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RETHINKING PRIMARY SPONTANEOUS PNEUMOTHORAX IN CHILDREN AND ADOLESCENTS: CURRENT EVIDENCE AND EVOLVING MANAGEMENT STRATEGIES

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ABSTRACT

Primary spontaneous pneumothorax (PSP) is increasingly identified in adolescents, but its management is still debated due to a lack of robust pediatric data and a reliance on adult guidelines. As a result, pediatric centers show significant differences in their approaches to diagnosis, imaging, treatment decisions, surgical timing, and follow-up care.

This review outlines the latest evidence on diagnosing and managing pediatric primary spontaneous pneumothorax (PSP). Current research favors a symptom-based diagnostic method, with chest X-rays serving as the primary imaging tool. Routine CT scans are discouraged because they expose children to unnecessary radiation, rarely change initial treatment plans, and fail to reliably predict recurrence based on radiographic blebs. Ultimately, treatment strategies should be customized based on the patient's clinical stability rather than relying solely on the size of the pneumothorax. Observation is a suitable approach for certain stable patients with small to moderate PSP. Conversely, treatments such as needle aspiration, chest tube drainage, or surgery should be utilized only for patients experiencing severe symptoms, continuous air leaks, unsuccessful lung re-expansion, or recurring pneumothorax. When surgical intervention is required, video-assisted thoracoscopic surgery is the favored method, though post-operative recurrence rates are higher in children compared to adults.

Current evidence indicates a lack of standardized follow-up procedures for pediatric patients. Therefore, follow-up care should center on the early detection of recurrences, which typically happen within the first year of the initial event. The use of routine computed tomography for follow-up is not recommended. Additionally, patient counseling needs to address smoking and vaping cessation, guidelines for resuming physical activity, postponing air travel until imaging shows complete healing, and avoiding compressed-air diving due to a lifelong recurrence risk.

Although recent progress has been made, significant knowledge gaps persist concerning the ideal selection of patients for conservative rather than surgical treatment, risk factors for recurrence, uniform follow-up protocols, and long-term results. To develop evidence-based, child-specific guidelines for diagnosing and treating primary spontaneous pneumothorax, future prospective multicenter pediatric studies are essential.

KEYWORDS

Primary Spontaneous Pneumothorax; Pediatric; Adolescent; Video-Assisted Thoracoscopic Surgery; Computed Tomography

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1. Introduction

Primary spontaneous pneumothorax (PSP) is the most frequent type of spontaneous pneumothorax seen in children and teenagers, serving as a major cause of sudden chest pain and shortness of breath in this age group [1]. While generally rare, its occurrence increases significantly during adolescence, especially among tall, slender males [2]. This leads to considerable healthcare use, including emergency room visits, hospitalizations, frequent imaging tests, and the management of repeat episodes [3]. Even though the condition is typically mild, PSP continues to pose significant diagnostic and treatment challenges due to its high recurrence rate and the lack of standardized management approaches [4].

Pediatric PSP has been researched significantly less than adult PSP. Current evidence primarily stems from small, retrospective, single-center studies, with a notable lack of prospective pediatric trials [3]. As a result, the management of pediatric cases heavily depends on data extrapolated from adults, despite key differences between the two groups regarding epidemiology, lung development, recurrence rates, and surgical approaches [5]. Multiple international surveys indicate that this shortage of child-specific research has led to substantial inconsistencies in clinical practices across different institutions and nations [4].

Over recent years, the body of evidence has advanced significantly. The release of the American Pediatric Surgical Association (APSA) systematic review delivered the first thorough synthesis of evidence tailored specifically to adolescents and young adults [3]. Furthermore, various modern cohort studies have

deepened our knowledge regarding imaging techniques, conservative treatments, chest drainage, criteria for video-assisted thoracoscopic surgery (VATS), recurrence rates, and long-term results [6]. Concurrently, growing evidence has called into question several conventional practices, such as routine pre-intervention computed tomography, early surgical intervention based merely on the radiographic presence of blebs, and extended activity limitations after recovery [3].

Given this context, an updated review focusing specifically on pediatric patients is necessary. While previous studies have primarily emphasized treatment algorithms and surgical results, little attention has been given to combining the latest evidence on diagnosis, imaging, risk assessment, treatment options, follow-up care, recurrence prevention, and patient counseling into a single, practical clinical guide.

This narrative review aims to synthesize the current evidence on diagnosing and managing primary spontaneous pneumothorax in children. It critically examines ongoing debates, evaluates different treatment options, and identifies knowledge gaps to direct future clinical research and the creation of pediatric-specific, evidence-based guidelines.

2. Methodology

This narrative review was undertaken to synthesize current evidence on the epidemiology, pathophysiology, diagnosis, and management of primary spontaneous pneumothorax (PSP) in children and adolescents. An extensive literature search was carried out using the PubMed/MEDLINE database, and the reference lists of relevant articles were also examined to locate additional eligible studies.

To accurately reflect modern clinical practice, the literature search primarily targeted articles published between 2014 and 2025. Older landmark studies and established guidelines were also included when necessary to provide historical context or support current recommendations. The search strategy utilized combinations of the following terms: *primary spontaneous pneumothorax*, *pediatric*, *children*, *adolescents*, *thoracoscopy*, *video-assisted thoracoscopic surgery*, *VATS*, *needle aspiration*, *chest tube drainage*, *conservative treatment*, *recurrence*, *follow-up*, and *guidelines*.

