ORIGINAL ARTICLE

The evaluation of secondary pneumomediastinum in children: the experience of a pediatric surgery clinic

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ABSTRACT

BACKGROUND: Pneumomediastinum, defined as mediastinal emphysema, is the term coined for the presence of air in the mediastinum. It is a rare condition that can occur in children due to various etiologies, especially trauma, and may appear without any underlying injury. We investigated the causes of secondary pneumomediastinum and the treatment approaches in children treated at our clinic.

METHODS: We retrospectively assessed 26 patients under the age of 18 diagnosed with pneumomediastinum at our clinic between 2011 and 2023. We reviewed patient files, evalua-ting clinical data including patient history, physical characteristics, symptoms, examination findings, imaging studies, hospital stay duration, treatment methods, and complications. The necessity for advanced imaging methods, bronchoscopy, and surgical interventions was de-termined.

RESULTS: Causes of pneumomediastinum included multiple body trauma in three patients, blunt thoracic trauma in four patients, blunt trauma to the cervical region in two, crush syndrome in three, penetrating trauma to the thorax and cervical region in three, hanging from the neck in one, drowning in water in one, birth trauma in one, foreign body aspiration in six, a tracheal polyp in one, and iatrogenic causes in one. Excluding those with foreign body aspiration, computed tomography was performed on all patients. Bronchoscopy was performed in six patients, detecting tracheal lacerations in two. Of these, tracheal lacerations during bronchoscopy were identified in two patients with foreign body aspiration. Twenty-three patients received conservative management, and six patients died. Patients were categorized into two groups: complicated and uncomplicated. It was observed that stays in intensive care and wards were longer in complicated patients ($p<0.05$). However, no difference was detected in the resolution time of pneumomediastinum between complicated and uncomplicated patients ($p>0.05$).

CONCLUSION: Although pneumomediastinum is a self-limiting pathology, ventilation difficulties alongside pneumomediastinum should raise suspicion of esophageal and tracheal injuries, necessitating further investigations. Since the etiologies are very different, each patient should be evaluated separately. In most patients, pneumomediastinum regresses on its own. However, patients with complications should be carefully evaluated for accompanying diseases and injuries.

Keywords: Children; pneumomediastinum; secondary pneumomediastinum; subcutaneous emphysema; trauma.

INTRODUCTION

Pneumomediastinum (PM), also known as mediastinal emphysema, is the term used to describe the presence of air in the mediastinum. It can occur without an underlying injury and is referred to as primary spontaneous pneumomediastinum (PSPM). Secondary pneumomediastinum (ScPM) can result from blunt and penetrating trauma to the thorax and neck,

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orofacial injuries, forced respiration such as foreign body aspiration, asthma, or lung infections; or as a complication of post-tonsillectomy, mismanagement of mechanical ventilation, or post-cardiopulmonary resuscitation, among others.[1-5]

The presence of PM is explained by the Macklin effect, described as a sudden increase in pressure in the bronchioalveolar system, followed by the passage of air to the perivascular and peribronchial sheaths and then to the mediastinum depending on the alveolar-interstitium pressure gradient. Free air that has advanced into the perivascular space may migrate into the neck, upper abdomen, and skin, causing subcutaneous emphysema (SE). If free air enters the pleural and pericardial spaces, then pneumothorax (Ptx) and pneumopericardium occur.[1,6,7]

Pneumomediastinum (PM) can cause a potentially life-threatening condition; however, most cases are self-limited and benign. Symptoms include chest and neck pain, pain with swallowing, and shortness of breath.[4,5] Pneumomediastinum is traditionally recognized on chest X-rays (CXR), but nowadays, it is diagnosed more frequently due to thorax computed tomography (CT) scanning, which has become increasingly common in trauma protocols.[8] Although the first case described by Laennec in 1819 involved a four-year-old boy who was run over by a dung cart, much of the literature on children still draws on adult studies.[9] In our article, we examined the causes of ScPM and the treatment approaches in children treated in our clinic.

