

High Resolution CT following Primary Spontaneous Pneumothorax in Adolescents:
Useful tool or wasted radiation?

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CT utility for Primary Spontaneous Pneumothorax

Background

The current trend in management of first-time primary spontaneous pneumothorax (PSP) in children is to obtain a high-resolution chest computerized tomography (HRCT) scan to look for bleb/bullae disease or other structural lung disease. We aimed to evaluate the significance of HRCT findings in relation to initial management strategies, and we hypothesized that these findings do not guide management.

Methods

We evaluated patients with first time PSP in a single-institution, retrospective, longitudinal study. The primary endpoint was the percentage of patients who underwent surgical intervention after HRCT.

Results

We identified ten children from 10-17 years old from January 2013 to November 2019 who met criteria for the study. Seven out of ten patients (70%) had HRCT after first-time PSP during the same hospital stay. Blebs/bullae were discovered in five out of seven (71%) of those patients. Two of those five patients had subsequent surgical intervention (40%). 28% of those who had a HRCT had surgery at that point. Of those treated conservatively with blebs/bullae identified on HRCT, 66% had recurrence of PSP and all patients subsequently underwent VATS with blebectomy and pleurodesis. Among the patients without initial HRCT, there were no recurrent cases of PSP noted.

Conclusions

There is value in obtaining HRCT after the first time PSP, as these results can be used to guide management strategies. Further studies in pediatric PSP are needed to

validate the sensitivity of HRCT in bleb detection, the predictive value of bleb disease and recurrence, and the benefits and risks of early surgical intervention

Introduction

Pneumothorax is defined as an accumulation of air that develops between the visceral and parietal pleura of the lung. Idiopathic or spontaneous pneumothorax occurs outside of the setting of trauma. Primary spontaneous pneumothorax (PSP) occurs when thorough investigation reveals that no underlying lung disease was causative (ex. Asthma, interstitial lung disease, cystic fibrosis, congenital pulmonary airway malformation, etc) ¹.

The incidence of PSP in children has been reported to occur in about 4/100,000 children, with most cases occurring in adolescents 14 to 17 years of age. There is an average 4:1 male to female predominance ^{2,3}. PSP classically presents in tall, thin, male adolescents. This can be due to blebs or bullae within the lung that lead to areas of weakened visceral pleura. These blebs or bullae can rupture spontaneously, leading to an air leak between the pleura. PSP can also occur without a predisposing factor. In addition, smoking increases the risk of PSP significantly ⁴. Patients present most commonly at rest with a sudden onset of dyspnea, pleuritic chest pain, and ipsilateral shoulder pain. Interestingly, symptoms usually resolve within 24 hours, even if the pneumothorax is not treated or resolved.

Management strategies in children with PSP are controversial. There are limited studies and conflicting data on the subject, which contribute to the uncertainty of optimal management. Some studies report a high recurrence rate of PSP in children managed conservatively without surgical intervention ⁵⁻⁹. The current trend in adolescents presenting with first-time PSP is obtaining high resolution chest CT scans (HRCTs) to assess for blebs/bullae or other underlying disease ^{7-8, 10-12}. This trend is supported by

the findings in some studies that HRCT has high yield in identifying blebs/bullae, though it is uncertain at this time if blebs/bullae predicts recurrence risk ^{8, 10-12}. Video-assisted thoracoscopic surgery (VATS) with blebectomy and pleurodesis has become a popular intervention for first-time PSP in an attempt to prevent recurrence ⁵⁻⁹.

CT is a widely used imaging modality secondary to its widespread availability, short scan times, high quality image production, and diagnostic capabilities in children. It also has the advantage of eliminating the need for sedation in children. The disadvantage of CT scan is the significant dose of ionizing radiation administered to children.

Cumulative doses of ionizing radiation increase the lifetime risk of cancer ¹³. This is especially relevant in children, since they are more radio-sensitive than adults. The radio-sensitivity in children occurs because they have longer lifespans after exposure, and also because they have more proliferating cells which tend to be more sensitive to the toxic effects of radiation. Pearce et al showed a 2-3 fold increase in incidence of leukemia and brain tumors in people who were exposed to ionizing radiation during childhood ¹⁴.

While the risk of ionizing radiation exposure is significant, this must be balanced with the risks of a recurrent pneumothorax, subsequent hospital stay and possible eventual surgical intervention. We performed a retrospective longitudinal study of children with first time PSP to determine if HRCT scan guided surgical management. Prior to our study, there have not been direct studies evaluating the utility of HRCT scan in determining need for surgical intervention after first time PSP. We hypothesized when

HRCT is performed after first time PSP, the results would not guide surgical management.