Eligible literature included original studies, systematic reviews, meta-analyses, consensus statements, and clinical practice guidelines published in English. While pediatric studies were the primary focus, the scarcity of high-quality pediatric evidence necessitated the inclusion of select adult studies and guidelines. These adult sources were incorporated if their recommendations are frequently applied to adolescents or if they cover areas that have not been adequately studied in children.

Studies were excluded if they focused solely on secondary spontaneous, traumatic, iatrogenic, or neonatal pneumothorax, or if they lacked adequate methodological quality or relevance to pediatric primary spontaneous pneumothorax (PSP). The final publications were chosen based on their clinical significance, methodological rigor, and contribution to the current knowledge of pediatric PSP. Due to considerable variations in study designs, patient populations, treatment strategies, and reported outcomes, the available evidence was summarized narratively.

3. Results and discussion

Definition of Primary Spontaneous Pneumothorax and Its Distinction from Secondary Spontaneous Pneumothorax

Primary spontaneous pneumothorax (PSP) occurs when air accumulates in the pleural cavity without any prior trauma, medical intervention, or known underlying lung disease [7]. This trapped air alters the natural negative pressure within the chest, causing the lung to partially or fully collapse. Although the word primary historically suggests a lack of structural lung defects, modern imaging and thoracoscopic procedures reveal that many individuals with PSP actually have subpleural blebs, bullae, or other minor pleural abnormalities [7]. As a result, PSP is now generally understood as a condition that develops in patients without a diagnosed respiratory illness, rather than in those with anatomically normal lungs [7].

Differentiating between primary (PSP) and secondary spontaneous pneumothorax (SSP) is crucial, as they vary significantly in their pathophysiology, clinical signs, treatment approaches, and overall prognosis [7]. PSP generally occurs in healthy teenagers and young adults, while SSP affects individuals with existing lung conditions that make them prone to pleural air leaks. In children, SSP is often linked to disorders such as asthma, cystic fibrosis, congenital pulmonary airway malformations, connective tissue diseases, interstitial lung disease, respiratory infections, or other chronic lung issues [3]. Identifying the specific type is vital, as pre-existing lung conditions heavily dictate the urgency of treatment and the strategy for long-term care.

Defining PSP in children and adolescents requires special attention. While pediatric patients are diagnosed using the same criteria as adults, their epidemiology, associated conditions, and treatment strategies differ significantly [3]. Furthermore, various inherited connective tissue disorders, including syndromes that compromise the lung tissue and pleura, can first appear as a spontaneous pneumothorax during youth [1]. Consequently, a thorough clinical assessment is essential to rule out underlying secondary causes before confirming a PSP diagnosis [3].

It is important to note that the dividing line between PSP and SSP is not always clear-cut. Growing evidence shows that microscopic pleural irregularities and emphysema-like alterations are frequently found even in patients with PSP [7]. This reinforces the idea that the condition exists on a spectrum of pleural disease, rather than occurring in completely healthy lungs. However, from a practical clinical standpoint, categorizing spontaneous pneumothorax as either primary or secondary remains essential, as it guides the diagnostic process, treatment choices, and prognostic assessment [7].

Clearly differentiating between PSP and SSP from the beginning is crucial for pediatric patients, as many diagnostic and treatment guidelines are still derived from adult data [3]. Using this terminology consistently makes it easier to comprehend existing research and lays the groundwork for the upcoming discussions on epidemiology, pathophysiology, diagnosis, and management.

Epidemiology

While primary spontaneous pneumothorax (PSP) is rare in young children, it becomes increasingly common during adolescence. Despite representing only a minor share of pediatric emergency room visits, its occurrence rises significantly following puberty, especially in males. This increase in frequency is likely due to rapid physical growth, hormonal shifts, and the formation of subpleural blebs in the teenage years [2].

The documented annual incidence of pediatric PSP fluctuates widely across studies due to variations in age brackets, diagnostic standards, and healthcare systems. However, most population-level research indicates a rate of roughly 3–4 per 100,000 children, which climbs to 15–18 per 100,000 adolescents. There is a distinct male majority, with a ratio of about 4–5:1. The highest rates are observed between 14 and 17 years of age, aligning with the teenage growth spurt [2].

Multiple studies indicate that hospital admissions for pediatric PSP have steadily risen over the last twenty years. However, it remains unclear whether this trend represents an actual increase in the condition's incidence or is simply the result of heightened awareness and more frequent chest imaging. Additionally, enhanced access to computed tomography (CT) has led to the greater detection of asymptomatic blebs and bullae, though their clinical importance is still debated [6].

A key epidemiological characteristic of pediatric PSP is its tendency to recur. Following an initial episode, documented recurrence rates vary from 20% to more than 50%, influenced by factors such as patient selection, treatment approaches, and the length of the follow-up period. While the majority of these relapses happen during the first year, instances of delayed recurrences occurring several years later have also been noted [8].

In general, pediatric PSP is an uncommon condition marked by specific epidemiological traits: it typically begins in adolescence, predominantly affects males, and carries a high risk of recurring.