MATERIALS AND METHODS

Between January 01, 2011 and April 30, 2023, 26 patients under the age of 18 who were diagnosed with ScPM at Harran University Hospital were evaluated retrospectively after Local Ethics Committee approval was obtained. The patients were initially followed in the pediatric intensive care unit and subsequently in the pediatric surgery ward. The medical records of patients diagnosed with PM were reviewed, and clinical data on patient history, physical characteristics, symptoms, examination findings, serious organ injuries within and outside the thorax, and other life-threatening diseases, imaging studies, treatment modalities, length of hospital stay, and complications were investigated. Since respiratory symptoms could not be adequately standardized in our patient population, which ranged widely from infancy to adolescence, all symptoms were categorized under the name of respiratory distress and evaluated together with oxygen saturation. Low oxygen saturation (LO_2) was defined as oxygen saturation below 94% during the initial evaluation in the emergency department.[10] The confirmation of PM was made via chest X-ray and thorax CT. Patients were divided into complicated and uncomplicated cases. Patients with tracheal laceration, esophageal laceration, injury to other organs in the thorax (except Ptx), serious injuries to other parts of the body (such as intracranial hemorrhage), severe pneumonia, and serious comorbidities (such as crush syndrome) were classified as complicated.

Esophagoscopy and bronchoscopy (E/B) were performed in patients whose clinical instability continued during follow-up and in those suspected of having tracheal or esophageal lacerations based on imaging studies. An appropriately sized rigid bronchoscope with optics was used in all foreign body removal procedures and diagnostic bronchoscopies. Additionally, either rigid or flexible esophagoscopy was employed in esophagoscopy procedures.

Surgery was performed in patients in whom esophageal laceration was detected during esophagoscopy, in those with tracheal laceration detected during bronchoscopy, and in cases where the endotracheal tube could not be placed beyond the laceration line. All other patients were initially followed conservatively. In cases of accompanying organ injuries, the management protocol was determined by the relevant specialty.

Patients with PSPM, pediatric intensive care unit pneumomediastinum patients consulted for underlying lung disease (e.g., secondary to pneumonia) or while receiving ventilator therapy, and patients who developed PM after thoracic or tracheal surgery were excluded from the study group.

Statistical Analysis

Data for age, resolution times of PM, and hospitalization times were expressed as median (minimum-maximum) values. The difference between the resolution time of PM and hospitalization times of the patients was calculated with the non-parametric Mann-Whitney U test. The correlation between mortality rates and respiratory distress, LO_2, and SE was investigated by the Fisher Exact test. A value of $p<0.05$ was considered statistically significant. IBM SPSS statistics version 20.0 for Windows was used for statistical analyses.

RESULTS

Of the 26 patients with ScPM, 17 (65%) were male and 9 (35%) were female. These patients were classified according to the mechanism of injury, and their median age (minimum-maximum) is presented in Table 1. The most common etiologies were blunt trauma to the thorax and neck, thoracic trauma as part of multiple traumas, penetrating thoracic injuries, and foreign body aspirations. Other rare etiologies included drowning in water, hanging by the neck, birth trauma, or iatrogenic causes. Our youngest patient was a 1-day-old baby who developed SE, PM, and Ptx due to birth trauma caused by forceps delivery (Fig. 1A-B).

Eighteen (69%) of 26 patients had a history of trauma. While the etiology was iatrogenic in one patient (4%), a polyp was detected in the trachea during bronchoscopy in another patient (4%). Six (23%) of our patients were referred to our clinic for bronchoscopy due to the suspicion of foreign body aspiration.

Table 1. Characteristics of patients

	Gender			Mean Age*	
	Male	Female	N	Median (min-max)	
Injury Mechanism					
Multiple trauma	2	1	3	7	(4-16)
Crush syndrome	1	2	3	13	(12-16)
Blunt thoracic trauma	3	1	4	12	(8-14)
Blunt trauma to the cervical region	2	0	2	12.5	(11-14)
Penetrating thoracic trauma	2	1	3	7	(4-16)
Polyp in trachea	1	0	1	17+	
Hanging from the neck	0	1	1	15+	
Drowning in water	1	0	1	17+	
Birth trauma	0	1	1	0&,+	
Iatrogenic origin	1	0	1	7+	
Foreign body aspiration	4	2	6	2.6	(1.5-11)
	17	9	26	11	(0-17)

*Year; &1 day; +The median value could not be calculated because there was only one patient.