Methods:

This study was approved by the IRB through the University of Arizona, Tucson.

This retrospective longitudinal study was performed in a single institution at the Diamond Children's Banner-University Medical Center Tucson in Tucson, Arizona. We identified children ages 10-17 years old who presented with a first time spontaneous pneumothorax. Data was collected from the medical records from January 2013 to November 2019 using the following ICD codes: ICD 9 - 512.81 and 512.89, ICD - 10 J93.11 and J93.9 (see table 1). The unspecified pneumothorax codes largely identified non-spontaneous pneumothoraces but were included to ensure patients were not miscoded and thus missed from study. Patients with recurrent pneumothorax, prior chest surgery or other chest trauma (such as radiation therapy, ventilation injury, etc) were excluded. We noted sex, age, BMI, laterality of pneumothorax based on CXR findings, and initial treatment of pneumothoraces (see table 2). BMI was calculated using the CDC pediatric calculator which includes age, height in inches, and weight in pounds.

We performed chart review to identify patient characteristics, initial treatment of patients, whether or not chest HRCT was obtained, presence or absence of bleb disease identified on final read of HRCT, subsequent interventions and subsequent recurrence of pneumothorax (see table 2). In those patients who underwent HRCT, the images were reviewed by pediatric radiologists.

The primary endpoint was the rate of surgical intervention after CT chest scans in patient's presenting after first-time PSP. The secondary endpoint was risk of recurrence with and without surgical intervention after first time spontaneous pneumothorax.

Results:

A total of 10 children were identified and met criteria for inclusion in the study. The average age of study patients was 15.6 years old and there was a male predominance (70% males). In 2 of the patients, BMI was unknown, however for the remaining 8 patients the average BMI was 18.2. There were 5 patients with left side PSP, 4 patients with right sided PSP, and 1 patient with bilateral PSP. The initial treatments were thoracostomy tube in 5 patients, 100% oxygen via non-rebreather mask in 3 patients, and observation without intervention in 2 patients.

We noted that seven out of ten patients (70%) had HRCT after first-time PSP during the same hospital stay. Of those patients who did not undergo HRCT, none required a thoracostomy tube for treatment of spontaneous pneumothorax. Of those that had HRCT, blebs/bullae were discovered in five out of seven (71%) of patients.

Specifically, bilateral apical blebs were reported on the final HRCT read in all patients.

Of the five patients who had blebs/bullae identified on initial HRCT, two patients had subsequent surgical intervention immediately after this finding (40%), and an additional two patients had surgical intervention after recurrence of pneumothorax (80% total).

Among the 70% who had HRCT performed, 28% had surgical intervention initially, and 57% had surgical intervention in total (both after first-time PSP and after recurrence).

Of the three patients who had positive blebs/bullae on HRCT but did not undergo initial surgical intervention, all had thoracostomy tubes placed as initial treatment. Of those three patients, two had recurrence of PSP and underwent VATS with blebectomy and pleurodesis after recurrence (recurrence rate of positive bleb/bullae disease = 66%).

Among the patients who did not have initial HRCT, there was no recurrence of PSP noted.

Discussion

Primary spontaneous pneumothorax is rare in children, and thus significant debate remains about optimal management strategies, use of HRCT after first time occurrence, timing of surgical intervention, and recurrence risk. Our hypothesis at the beginning of this study was that HRCT would not guide surgical management of first time PSP; however, our results show that a high percentage of patients with first-time PSP did have findings on HRCT leading to surgical intervention.

The yield of HRCT in identifying bleb/bullae disease in children after first-time PSP when compared to intraoperative identification is still uncertain at this time. In our study, there was 100% yield of HRCT for intraoperative bleb detection, though our sample size is small and revealed no occurrences of operative management without preceding HRCT revealing bleb disease. Similarly Nathan, et al found a sensitivity of 75% for CT scan identification of blebs confirmed intraoperatively among 25 patients under the age of 18 years old ⁸. In contrast, Laituri, et al evaluated 10-23 year old patients who had preoperative chest CT scans prior to VATS, and the sensitivity of CT scan for identifying blebs intraoperatively was only 36% ¹⁵. Future studies are needed to determine whether younger patients have increased sensitivity of CT scan for bleb identification. Additionally, studies aimed at establishing sensitivity of HRCT for identifying patients with bilateral apical involvement of blebs could provide evidence of a higher risk group likely to benefit from early CT to better guide operative management.