Predisposing factors

While PSP develops in the absence of obvious underlying lung conditions, various anatomical, demographic, environmental, and genetic elements heighten a person's risk [1].

The most reliable predictor is the specific body type of the affected individuals. Young patients with PSP are generally tall, thin adolescent males, indicating that swift vertical growth leads to greater mechanical pressure at the top of the lungs. This theory is reinforced by the frequent presence of apical blebs and bullae seen during CT scans and thoracoscopy [3].

Although subpleural blebs are commonly seen in children with PSP, their precise significance is still debated. These blebs are present in both surgical patients and asymptomatic individuals, meaning their detection on a CT scan is not a dependable predictor of recurrence. Because of this, current evidence does not justify the use of routine CT scans merely to find blebs for risk assessment [9].

The role of genetic susceptibility has drawn growing interest in recent years. While the majority of pediatric cases are isolated occurrences, PSP can manifest as a component of various inherited cystic lung or connective tissue diseases. These include Birt–Hogg–Dubé syndrome, Marfan syndrome, vascular Ehlers–Danlos syndrome, Loeys–Dietz syndrome, α1-antitrypsin deficiency, tuberous sclerosis complex, and cystic fibrosis. A positive family history is present in roughly 10–12% of pediatric cases, which should trigger an

evaluation for an underlying genetic condition, especially in children presenting with recurrent, bilateral, or unusual pneumothorax [10].

Environmental factors also play a significant role in disease risk. For PSP, cigarette smoking is still the primary preventable risk factor, drastically raising the chances of both initial onset and relapse. Furthermore, new research indicates that electronic cigarette use (vaping) might similarly make adolescents more susceptible to spontaneous air-leak syndromes and prompt earlier recurrences, though the existing data is mostly confined to retrospective studies and case reports [11,12].

Recent research has explored the impact of weather-related factors, such as atmospheric pressure, temperature, humidity, and seasonal changes. However, the findings are mixed, and no specific environmental element has been definitively proven to cause pediatric PSP [13].

Overall, existing evidence indicates that pediatric PSP does not stem from a single cause. Instead, it arises from a combination of physical susceptibility, structural defects in the lung apex, genetic tendencies, and environmental influences [3].

Etiology and pathophysiology

The exact mechanisms behind pediatric PSP are not fully understood. Historically, the condition was thought to be caused by the bursting of subpleural blebs or bullae, which releases air into the pleural space. However, a growing body of evidence suggests that this process alone cannot account for every case [14].

While thoracoscopic procedures reveal apical blebs or bullae in many adolescents undergoing surgery for PSP, these lesions are also commonly found in healthy individuals who do not have pneumothorax. Conversely, some PSP patients show no evidence of blebs during surgery or on CT scans. Furthermore, multiple pediatric studies indicate that blebs identified via CT scan are unreliable at predicting recurrences, which casts doubt on them being the single underlying cause of the condition [9].

Another explanation is the pleural porosity theory, which suggests that microscopic flaws in the visceral pleura allow air to escape even without the rupture of macroscopic blebs. Tissue studies have shown evidence of elastofibrosis, chronic inflammation, mesothelial damage, and subpleural scarring, reinforcing the idea that widespread pleural defects can lead to spontaneous air leaks [15].

Mechanical forces likely have a significant impact. Because the upper sections of the lungs experience greater transpulmonary pressure than the lower sections, they are especially susceptible to structural damage. Furthermore, the rapid vertical growth that occurs during adolescence can heighten mechanical strain at the top of the lungs before the chest cavity expands proportionally. This offers a logical explanation for why the condition typically affects tall, thin teenagers [3].

Smoking and vaping can hasten these disease processes by causing airway inflammation, oxidative stress, alveolar damage, and structural changes in the distal airways. While specific mechanistic evidence for children is still lacking, clinical and experimental studies indicate that these exposures can lead to bleb formation and a higher risk of pleural air leaks [16].

The role of structural vulnerability in the visceral pleura is further highlighted by genetic conditions that weaken connective tissue. Disorders like Birt–Hogg–Dubé and Marfan syndrome feature defects within the extracellular matrix, increasing the likelihood that affected individuals will develop cysts and experience repeated episodes of pneumothorax [10].

Current evidence supports a multifactorial model where inherent vulnerability, mechanical stress, microscopic pleural defects, and environmental factors combine to cause spontaneous pleural air leaks. Instead of stemming from a single cause, pediatric PSP is now widely recognized as the end result of multiple interacting biological processes [3].

Clinical Presentation and Diagnosis

Primary spontaneous pneumothorax (PSP) typically occurs as a sudden event in children and adolescents, though its symptoms vary depending on the pneumothorax's size, the speed of pleural air buildup, and the patient's physical resilience. The majority of affected children are otherwise healthy and experience unexpected symptoms without any clear trigger. While diagnosing teenagers with classic signs is generally simple, identifying the condition may be delayed in cases involving smaller pneumothoraces or unusual symptoms, especially in younger children [3].

The defining symptom is sudden-onset ipsilateral chest pain, which is generally sharp and pleuritic, making it the most frequent initial complaint in pediatric cases. Dyspnea is the second most common symptom, varying from mild breathlessness to severe respiratory distress based on the degree of lung collapse. Less frequent signs include a dry cough, shoulder pain, and chest tightness, whereas individuals with minor pneumothoraces might feel only slight discomfort or remain almost asymptomatic [6].