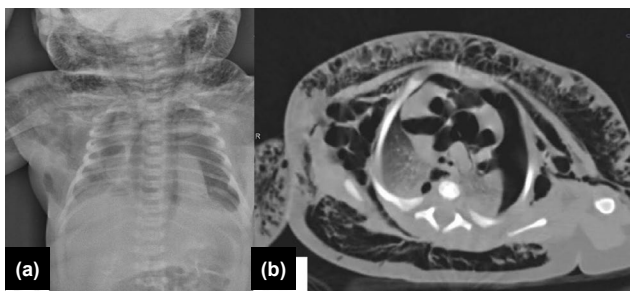

Figure 1. (a) Chest radiograph displaying subcutaneous emphysema in both the neck and thoracic regions. Additionally, there are bilateral pneumothoraces and pneumomediastinum (PM). **(b)** Computed tomography of the thorax showing subcutaneous emphysema in both the neck and thoracic regions, PM with air outlining the blood vessels and airways, and bilateral pneumothoraces.

The most common finding on inspection was respiratory distress, and the most significant physical examination finding was SE. Respiratory distress was present in 14 (54%) patients, and O_2 saturation was low in 12 (46%) patients. Various degrees of SE were detected in 19 (73%) of our patients, and a catheter was placed in 5 (26%) of these patients for SE. Tube thoracostomy was inserted in four of our patients (15%) due to Ptx.

Chest X-rays were taken in all patients, and thorax CT was performed in 21 (81%) of the 26 patients. Five patients who did not undergo thorax CT had urgent bronchoscopy due to foreign body aspiration. Tracheal laceration (Fig. 2A) was detected in three of our patients (14%) by thorax CT taken before bronchoscopic intervention.

Simultaneous E/B was performed in 5 (26%) of 19 patients with a history of trauma. While synchronous traumatic lacerations of the esophagus and trachea were detected in one patient, tracheal laceration alone was detected in two patients and esophageal laceration in one patient. In a trauma patient with severe respiratory distress and PM, the esophagus and trachea were evaluated as normal. In all three patients with tracheal laceration, the tracheal laceration had been previously detected by thorax CT (Fig. 2B). A tracheal polyp was detected during bronchoscopy in one of our patients who had no history of trauma but had severe respiratory distress and PM. Tracheal laceration was detected in two of our patients who underwent bronchoscopy due to foreign body aspiration, and esophagoscopies of these patients were normal.

Pneumomediastinum was managed conservatively in 23 of our patients. One of our patients who had esophageal and tracheal lacerations during E/B underwent thoracotomy for repair. In our two patients with only tracheal laceration, pri-

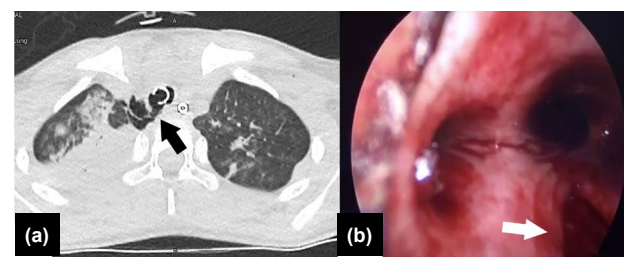

Figure 2. (a) Computed tomography of the thorax showing a ground glass appearance and consolidation in the right lung's upper lobe. Tracheal rupture and pneumomediastinum (PM) are indicated by air visible in the right paratracheal region, marked with a black arrow. **(b)** Laceration beneath the entrance of the right main bronchus, indicated with a white arrow.

