7.0	
No	7.0	4.5-13.0	
Resuscitation at birth			0.882
Yes	6.0	5.0-13.0	
No	6.0	4.0-11.8	
Intubation			0.694
Yes	6.0	4.0-12.2	
No	7.0	5.0-12.5	
Surfactant therapy			0.061
Yes	6.0	3.0-7.0	
No	8.0	5.0-13.8	
Cesarean delivery†			0.273
Yes	6.5	4.0-13.0	
No	5.0	5.0-6.0	
Primary diagnosis‡			0.348
Respiratory distress syndrome	5.0	3.0-7.0	
Transient tachypnea of the newborn	8.0	5.5-13.5	
Pneumonia/sepsis	5.5	4.8-9.5	
Referred PNX	7.5	5.0-11.2	

IQR, interquartile range; PNX, pneumothorax; †, Elective versus emergency cesarean status was not available; ‡, Compared across categories by the Kruskal-Wallis test; category frequencies are detailed in Table 1. Pneumonia and sepsis were recorded as a single combined category, and meconium aspiration syndrome (n = 1) and 'other' diagnoses were not included in this comparison. Analyses were performed in the 55 survivors after excluding three patients who died before tube removal; the frequencies (n, %) of all listed factors are reported in Table 1. Group comparisons used the Mann-Whitney U test (binary factors) or the Kruskal-Wallis test (primary diagnosis). None of these factors was significantly associated with chest tube duration.

duration (adjusted ratio 2.75, 95% confidence interval [CI]: 1.92 to 3.95; $p < 0.001$), whereas PNX size ($p = 0.095$) and early lung re-expansion ($p = 0.487$) were no longer statistically significant after adjustment. All variance inflation factors were < 1.4, and the findings were confirmed in a gamma generalized linear model. In a sensitivity analysis excluding persistent air leak, PNX size became statistically significant ($p = 0.042$), whereas early lung re-expansion remained non-significant ($p = 0.266$), as shown in Table 5.

DISCUSSION

In the present study, we evaluated the factors associated with chest tube duration in neonates with PNX requiring tube thoracostomy. Our results showed that persistent air leak ≥ 72 h was the only factor independently associated with prolonged drainage, whereas larger PNX size and absence of early lung re-expansion were associated with longer duration only in univariable analysis, and baseline perinatal risk factors were not associated with duration. These findings suggest that, once a chest tube is inserted, drainage duration is driven mainly by post-procedural resolution dynamics, and that close monitoring of air leak and the first control radiograph may help identify infants likely to require prolonged drainage.

Most published studies on neonatal PNX have focused on risk factors for occurrence, indications for drainage, or overall outcomes in heterogeneous

NICU populations.[7-9] In contrast, the present study specifically evaluated a treatment-defined subgroup of neonates who required tube thoracostomy and examined factors associated with chest tube duration, a clinically meaningful yet comparatively underexplored outcome in this setting. In this cohort, the median chest tube duration was six days among survivors, and prolonged drainage was associated with larger PNX size, persistent air leak lasting ≥ 72 h, and failure of early lung re-expansion after tube placement. By contrast, timing of onset, mediastinal shift, and laterality were not significantly associated with drainage duration. In addition, the substantial frequencies of tube malposition and revision underscore that outcomes in neonatal PNX may be shaped not only by disease severity but also by procedural factors.[9-13]

Several of the factors associated with chest tube duration in univariable analysis, such as PNX size, delayed lung re-expansion, and persistent air leak, are not independent of one another but rather represent overlapping markers of disease severity and of the dynamics of PNX resolution. This was borne out by our multivariable analysis, in which only persistent air leak remained associated with duration once the variables were considered jointly, while the apparent effects of PNX size and early re-expansion were no longer significant. Conversely, when persistent air leak was removed in a sensitivity analysis, PNX size re-emerged as significant. This pattern indicates that these variables largely capture a single underlying process, namely the severity and resolution of the air leak, rather than acting as three distinct prognostic determinants.

Persistent air leak warrants particular caution in interpretation. As persistent air leak is one of the indications to maintain the chest tube, the association between persistent air leak and longer drainage is partly inherent to the management of the condition. At the same time, chest tube duration was not determined by air leak alone: in our protocol, even after cessation of air leakage the tube was maintained until complete radiographic resolution of the PNX was confirmed and a clamping trial was passed (as described in the Methods).

Moreover, persistent air leak, defined by inspiratory bubbling in the underwater seal drainage and reflecting an underlying bronchopleural fistula, represents a distinct, measurable clinical phenomenon rather than a restatement of the outcome measure. The association between persistent air leak and chest tube duration is therefore overlapping but not fully tautological. Accordingly, persistent air leak is best understood as a marker of unresolved PNX and difficult clinical resolution rather than as a fully independent or modifiable prognostic factor. The retrospective, single-center design and the modest sample size further limit causal inference and the ability to fully adjust for confounding among these interrelated variables.