Physical exam results vary widely and often do not align well with the actual size of a small pneumothorax. Children with minimal air in the pleural space might have a completely normal exam. Conversely, larger pneumothoraces typically result in decreased or missing breath sounds, lower tactile fremitus, hyperresonance when percussed, and restricted chest movement on the involved side. A rapid heart rate and accelerated breathing become more frequent as lung collapse worsens, while low blood oxygen is generally limited to severe cases. Even though a tension pneumothorax is rare in pediatric primary spontaneous pneumothorax (PSP), it is a critical emergency that demands swift identification and immediate decompression [3].

Imaging is the primary method used to establish a diagnosis. Standard posteroanterior chest radiography continues to be the preferred initial test and is adequate for confirming PSP in the majority of pediatric patients. Common radiographic signs consist of a distinct visceral pleural line, a lack of peripheral lung markings, and varying levels of lung collapse. While expiratory chest X-rays were previously advised to increase diagnostic accuracy, current data reveals minimal extra value, making routine expiratory imaging no longer recommended [17].

Computed tomography (CT) serves a more targeted purpose. Although it offers exceptional imaging of apical blebs, bullae, and underlying structural lung defects, its routine application during the initial assessment of uncomplicated PSP is not recommended. Rather, CT should be limited to specific cases, such as patients experiencing recurrent or bilateral pneumothorax, continuous air leaks, suspected secondary spontaneous pneumothorax, or unusual clinical and radiological signs. This cautious approach is especially vital for children due to the risks of cumulative radiation exposure, and because numerous pediatric studies demonstrate that blebs identified via CT do not accurately predict the initial onset or future recurrences [9].

In addition to verifying the presence of pleural air, diagnostic imaging should assist in detecting underlying conditions in pediatric patients. Further investigation for congenital lung anomalies, diffuse cystic lung diseases, connective tissue disorders, or genetic syndromes is necessary for younger children, those experiencing bilateral or recurrent pneumothoraces, and individuals with atypical imaging results. Recognizing these underlying issues is crucial, as it changes the diagnosis to a secondary spontaneous pneumothorax, which significantly impacts future treatment and ongoing monitoring [3].

In children, the differential diagnosis for acute chest pain and shortness of breath is extensive, encompassing musculoskeletal issues, pneumonia, asthma exacerbations, pulmonary embolism, cardiac conditions, and, more rarely, congenital or neoplastic lung diseases. Although sudden pleuritic chest pain combined with dyspnea strongly indicates primary spontaneous pneumothorax (PSP), clinicians should not automatically assume an uncomplicated primary condition. Any persistent or recurring pneumothorax, abnormal imaging results, or unusual clinical progression warrants further investigation to identify potential underlying causes [3].

Overall, diagnosing pediatric PSP depends heavily on a thorough clinical evaluation and chest X-rays, reserving CT scans for specific cases where the results will alter the treatment approach. Furthermore, it is crucial to identify children whose recurrent, bilateral, or unusual symptoms might indicate an underlying genetic or pulmonary condition, as these patients require a more comprehensive diagnostic investigation before a final treatment plan is established [3].

Management of Primary Spontaneous Pneumothorax

Initial Assessment and Therapeutic Decision-Making

Over the past decade, the treatment of primary spontaneous pneumothorax (PSP) in children and teenagers has changed significantly. However, unlike adult care, pediatric practices remain highly inconsistent due to a lack of prospective research and an ongoing dependence on retrospective data. While multiple medical organizations have developed treatment guidelines, current recommendations are primarily based on expert opinion, clinical experience, and data adapted from adult studies, rather than rigorous pediatric clinical trials [3].

Evaluating hemodynamic and respiratory stability is the initial step in clinical decision-making. Individuals experiencing respiratory distress, severe hypoxemia, hemodynamic instability, or indications of a tension pneumothorax need prompt pleural decompression, and treatment should not be delayed for additional testing. Conversely, clinically stable patients can be managed more conservatively. Their care is customized based on symptom severity, imaging results, and the probability of natural resolution [3].

Treatment choices must also consider various clinical factors, such as whether the episode is an initial occurrence or a recurrence, the presence of a continuous air leak, bilateral pneumothorax, the failure of the lung to re-expand after pleural drainage, and any suspicion of underlying lung disease indicating secondary spontaneous pneumothorax. Additionally, the selected therapy may be guided by the patient's age, existing health conditions, access to pediatric surgical specialists, and family preferences [6].

Over recent years, there has been a significant shift away from relying on radiographic size as the primary factor for guiding treatment. While the size of a pneumothorax remains a key part of the initial evaluation, growing evidence indicates that the severity of symptoms is a better predictor of the need for intervention than X-ray measurements alone. This approach is now standard in current adult guidelines and is increasingly being adopted in pediatric reviews and expert advice, even though pediatric evidence remains limited [3].

Although there is increasing consensus on these broad principles, significant differences remain across pediatric centers. Surveys indicate that pediatric surgeons vary widely in their preferred initial treatments, surgical indications, and perioperative care, underscoring the lack of a standardized treatment protocol. This inconsistency stems from differing institutional practices as well as ongoing uncertainty caused by a shortage of randomized pediatric trials [4].