Table 2. Resolution time of pneumomediastinum and hospitalization times in complicated* and uncomplicated patients

	Complicated (n=14)		Uncomplicated (n=12)			
	Median (min-max)		Median (min-max)		MNU	P
RT	3	(2-8)	4	2-7)	33	0.236
ICU	5	(1-27)	3	(2-10)	43	0.035
PSS	7	(4-30)	1	(1-3)	0.00	0.00

*Complications include head trauma, aspiration pneumonia, and other organ injuries in the thorax, etc. Abbreviations: RT: Resolution Time; ICU: Intensive Care Unit; PSS: Pediatric Surgery Service.

mary repair was performed by thoracotomy. One patient with esophageal laceration and two patients with tracheal laceration were followed up conservatively. In one of these tracheal laceration patients, the endotracheal tube was advanced beyond the laceration line and managed by mechanical ventilation; the other patient was successfully followed up conservatively as there was no separation in the laceration line under bronchoscopy.

Fourteen (54%) of our patients were evaluated as complicated and 12 (46%) as non-complicated. Of our 14 complicated patients, three had trachea and one had synchronous tracheal and esophageal injuries. One patient had only esophageal laceration. Ten of our patients had serious injuries or diseases in other body parts (such as head trauma, severe aspiration pneumonia, crush syndrome, etc.). Uncomplicated patients had trauma to the neck or thorax, and some were considered to have general body trauma with minor injuries to other body parts.

Comparing the length of stay in the intensive care unit and pediatric surgery ward between complicated and uncomplicated patients (Table 2), it was observed that complicated patients, as expected, had statistically significantly longer hospital stays ($p<0.05$). When the resolution duration of PM was evaluated (Table 2), there was no statistically significant difference between complicated and uncomplicated patients ($p>0.05$).

Respiratory distress, LO_2, Ptx, development of SE, and mortality in complicated and uncomplicated patients could not be analyzed due to the small number of cases. Consequently, Fisher's Exact test was performed by considering mortality, respiratory distress, LO_2, and SE as separate groups, but no statistically significant difference was found ($p=0.31$).

We evaluated the main factor and the cause of death together in our deceased patients in the etiology; one patient, who had a tracheal tear and PM due to hanging, died from asphyxia and aspiration pneumonia after surgical tracheal repair. Another patient who drowned in water died due to asphyxia and associated complications even though his PM resolved. In one of our patients who developed a tracheal tear due to foreign body aspiration, the diagnosis of laceration was established during bronchoscopy, and he died during the thoracotomy preparations planned after bronchoscopy before he could be clinically stabilized. In the patient with a linear tracheal tear in the carina region and an accompanying linear esophageal injury, primary repair was performed for esophageal and tracheal lesions, and a pleural flap was placed. Unfortunately, the patient died due to mediastinitis after surgical repair. One of our patients died due to complications from head trauma. Our last patient, who had a history of foreign body aspiration witnessed, was referred to our clinic with endotracheal intubation after cardiac arrest and subsequent cardiopulmonary resuscitation. No foreign body was detected during bronchoscopy, yet a 2 cm long tracheal laceration was found 2 cm proximal to the carina. The endotracheal tube was advanced beyond the tracheal laceration line, yet he died of a recent cardiac arrest while being prepared for veno-venous extracorporeal membrane oxygenation.

DISCUSSION

In our retrospective study, the most common cause of PM was blunt trauma to the neck and thorax combined, and chest or neck trauma as part of multiple traumas. Pneumomediastinum has been reported to develop in up to 10% of severe blunt cervical and thoracic traumas and may rarely be associated with potentially life-threatening tracheobronchial, esophageal, or vascular thoracic injuries.[2,4] Because children's airway structures are flexible and mobile, they are less prone to fractures, thus increasing the severity of injury. Additionally, in children with neck trauma, the high position of the larynx, relatively larger mandible, and shorter neck protect the larynx and trachea.[4]