Our cohort was characterized by early presentation and a high burden of respiratory support. Pneumothorax was diagnosed at a median postnatal age of two days, 70.7% of cases occurred within the first three postnatal days, and 96.6% developed during mechanical ventilation. These findings are consistent with prior reports identifying positive-pressure respiratory support and underlying pulmonary disease as major contributors to neonatal PNX, particularly in critically ill NICU populations.[7,8,14-17]

In our series, the underlying conditions reflected this mechanism. Respiratory distress syndrome (34.5%), transient tachypnea of the newborn (27.6%), and pneumonia/sepsis (17.2%) were the leading diagnoses, followed by referred PNX (12.1%), other causes (6.9%), and meconium aspiration syndrome (1.7%). The predominance of respiratory distress syndrome, together with the high rates of intubation (87.9%) and surfactant therapy (44.8%), indicates a population with stiff, surfactant-deficient lungs exposed to positive-pressure ventilation, a combination that favors alveolar overdistension and air leak. Transient tachypnea and aspiration syndromes may similarly produce uneven alveolar compliance and gas trapping, whereas pneumonia and sepsis can impair lung mechanics and predispose to barotrauma. This heterogeneous but ventilation-dominated etiology is consistent with the pathophysiology of neonatal air-leak syndromes and indicates that, in our cohort, PNX arose predominantly in the setting of parenchymal lung disease requiring respiratory support.

Notably, in the present cohort, none of these well-recognized perinatal risk factors for the development of PNX, such as prematurity, low birth

weight, resuscitation at birth, surfactant therapy, mode of delivery, or primary diagnostic category, was associated with chest tube duration. This dissociation suggests that the factors that predispose to PNX are not necessarily the same as those that govern how long drainage is required once tube thoracostomy has been undertaken. A central finding was the association between radiographic PNX size and drainage duration in univariable analysis. Median drainage duration increased stepwise from 4.5 days in small pneumothoraces to 6.5 days in moderate and 7.0 days in large pneumothoraces. This graded relationship is biologically plausible, as a greater pleural air burden likely reflects more extensive lung collapse and a longer interval to sustained re-expansion and pleural healing. Radiographic PNX size has previously been linked to adverse outcomes in neonates.[5] Importantly, Tan et al.[10] showed that greater initial lung collapse predicted the need for chest drainage, while Halibullah et al.[11] reported that radiographic severity markers were associated with intercostal catheter insertion. Our findings extend this literature by suggesting that, among neonates already selected for tube thoracostomy, radiographic size may also relate to the likely duration of treatment, although this association was attenuated after adjustment.

By contrast, mediastinal shift was not significantly associated with chest tube duration, despite a numerically longer drainage course in affected infants. This distinction is clinically relevant, as radiographic findings associated with the initial urgency of intervention may not be the same as those determining the subsequent pace of recovery after drainage has been established. Mediastinal shift may therefore be more useful for identifying acute compromise at presentation, whereas post-procedural duration appears to depend more strongly on whether the air leak persists and whether the lung re-expands promptly.[10,18,19]

Persistent air leak demonstrated the strongest association with prolonged drainage. Infants with persistent air leak lasting ≥ 72 h had a markedly longer median chest tube duration than those without prolonged leakage (16.5 *vs.* 5.0 days). From a pathophysiologic standpoint, this is expected, as persistent alveolar-pleural or airway-pleural communication prevents definitive resolution and prolongs the need for drainage. Persistent leak likely identifies a subgroup with more severe parenchymal injury, impaired sealing, or more complex recovery dynamics.[20] As emphasized before, prolonged air leak represents one of the most challenging scenarios in neonatal PNX management.[21,22]

Failure of early lung re-expansion was another marker of longer drainage duration in univariable analysis. Infants with early re-expansion had a median chest tube duration of 5.5 days, whereas those without early re-expansion required 9.0 days of drainage. Although this variable has been less explicitly examined in the neonatal PNX literature, it is clinically intuitive and potentially useful. Delayed re-expansion may reflect persistent air leak, incomplete tube function, residual pleural air, or reduced pulmonary compliance related to the underlying lung disorder. Thus, the first post-procedural radiograph may provide not only technical confirmation but also early prognostic information, even though it did not retain independent significance after adjustment for persistent air leak. From a clinical standpoint, early identification of infants without lung re-expansion on the first radiograph may help stratify those at risk for prolonged drainage; however, whether earlier intervention strategies can modify this trajectory requires prospective investigation.