Overall, current evidence supports a personalized treatment approach based on the patient's symptoms, physical stability, imaging results, and risk of recurrence. Instead of relying on a single treatment method, modern pediatric care focuses on choosing the least invasive option to safely re-expand the lung. More intensive interventions are reserved for patients experiencing ongoing air leaks, repeated episodes, or a declining clinical condition [3].

Conservative Management

Conservative care is becoming increasingly accepted as the first line of treatment for specific children and adolescents experiencing primary spontaneous pneumothorax (PSP). This trend highlights a shift away from automatic medical interventions toward a patient-focused strategy that prioritizes clinical stability over the size of the pneumothorax on an X-ray. Even though the evidence backing this non-invasive approach is not as strong in pediatric cases as it is for adults, current reviews and expert guidelines agree that simple observation is a suitable initial choice for stable patients who have mild symptoms and no breathing difficulties [3].

Conservative management typically involves careful clinical monitoring, effective pain control, and repeated chest X-rays to track whether the pneumothorax worsens or heals on its own. While supplemental oxygen has historically been used to speed up the absorption of pleural air by altering the nitrogen diffusion gradient, its actual clinical value is unclear, especially for patients with normal oxygen levels. As a result, modern medical practice prefers administering oxygen only when specifically indicated rather than as a routine measure [3].

The main benefit of conservative management is preventing complications linked to pleural procedures. While inserting a chest drain is usually safe, it can cause pain, bleeding, infection, extended hospital stays, and significant patient distress. Therefore, it is especially important to avoid unnecessary invasive procedures in children when a safe, spontaneous recovery is expected [3].

There is growing evidence to support this approach. Spezzotto et al. reported shorter hospitalization in carefully selected pediatric patients managed without pleural intervention, while recurrence rates did not differ significantly from those observed after chest drainage [18]. Likewise, Zarfati et al. showed that asymptomatic or mildly symptomatic patients who were initially managed conservatively had positive short-term results and recurrence rates similar to those undergoing more invasive procedures [6].

Proper patient selection remains crucial. Observation is typically suitable only for hemodynamically stable individuals who do not exhibit severe respiratory distress, worsening symptoms, or radiological evidence of tension physiology. If the patient's clinical condition declines, the pneumothorax expands during monitoring, the lung fails to naturally re-expand, or a continuous air leak develops, treatment must be escalated. Although the exact criteria for a persistent air leak differ across studies, numerous pediatric hospitals advise seeking surgical consultation after 3 to 5 days of an ongoing leak, closely aligning with adult guidelines [3].

The primary drawback of conservative management is the ongoing risk of relapse. Meta-analyses consistently show that surgical intervention results in fewer recurrences than non-surgical approaches. For example, Miscia et al. noted a recurrence rate of roughly 32% following conservative care compared to 18% after surgery, while Hung et al. also found a substantially decreased risk of recurrence with operative treatment [19]. However, these comparisons must be evaluated carefully. Since surgery is usually reserved for patients presenting with persistent air leaks, recurring episodes, or greater disease severity, retrospective analyses are prone to considerable selection bias [3].

Crucially, the reduced risk of recurrence following surgery does not warrant making operations the standard treatment for a first episode of PSP. Multiple pediatric studies have shown no significant difference in long-term recurrence rates regardless of the initial treatment method. Furthermore, experts estimate that performing surgery after every initial episode would subject many children to unnecessary procedures.

Therefore, current pediatric guidelines support a step-by-step, personalized approach. Conservative care remains the preferred initial choice for eligible patients, with surgical interventions reserved for specific, clear indications [3].

Recent studies reveal a notable gap between scientific evidence and routine clinical practice. While current reviews increasingly advocate for observing stable patients, surveys show that pediatric surgeons at many institutions still favor chest tube drainage as the primary intervention, with needle aspiration remaining uncommon. This inconsistency highlights the continued lack of consensus on the best management strategy and emphasizes the necessity for further prospective pediatric studies [3].

Pleural Interventions

Present evidence indicates that conservative treatment is a safe and effective initial approach for appropriately chosen children facing their first episode of PSP. However, since the existing data is primarily retrospective and prone to selection bias, rigorous multicenter prospective studies are needed to improve patient selection and create uniform guidelines for escalating therapy [3].

Pleural intervention is required when conservative management is no longer viable due to severe symptoms, a worsening pneumothorax, or a lack of spontaneous healing. While treatment options include needle aspiration and tube thoracostomy, their application differs significantly among pediatric facilities. This inconsistency is due to a shortage of randomized pediatric trials and an ongoing dependence on guidelines designed for adults [3].

Recent evidence increasingly supports a tailored, symptom-driven strategy rather than relying strictly on radiographic measurements to dictate intervention. The latest APSA systematic review advises that treatment choices should be based primarily on clinical stability, respiratory symptoms, and general health, rather than the exact size of the pneumothorax. Recent pediatric cohort studies echo these findings, demonstrating that even sizable pneumothoraces can be safely managed without immediate pleural drainage in stable, carefully chosen patients [3].