HRCT scan may be useful in guiding surgical management with the ultimate goal of reducing recurrence rate. In our study, 40% of patients with bleb/bullae disease

identified on HRCT underwent surgery during the initial hospital admission. An additional two patients with bilateral apical bleb disease identified on HRCT experienced recurrence of symptoms, and subsequently underwent VATS procedures, ultimately resulting in 80% of those with identified bleb disease on initial HRCT requiring surgical intervention overall. Among the 70% who had HRCT performed, 28% had surgical intervention initially, and 57% had surgical intervention in total (both after first-time PSP and recurrence).

Interestingly, all patients identified by HRCT to have bleb disease showed bilateral apical involvement, indicating a potential subset of patients undergoing spontaneous pneumothorax at higher risk physiologically for both recurrence and severity of symptoms. Patients found to have bilateral bleb disease may be more likely to benefit from aggressive surgical management, as our results indicate that 80% of these patients ultimately required surgical intervention in this pilot study. Further research is needed to better define clinical characteristics leading to the decision to obtain HRCT in these patients initially. Correlation between severity of presentation and initial radiograph findings with the clinician's decision to obtain HRCT may indicate some evidence of risk stratification occurring in clinical decision making in practice. This would be supported by the finding that all our patients who needed a chest tube subsequently underwent HRCT and 4 out of 5 (80%) of those patients had bleb disease with ultimate surgical intervention.

Many studies have found a decrease in recurrence rate with initial operative management versus non-operative management of children and adolescents with first

time PSP ⁵⁻⁹. There is uncertainty about bleb disease predicting recurrence in these studies. Our study found the recurrence rate of patients with blebs visualized on HRCT and treated conservatively was 66%, while those who did not undergo HRCT and were treated conservatively had a 0% recurrence rate. In Segiuer-Lipszyc, et al. the recurrence rate among conservatively treated patients was 50%, and recurrence rate was significantly lower following surgical intervention ⁶. In contrast to our findings, they found that recurrence rates in cases with and without blebs on CT was comparable ⁶. Similarly in Soler, et al recurrence rate was 45% in the operative group compared to 14% in the non-operative group. They found that a negative CT scan for subpleural blebs did not predict recurrence ⁷. Lopez, et al showed 40% recurrence rate for those treated nonoperatively and noted that initial nonoperative management resulted in more total hospital days ⁵. The low recurrence rate our study revealed in patients not evaluated by HRCT may indicate that these were mild cases, with clinical features indicating low severity. Most of the patients who did not undergo HRCT were treated only with observation, or supplemental oxygen, with no patients in this group requiring thoracostomy tube treatment. We cannot determine exactly why these patients did not undergo HRCT, though it was likely due to less severe physical symptoms at presentation. Again, this may point to potential for differentiation of presenting patients with spontaneous pneumothorax into high and low risk groups. Further studies are needed to examine the clinical features evaluated when deciding to obtain HRCT.

Adult British Thoracic Society (BTS) guidelines support observation alone without needle aspiration in patients with small (<2cm) PSP and/or not breathless¹⁶. In our study, the patients who did not undergo HRCT were presumed to have very mild

symptoms, and therefore the BTS guidelines could only be applied to this subset of patients. The adult BTS guidelines note that CT scanning is the gold standard in detection of small pneumothoraces and in size estimation, and also helpful in identifying underlying lung pathology, but practical constraints preclude its general use as the initial diagnostic modality. They don't recommend surgical consultation until secondary spontaneous pneumothorax occurs or unless persistent air leak greater than 24 hours with other methods (chest tube, etc). Our results suggest that these specific recommendations cannot be applied to children, based on our findings of high recurrence risk requiring surgical intervention in children with bilateral apical blebs identified on HRCT after PSP. The adult BTS guidelines do not take into consideration the relationship between presence of bullae and risk of recurrence in children. Similarly, Soccorso, et al comments that adult BTS guidelines aren't applicable to children with large PSP, considering the high recurrence rate (50%) if contralateral asymptomatic bullae were present¹¹.

Our study is limited by small sample size, and serves best as a pilot study for further investigation. Additionally, limits include the potential for loss to follow up, as the data collected was from only one children's hospital in town, and recurrence incidence may have been falsely lowered by family presentation to alternative hospital systems for recurrence episodes.

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