The timing of onset and laterality did not have an impact on the duration of drainage. The median duration was similar for both early- and late-onset PNX, and it was also comparable between unilateral and bilateral cases. These findings suggest that once tube thoracostomy is deemed necessary, the subsequent course is less influenced by when or where the PNX occurs. Instead, it is more affected by post-intervention factors, particularly persistent air leak and the effectiveness of early lung re-expansion.

Another notable finding was the relatively high burden of tube-related technical problems. Tube malposition occurred in 25.9% of cases, and revision was required in 24.1%. These data indicate that neonatal PNX outcomes may be shaped not only by disease severity but also by the quality and precision of procedural execution. In this regard, Reed et al.[12] demonstrated that percutaneous thoracostomy in neonates and infants carries clinically meaningful risks, while Goelz et al.[23] emphasized safe insertion depth and anatomical accuracy during neonatal

chest drain placement. Our findings support the view that procedural technique is a potentially modifiable determinant of treatment burden, repeat intervention, and possibly drainage duration. Future studies should evaluate whether standardized insertion protocols or imaging-guided placement can reduce these complications and improve outcomes.

With regard to overall outcomes, recurrence after tube removal was rare during hospitalization, and in-hospital mortality was 5.2%. These findings should be interpreted with caution, given that the cohort was restricted to infants who underwent tube thoracostomy and therefore does not represent the full spectrum of neonatal PNX managed conservatively. Reported mortality in previous studies has varied substantially according to gestational age, birth weight, respiratory severity, and NICU case mix. Cohorts enriched for very low birth weight infants or severe ventilator dependence generally report higher morbidity and mortality.[7-9,15,17,19] The low recurrence observed in our series may partly relate to the structured tube removal approach and close radiographic reassessment used in our unit, although recurrence beyond discharge was not available for analysis.

Several limitations should be acknowledged. The retrospective single-center design limits generalizability and introduces the possibility of incomplete documentation and selection bias. The sample size was modest, which may have reduced statistical power for some subgroup comparisons. Given that the cohort was restricted to infants requiring tube thoracostomy, these findings cannot be generalized to all neonatal pneumothoraces, especially those managed conservatively. Furthermore, several factors known to be associated with neonatal PNX could not be evaluated: the mode of mechanical ventilation was adjusted dynamically according to clinical course and was not consistently documented; persistent pulmonary hypertension and elective versus emergency cesarean status were not available; and infants with congenital pulmonary malformations, congenital diaphragmatic hernia, esophageal atresia, and conditions requiring thoracic or cardiac surgery were excluded by design. There was no fully standardized protocol for chest tube removal, and radiographic assessments are subject to potential measurement bias; the interrelated nature of the studied variables and the modest sample size precluded a more extensively adjusted multivariable model, and no formal inter-observer agreement analysis was performed for the radiographic assessments. The exclusion of the three patients who died before tube removal may also have introduced a degree of survivorship bias. Finally, given that persistent air leak is conceptually intertwined with chest tube duration, its association with the outcome should be interpreted as a marker of unresolved PNX rather than as evidence of an independent causal effect. Tube type and some procedural details were not fully standardized, and recurrence was assessed only during NICU hospitalization.