Needle aspiration

As the least invasive pleural procedure, needle aspiration is now recognized as the primary drainage method in multiple modern adult guidelines, including the Joint European Respiratory Society (ERS), European Association for Cardio-Thoracic Surgery (EACTS), and European Society of Thoracic Surgeons (ESTS) clinical practice guidelines on adults with spontaneous pneumothorax (ERS/EACTS/ESTS recommendations). Randomized trials and meta-analyses in adults indicate that it provides immediate success and recurrence rates similar to those of tube thoracostomy, while also decreasing hospital length of stay, procedural discomfort, and treatment-associated complications [7].

Although the results are promising, its application in pediatric medicine remains restricted. Surveys across North America, Europe, and Turkey indicate that needle aspiration is utilized as the primary treatment in less than 5% of initial occurrences, while various adolescent studies also note infrequent use. This low rate of adoption is likely driven by a shortage of pediatric-specific data, apprehensions about technical success, and a general preference for chest tube drainage, rather than actual evidence showing aspiration to be less effective [1].

Chest tube drainage

Consequently, tube thoracostomy continues to be the most frequent pleural procedure for children with PSP. Recent surveys show that 57–76% of pediatric surgeons choose chest drainage as their initial invasive approach, especially for patients with large pneumothoraces, breathing difficulties, or those who do not improve with conservative observation [4].

Chest drainage continuously removes pleural air and allows for the monitoring of active air leaks, which is especially beneficial for patients with incomplete lung expansion or a persistent alveolar-pleural fistula. However, when compared to simple observation or needle aspiration, these benefits are offset by increased patient discomfort, extended hospital stays, potential procedural complications, and higher healthcare costs [3].

It is notable that clinical practice still depends heavily on radiographic measurements. While modern pediatric guidelines increasingly recommend basing decisions on patient symptoms, many surgeons continue to view a pleural distance greater than 2 cm as a primary reason for chest tube placement. This inconsistency highlights the ongoing divide between new medical evidence and standard clinical routines [4].

Transition to operative management

Pleural drainage should be considered a single step in a progressive treatment plan rather than the ultimate objective. If the lung fails to re-expand, an air leak continues for about 3 to 5 days, an ipsilateral pneumothorax recurs, bilateral disease is present, or the patient's condition worsens despite drainage, surgical options should be explored. Consequently, for many patients, chest tube placement acts either as the final treatment or as a transitional step toward video-assisted thoracoscopic surgery (VATS) [3].

Pleural interventions should be viewed as components of a progressive treatment plan rather than standalone procedures. The transition from observation to pleural drainage is largely determined by the patient's clinical progress; however, ongoing inconsistencies across pediatric centers highlight the need for future studies to establish clear, evidence-based guidelines for intervening in children and adolescents [4].

Role of Video-Assisted Thoracoscopic Surgery (VATS)

Video-assisted thoracoscopic surgery (VATS) is now the primary surgical method for treating pediatric primary spontaneous pneumothorax (PSP). It has largely taken the place of open thoracotomy due to its minimally invasive approach, quicker recovery times, and positive long-term results. While surgery is only recommended for specific patients, VATS is considered the standard procedure when operative intervention is required [3].

Why VATS?

The extensive use of VATS is due to its numerous benefits compared to a traditional thoracotomy. Thoracoscopic surgery offers a clear view of the pleural cavity while simultaneously reducing tissue trauma, post-operative pain, hospital stays, and scarring—which is especially important for adolescents [20].

Consequently, the APSA systematic review and current pediatric research advise using VATS for persistent air leaks, recurrent ipsilateral pneumothorax, failed lung re-expansion, and specific cases of bilateral disease. Furthermore, surveys from North America, Europe, and Turkey indicate that VATS is now the preferred surgical method when an operation is necessary [3].

Operative technique

Despite technical variations across different facilities, modern VATS adheres to a fundamental approach: the thoracoscopic detection and stapled removal of apical blebs or bullae, accompanied by a pleural procedure designed to minimize the risk of recurrence [3].

Various techniques have been documented, including mechanical pleurodesis, pleural abrasion, partial pleurectomy, and, less frequently, chemical pleurodesis. Since no single method has proven definitively superior, significant practice variations remain among pediatric centers. Although prospective comparative data in children are still needed, current retrospective studies indicate that combining a blebectomy with a pleural procedure prevents recurrence more effectively than a bleb resection alone [21].

Clinical outcomes

Pediatric studies consistently show that VATS is a safe and effective method, successfully re-expanding the lung in over 90% of cases with low postoperative complication rates. Additionally, recurrence rates typically fall between 5% and 12%, which is significantly lower than those seen following conservative management [20].

For instance, Saraç et al. demonstrated a success rate of over 94% in patients who underwent thoracoscopic wedge resection combined with mechanical pleurodesis, noting only two postoperative recurrences. Likewise, Pogorelić et al. found that video-assisted thoracoscopic surgery (VATS) resulted in a lower recurrence rate compared to non-surgical management, despite being linked to a longer initial hospitalization [22].

It is significant to note that surgery does not entirely prevent recurrence. Extensive pediatric studies show a postoperative recurrence rate of nearly 10%, with younger age and extended postoperative air leaks serving as reliable predictors of failure. These results indicate that recurrences are driven not solely by surgical technique, but also by the inherent biological tendencies that cause PSP [23].

Timing of surgery

Although VATS is widely accepted, the ideal timing for surgical intervention is still debated. Rather than advising surgery after the initial occurrence, the majority of pediatric surgeons reserve operative treatment for cases involving a persistent air leak or recurrent ipsilateral pneumothorax [3].