Traumatic PM is usually a self-limiting condition. In one study, a retrospective review of 32 pediatric patients with PM secondary to blunt chest trauma was performed, and bronchial rupture was detected in only one patient who presented with respiratory distress.[2] In another multicenter study conducted to determine the rates of life-threatening tracheobronchial, esophageal, and vascular thoracic injuries in pediatric patients with traumatic PM secondary to blunt chest trauma, the rate of thoracic tracheobronchial, esophageal, or vascular injuries was found to be as low as 4.1%, which were accompanied by abnormal vital signs. However, in this study, it was stated that the patients were not classified as isolated or complicated PM

because they had other organ system injuries.[11]

It has been stated that patients who develop isolated PM after blunt thoracic trauma can be followed up without further investigation if their condition is stable. However, it is recommended that in patients with blunt thoracic trauma, one should pay close attention to dyspnea, respiratory distress, SE, Ptx, as well as neck and chest contusion on physical examination. Further investigations should be performed if there are signs of tracheobronchial injury such as PM, disseminated SE, persistent Ptx despite a tube thoracostomy.[2,12-15]

The rate of diagnosis in isolated PM is increasing with CT scanning, which is becoming increasingly common in trauma protocols. Computed tomography scan is the gold standard in the diagnosis of tracheoesophageal trauma. However, it has been reported that in the absence of abnormal vital signs, distress, or airway discomfort, CXR alone may be sufficient, and the risk of unnecessary radiation from CT may be avoided.[8,16] However, since some patients may have been exposed to high-energy trauma, routine CT scans are performed on all trauma patients in our emergency department, in accordance with the trauma protocols of our hospital's emergency clinic. Although the number of cases in our study is limited, one can speculate that three traumatic tracheal laceration cases in our study could have been detected with thorax CT before bronchoscopy.

In the literature, the value of mandatory E/B to exclude a major respiratory-digestive system injury in the evaluation of all patients with PM has been discussed. Esophagoscopy is not recommended in PSPM, and similarly, esophagoscopy is not routinely recommended in pediatric patients with PM following blunt trauma unless there are clinical or imaging findings supporting esophageal injury.[8,17] In our case series, E/B was performed in 6 of 20 patients without a history of foreign body aspiration, based on the clinical findings of the patient. Esophageal and/or tracheal lacerations were detected in four patients. This supports our argument to make patient-based judgments according to clinical findings. We believe that the indication for E/B should be decided on a patient basis.

Foreign body aspiration (FBA) is common in children and is a life-threatening emergency. Presentation ranges from cough and wheezing to recurrent pneumonia. If there is a history of obstruction accompanied by a witness, it is very valuable. In rare cases, PM, SE, or Ptx may occu.[5,18] However, tracheal and bronchial lacerations may occur during forced expiration. We detected fatal tracheal laceration as the cause of PM in two of our six cases with foreign body aspiration. For this reason, in FBA patients with PM, the trachea and main bronchi should be carefully examined for lacerations during bronchoscopy. We attempted to explain the cause of PM in our other four patients with the Macklin effect.,[4,6,7] and in these patients, PM decreased within a few days.

In this study, the small number of cases, wide age range, different etiologies, and the presence of other life-threatening organ injuries were the limiting factors. In our case series, the presence of PM in cases such as blunt trauma, foreign body aspiration, drowning in water, and tracheal polyp, where there were no other injuries, was attributed to the Macklin theory. However, tracheal laceration is also encountered in similar cases, indicating that the trachea may also rupture during forced expiration. Therefore, in the presence of severe respiratory distress, advanced imaging methods should be used and bronchoscopy should be performed.

Our case series primarily includes trauma patients treated in the pediatric surgery clinic. In our series, there was no statistically significant difference between complicated and uncomplicated patients in terms of the resolution time of PM. Long-term hospitalizations in intensive care units and pediatric surgery wards of patients complicated by esophageal/tracheal injury, other serious organ injuries (such as intracranial hemorrhage), or serious comorbidities (such as aspiration pneumonia and crush syndrome) have been observed. Additionally, mortality occurred among complicated patients. For this reason, we believe that PM per se is benign, but that morbidity and mortality result from complications of trauma.