In conclusion, among neonates undergoing tube thoracostomy for PNX, larger PNX size, absence of complete lung re-expansion on the first control radiograph, and persistent air leak were associated with longer chest tube duration in univariable analysis, whereas early versus late neonatal onset, mediastinal shift, bilaterality, and the perinatal risk factors examined were not. These findings indicate that, after chest tube insertion, treatment duration is influenced more by post-procedural resolution dynamics than by baseline presentation features. In clinical practice, persistent air leak status and early radiographic recovery may help identify infants likely to require a more prolonged drainage course and closer follow-up; however, they should be interpreted as markers of disease course rather than definitive causal determinants. Prospective, multicenter studies with standardized management protocols are needed to validate these observations.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. Mosalli R. Clinical profile and outcome of neonatal PNX: Seven years of experience in a tertiary care center. Cureus 2023;15:e37625. doi: 10.7759/cureus.37625.
2. Aşık A, Akar S. Retrospective evaluation of cases with PNX in our neonatal intensive care unit. Northwestern Med J 2025;5:156-61.
3. Baudat-Nguyen J, Schneider J, Roth-Kleiner M, Barrielle L, Diebold P, Duvoisin G, et al. Incidence and management of neonatal pneumothorax in a 10-hospital regional perinatal network in Switzerland: A retrospective observational study. Am J Perinatol 2024;41:e3305-12. doi: 10.1055/s-0043-1777861.
4. Akamine T, Kometani T, Hashinokuchi A, Akamine S, Shikada Y, Wataya H. Interpleural distance predicts persistent air leak after initial primary spontaneous pneumothorax. J Thorac Dis 2020;12:2228-35. doi: 10.21037/jtd.2020.04.48.
5. Ozer EA, Ergin AY, Sutcuoglu S, Ozturk C, Yurtseven A. Is pneumothorax size on chest x-ray a predictor of neonatal mortality? Iran J Pediatr 2013;23:541-5.
6. Wilson PM, Rymeski B, Xu X, Hardie W. An evidence-based review of primary spontaneous pneumothorax in the adolescent population. J Am Coll Emerg Physicians Open 2021;2:e12449. doi: 10.1002/emp2.12449.
7. Aly H, Massaro A, Acun C, Ozen M. Pneumothorax in the newborn: Clinical presentation, risk factors and outcomes. J Matern Fetal Neonatal Med 2014;27:402-6. doi: 10.3109/14767058.2013.818114.
8. Duong HH, Mirea L, Shah PS, Yang J, Lee SK, Sankaran K. Pneumothorax in neonates: Trends, predictors and outcomes. J Neonatal Perinatal Med 2014;7:29-38. doi: 10.3233/NPM-1473813.
9. Madenci H, Uysal M. Risk factors associated with neonatal pneumothorax in the neonatal intensive care unit: 10 Years of experience in a single-center. Pediatr Surg Int 2024;41:46. doi: 10.1007/s00383-024-05939-y.
10. Tan YL, Zhan Y, Geng J, Chen W, Guo WL. Predictors of chest drainage of pneumothorax in neonates. Braz J Med Biol Res 2020;53:e9469. doi: 10.1590/1414-431X20209469.
11. Halibullah I, Hammond F, Hodgson K, Duffy N, Stewart M, Sett A. Management of pneumothorax in neonatal retrieval: A retrospective cohort study. Arch Dis Child Fetal Neonatal Ed 2023;108:182-7. doi: 10.1136/archdischild-2022-324352.
12. Reed RC, Waters BL, Siebert JR. Complications of percutaneous thoracostomy in neonates and infants. J Perinatol 2016;36:296-9. doi: 10.1038/jp.2015.190.
13. Wei YH, Lee CH, Cheng HN, Tsao LT, Hsiao CC. Pigtail catheters versus traditional chest tubes for pneumothoraces in premature infants treated in a neonatal intensive care unit. Pediatr Neonatol 2014;55:376-80. doi: 10.1016/j.pedneo.2014.01.002.
14. Boo NY, Cheah IG; Malaysian National Neonatal Registry. Risk factors associated with pneumothorax in Malaysian neonatal intensive care units. J Paediatr Child Health 2011;47:183-90. doi: 10.1111/j.1440-1754.2010.01944.x.
15. Klinger G, Ish-Hurwitz S, Osovsky M, Sirota L, Linder N. Risk factors for pneumothorax in very low birth weight infants. Pediatr Crit Care Med 2008;9:398-402. doi: 10.1097/PCC.0b013e31816c6e55.
16. Malek A, Afzali N, Meshkat M, Yazdi NH. Pneumothorax after mechanical ventilation in newborns. Iran J Pediatr 2011;21:45-50.
17. Nogueroles Blanco C, Herranz-Barbero A, Velilla-Aparicio M, Balcells-Esponera C, Teresa-Palacio M, Alsina Casanova M, et al. Risk factors and outcomes associated with pneumothorax in very preterm infants. Children (Basel) 2024;11:1179. doi: 10.3390/children11101179.
18. Ali K, Shahzad S, Iqbal A, Hamid N, Ahmad F, Javed S, et al. Clinical profile, risk factors and outcomes of neonatal pneumothorax at a tertiary care hospital of Bahawalpur. JHWCR 2025;3:e544. doi: 10.61919/9rj74k87.
19. Vibede L, Vibede E, Bendtsen M, Pedersen L, Ebbesen F. Neonatal pneumothorax: A descriptive regional Danish study. Neonatology 2017;111:303-8. doi: 10.1159/000453029.
20. Jeng MJ, Lee YS, Tsao PC, Soong WJ. Neonatal air leak syndrome and the role of high-frequency ventilation in its prevention. J Chin Med Assoc 2012;75:551-9. doi: 10.1016/j.jcma.2012.08.001.
21. Huseynov M, Hakalmaz AE. Neonatal pneumothorax from the perspective of a pediatric surgeon: Classification and management protocol: A preliminary algorithm. Turk J Med Sci 2021;51:1201-10. doi: 10.3906/sag-2010-286.
22. Sarkar S, Hussain N, Herson V. Fibrin glue for persistent pneumothorax in neonates. J Perinatol 2003;23:82-4. doi: 10.1038/sj.jp.7210852.
23. Goelz R, Krumrey S, Dietz K, Esser M, Poets CF. Safely inserting neonatal chest drains. Neonatology 2022;119:33-40. doi: 10.1159/000520041.