This approach is backed by evidence indicating that many children do not suffer a recurrence following their first PSP. As a result, performing routine primary surgery would subject a large number of patients to needless operations. However, various multicenter studies indicate that carefully chosen early VATS can decrease hospital readmissions and overall healthcare usage [24].

Overall, current evidence favors a personalized approach where the decision to perform surgery is based on the patient's clinical progress, ongoing air leaks, and the likelihood of recurrence, rather than relying solely on the initial episode [3].

Follow-up assessment

At present, there are no validated international guidelines for pediatric PSP follow-up. As a result, follow-up care is individualized, relying primarily on APSA recommendations, institutional practices, and adaptations from adult guidelines instead of standardized pediatric protocols [3].

The main goal of follow-up care is to detect recurrences early, especially within the first year following the initial event, which is when most relapses happen. Patients treated conservatively should be evaluated for ongoing symptoms and complete radiographic healing. In contrast, postoperative follow-up focuses on tracking recovery from VATS and identifying any recurrent pneumothorax on the same or opposite side [25].

Routine CT monitoring is not advised. An APSA systematic review found no evidence to justify cross-sectional imaging during follow-up care, and pediatric studies consistently show that blebs identified on CT scans are unreliable predictors of recurrence or the need for future surgery. Consequently, CT imaging should be restricted to specific cases involving recurrent pneumothorax, ongoing air leaks, or continuing diagnostic uncertainty [3].

Surveys from North America, Europe, and Turkey highlight a lack of uniform follow-up guidelines, revealing significant differences in outpatient evaluations, imaging protocols, and reasons for reassessment. Consequently, current follow-up methods prioritize monitoring for recurrence over following a strict outpatient schedule [4].

Activity counselling after recovery

After recovering from PSP, patients and their families often seek guidance on resuming daily activities and minimizing the risk of recurrence. Although specific guidelines for children are scarce, current evidence consistently focuses on four key areas: air travel, compressed-air diving, quitting smoking and vaping, and returning to physical activity. The most robust evidence supports smoking cessation and the avoidance of scuba diving, while advice on sports participation relies primarily on expert consensus and practices adapted from adult care [26,27,7].

Air travel

Commercial flights are generally safe once medical imaging confirms complete healing. However, because changes in cabin pressure can cause lingering pleural air to expand, non-essential travel should be delayed until complete radiographic resolution of the pneumothorax has been confirmed, followed by an additional waiting period of at least 7 days [28,7].

Since no pediatric studies have defined a specific waiting period, current guidelines are based on adult recommendations. Notably, the presence of apical blebs or bullae alone does not restrict commercial air travel as long as there is no active pneumothorax. Because recurrences happen most frequently within the first year, patients should be advised to seek immediate medical care if they experience chest pain or shortness of breath during or after a flight [28,29].

Diving

Conversely, compressed-air diving is generally advised against following a PSP, as a recurrence during the ascent can quickly escalate into a life-threatening tension pneumothorax [27,7].

While pediatric data is limited, systematic reviews in adults consistently show recurrence rates high enough to warrant a permanent ban from recreational scuba diving. Although surgical intervention significantly lowers this risk, it does not completely eliminate it, and late recurrences have been documented even years after a VATS pleurectomy [27,30].

As a result, standard medical clearance for diving is not advised. In rare cases, exceptions may be considered following definitive bilateral surgery, a normal high-resolution CT scan, and normal pulmonary function tests, but only after an evaluation by specialists in thoracic surgery and diving medicine [27,7].

Smoking and vaping

Quitting smoking is one of the few adjustable behaviors linked to a decreased chance of recurrence. Cigarette smoking serves as the most significant proven risk factor for PSP, and continuing to smoke after an initial episode seems to heighten the likelihood of another occurrence. Furthermore, a systematic review showed that patients who successfully quit smoking experienced roughly a four-fold decrease in recurrence rates [26].

There is growing focus on the use of electronic cigarettes, particularly among adolescents. Although evidence is still emerging, vaping has been linked to spontaneous pneumothorax, pneumomediastinum,

quicker relapses, and more complex clinical outcomes. Potential mechanisms for this include inflammatory damage to the alveoli, the development of blebs, and the repetitive Valsalva-like actions performed during inhalation [11,12].

Therefore, patients recovering from PSP should be advised to completely avoid both traditional and electronic cigarettes [26,11].

Return to sports

Evidence regarding return to sports remains limited. No pediatric guideline defines a standardized interval before resuming athletic activity, and available studies do not demonstrate that sports participation itself increases recurrence risk after complete recovery [31,7].

Current practice advises a gradual resumption of physical activity once complete clinical and radiographic recovery is achieved, while avoiding heavy exertion during the initial healing phase. Typically, contact sports and high-impact activities are only reintroduced after a medical evaluation verifies the complete resolution of symptoms and full lung re-expansion. Since current guidelines rely mostly on expert consensus, decisions regarding a return to sports must be tailored to each patient, taking into account the severity of the disease, the specific treatments used, and any prior recurrences [31,7].