Limitations

Different age groups from infancy to adolescence and very different etiologies were the limiting factors of our study.

CONCLUSION

In most patients, PM can usually be considered a benign complication of trauma. In complicated patients, the physician should primarily focus on the underlying cause and form a patient-based evaluation. Therefore, we believe that long hospital stays either in the intensive care unit or in the pediatric surgery ward are driven by the consequences of trauma.

Ethics Committee Approval: This study was approved by the Harran University Medical Faculty Ethics Committee (Date: 23.01.2023, Decision No: 2023/02/08).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Çocuklarda sekonder pnömomediastinumun değerlendirilmesi: Bir çocuk cerrahisi kliniğinin deneyimi

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AMAÇ: Mediastinal amfizem olarak da tanımlanan pnömomediastinum, mediastende hava varlığı için kullanılan terimdir. Çocuklarda başta travma olmak üzere farklı etiyolojilere bağlı olarak ortaya çıkabilen ve altta yatan bir yaralanma olmadan da görülebilen nadir bir durumdur. Kliniğimizde tedavi gören çocuklarda sekonder pnömomediastinumun nedenlerini ve tedavi yaklaşımını inceledik.

GEREÇ VE YÖNTEM: Kliniğimizde 2011-2023 yılları arasında pnömomediastinum tanısı alan 18 yaş altı 26 hasta retrospektif olarak değerlendirildi. Pnömomediastinum tanısı alan hastaların dosyaları değerlendirilerek hastanın öyküsü, fiziksel özellikleri, semptom ve muayene bulguları, görüntüleme çalışmaları, hastanede kalış süresi, tedavi şekli ve komplikasyonlara ilişkin klinik veriler araştırıldı. İleri görüntüleme yöntemleri, bronkoskopi ve cerrahi müdahaleye ihtiyacı belirlendi.

BULGULAR: Pnömomediastinum nedeni; hastaların 3'ünde çoklu vücut travması, 4'ünde künt toraks travması, 2'sinde servikal bölgeye künt travma, 3'ünde Crush sendromu, 3'ünde toraks ve servikal bölgeye penetran travma, 1'inde boyundan ası, 1'inde suda boğulma, 1'inde doğum travması, 6'sında yabancı cisim aspirasyonu 1'inde trakeal polip ve 1'inde ise iyatrojenik idi. Yabancı cisim aspirasyonu gelişen hastalar dışında tüm hastalara bilgisayarlı tomografi çekildi, 6 hastaya bronkoskopi yapıldı, 2 hastada trakeal laserasyon tespit edildi. Yabancı cisim aspirasyonu nedeniyle bronkoskopi yapılan 2 hastada trakeal laserasyon tespit edildi. Yirmi üç hasta konservatif olarak takip edildi ve 6 hasta kaybedildi. Hastalar komplike ve komplikasyonsuz olarak ikiye ayrıldı. Komplike hastaların yoğun bakım ve servis kalış sürelerinin daha uzun olduğu görüldü ($p<0.05$). Ancak komplike ve komplike olmayan hastalar arasında pnömodiastinumun kaybolma süresinde fark saptanmadı ($p>0.05$).

SONUÇ: Pnömomediastinum kendi kendini sınırlayan bir patoloji olmasına rağmen, pnömomediastinum ve solunum sıkıntısı olan hastalarda özofagus ve trakeal yaralanma şüphesini uyandırmalı ve ileri tetkikler yapılmalıdır. Etiyolojiler çok farklı olduğundan her hasta için ayrı değerlendirme yapılması gerekmektedir. Çoğu hastada pnömodiastinum kendi kendine geriler. Ancak komplike hastalarda hastaların eşlik eden hastalıklar ve yaralanmalar açısından dikkatle değerlendirilmesi gerekir.

Anahtar sözcükler: Çocuklar; deri altı amfizemi; pnömomediastinum; sekonder pnömomediastinum; travma.

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