Knowledge gaps and future directions

While research on pediatric primary spontaneous pneumothorax (PSP) is expanding, the available evidence is still significantly weaker than what exists for adults. Current guidelines largely depend on single-center retrospective studies, institutional practices, and adaptations from adult protocols, which leads to considerable inconsistencies in patient care. Even with notable progress over the last ten years, many elements of managing pediatric PSP are still not clearly established [32,3].

A primary drawback is the shortage of high-quality prospective studies focused on pediatric patients. There are virtually no randomized controlled trials evaluating conservative care, needle aspiration, chest tube drainage, or early surgical intervention in children and teenagers. As a result, the comparative advantages of various treatments are mostly deduced from retrospective studies that feature inconsistent participant criteria, treatment methods, and outcome evaluations. Therefore, well-structured, multicenter prospective research is crucial to developing evidence-based care guidelines tailored specifically for children [19,32,3].

A significant gap is the lack of specific clinical practice guidelines for pediatric patients. While the 2023 APSA systematic review offers the most thorough collection of pediatric data currently available, it is not an official guideline and provides few recommendations for long-term follow-up, outpatient monitoring, or activity counseling. Consequently, the majority of medical centers continue to modify adult guidelines from the British Thoracic Society (BTS), ERS/EACTS/ESTS, or older American College of Chest Physicians (ACCP) standards, despite the crucial physiological and epidemiological distinctions between adolescents and adults [32,3].

Uncertainties also persist regarding surgical treatment. Even though persistent air leaks and recurrent pneumothorax are commonly agreed-upon reasons for VATS, the ideal timing for an operation following the initial episode is still unclear. Furthermore, because comparative pediatric studies are rare and lack sufficient statistical power, the relative efficacy of pleurectomy, pleural abrasion, mechanical or chemical pleurodesis, and limited wedge resection remains undetermined [3,19,33].

Further research is required to fully understand the role of imaging. Current data does not support the routine use of CT scans for initial or follow-up assessments, as blebs and bullae offer little predictive value for recurrence. However, the frequent use of CT in everyday clinical practice highlights a clear need for proven, imaging-based risk assessment tools. In the future, emerging methods like quantitative CT analysis and AI-assisted image interpretation could enhance personalized risk prediction while reducing unnecessary radiation exposure [19,3].

Accurately predicting recurrence continues to be a significant unmet need. While factors such as younger age, ongoing air leaks, partial lung re-expansion, smoking, and extended postoperative air leakage are linked to relapse, there is currently no proven prediction model for pediatric patients. Dependable risk assessment tools would help customize treatment plans, identify the patients who would gain the most from early surgical intervention, and minimize both overtreatment and unneeded procedures [3,29].

Going forward, research should prioritize patient-reported outcomes and overall quality of life. While most pediatric studies concentrate on recurrence rates, length of hospital stays, and surgical success, very little is known about the psychosocial impacts of PSP. This includes returning to school and sports, anxiety regarding recurrence, and long-term health-related quality of life. These factors are particularly crucial during

adolescence, a time when recurrent pneumothorax can significantly disrupt physical, educational, and social growth [3].

Advancing the management of pediatric PSP relies on prospective multicenter research, uniform outcome reporting, validated risk prediction models for children, and the establishment of specific international clinical guidelines. These combined initiatives will help minimize variations in current practices and promote reliable, evidence-based care for children and adolescents affected by PSP [32,3].

4. Conclusions

Primary spontaneous pneumothorax (PSP) in children and teenagers is a rare but increasingly identified condition, and its treatment has shifted significantly over the last ten years. Emerging pediatric research has questioned the standard use of invasive procedures, favoring a personalized strategy that prioritizes a patient's clinical stability and symptoms over X-ray findings. However, significant diagnostic and treatment difficulties persist, largely because most existing data is retrospective and many guidelines are still adapted from adult studies [32,3].

Current evidence supports conservative management as a reasonable initial approach for clinically stable patients, particularly when symptoms are mild and there is no evidence of respiratory compromise. Invasive treatments should be reserved for individuals experiencing severe symptoms, ongoing pneumothorax, breathing difficulties, or a lack of lung re-expansion. While needle aspiration is an effective first-line option for suitable patients, it is currently underused in pediatric care. Chest tube drainage remains an important treatment option for larger or symptomatic pneumothoraces, particularly when observation or less invasive approaches are unlikely to provide adequate lung re-expansion. Furthermore, video-assisted thoracoscopic surgery (VATS) is generally considered the preferred surgical approach for recurrent pneumothorax, continuous air leaks, or unsuccessful conservative treatments, rather than a routine procedure for a first episode [3,7].

Care continues well after the initial incident. Follow-up appointments should mainly aim to identify any recurrence, which usually happens within the first year but can still occur years post-surgery. Current evidence does not support the use of regular CT scans; rather, it highlights the importance of thorough clinical evaluations and targeted imaging for patients showing signs of a relapse or an ongoing air leak. Additionally, long-term management must involve clear guidance on flying, avoiding scuba diving, quitting smoking and vaping, and a personalized plan for resuming physical activities [29,28,27,26].

In summary, the treatment of pediatric PSP has transitioned toward a more conservative, patient-focused approach, while still maintaining prompt surgical options for specific cases. Ongoing efforts to expand pediatric research and standardize medical practices will be vital to improve results, decrease unneeded procedures, and deliver reliable, evidence-based care to children and adolescents experiencing primary spontaneous pneumothorax [3,32].

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