ORIGINAL ARTICLE

Predicting recurrence in primary spontaneous pneumothorax: The role of the Haller index in emergency department patients

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ABSTRACT

BACKGROUND: Primary spontaneous pneumothorax (PSP) is a common condition encountered in emergency departments, typically affecting young, otherwise healthy individuals. Identifying patients at risk for recurrence is critical for optimizing management strategies and preventing complications. This study aimed to evaluate the predictive value of the Haller index in determining the risk of recurrence in patients diagnosed with PSP.

METHODS: A retrospective analysis was conducted on patients diagnosed with PSP between January 1, 2019 and January 1, 2024, in the emergency department of a tertiary care hospital. Patients were categorized into two groups: those experiencing a single PSP episode and those with recurrent pneumothorax. Propensity score matching was employed to control for confounders, including age, gender, smoking status, and body mass index (BMI). The Haller index was calculated from chest computed tomography (CT) scans, and its predictive accuracy for recurrence was evaluated using Receiver Operating Characteristic (ROC) curve analysis.

RESULTS: A total of 182 patients were included in the study, with 91 patients in each group after propensity score matching. The Haller index was significantly higher in the recurrent pneumothorax group (2.72±0.47) compared to the single pneumothorax group (2.15±0.34), with a mean difference of 0.56 (95% confidence interval [CI]: 0.44-0.69, p<0.001). ROC analysis demonstrated an area under the curve (AUC) of 0.830 (95% CI: 0.768-0.882), with a Youden index of 0.50, sensitivity of 72.53%, and specificity of 76.92% for a cutoff value of >2.38.

CONCLUSION: The Haller index is a strong predictor of recurrent pneumothorax in patients with PSP. Its integration into clinical assessments can help identify patients at elevated risk of recurrence, enabling tailored treatment strategies.

Keywords: Primary spontaneous pneumothorax; Haller index; recurrence.

INTRODUCTION

Primary spontaneous pneumothorax (PSP) is defined as the accumulation of air in the pleural space due to the rupture of subpleural blebs in individuals without apparent lung disease. It predominantly affects young, thin males and typically presents with acute chest pain and shortness of breath, resulting in frequent visits to emergency departments.[1-4] The recurrence risk of PSP is highly variable, ranging from 8% to 74%, and poses significant challenges due to prolonged hospital stays and the need for invasive interventions.[5-8] Known risk factors for recurrence include smoking, low body mass index (BMI), large pneumothorax size, and the presence of subpleural blebs, as identified through chest tomography.[9,10] Identifying patients at high risk for recurrence is essential to guide management decisions and optimize clinical outcomes.

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The Haller index, calculated as the ratio of the anteroposterior chest diameter to the transverse chest diameter on chest tomography, serves as a measure of chest wall deformities. Elevated Haller index values indicate structural abnormalities that compromise lung stability, increasing susceptibility to bleb formation and rupture.[11] Previous studies suggest that a higher Haller index may be associated with an increased risk of PSP recurrence, highlighting its potential utility as a predictive tool in clinical practice.[12]

This study aims to evaluate the potential role of the Haller index in predicting recurrence in patients diagnosed with PSP.

MATERIALS AND METHODS

This study was conducted with the approval of the İstanbul Yeni Yüzyıl University Clinical Research Ethics Committee (Approval Number: 2024/11-1359, Date: 04.11.2024). All procedures were carried out in accordance with ethical guidelines and the principles of the Declaration of Helsinki. The study was retrospectively designed and conducted on patients diagnosed with PSP in the emergency department of a tertiary care hospital between January 1, 2019 and January 1, 2024.

The inclusion criteria for the study consisted of patients diagnosed with PSP in the emergency department who had chest computed tomography (CT) scans available for calculating the Haller index. Patients without thoracic CT scans were excluded, as this imaging modality is essential for calculating the Haller index. Additionally, patients with secondary spontaneous pneumothorax, traumatic pneumothorax, a history of thoracotomy, or incomplete data were excluded from the study.

Demographic information (age, gender), medical history (smoking status), physical examination findings (side of pneumothorax, British Thoracic Society [BTS] classification of pneumothorax size), treatment interventions (tube thoracostomy, operative intervention, chemical pleurodesis), body mass index, and imaging results were retrospectively retrieved from the electronic medical records system. The diagnosis of primary spontaneous pneumothorax was confirmed based on clinical findings and imaging, with the presence of subpleural blebs identified on CT scans. Recurrent pneumothorax was defined as a pneumothorax that recurred after the initial episode and was confirmed through radiological imaging.

The Haller index was calculated using chest CT images. The index is determined by dividing the maximum transverse diameter of the chest by the shortest anteroposterior diameter between the sternum and vertebra (Fig. 1).[12]

Statistical Analysis

Statistical analyses were performed using SPSS for Windows (Version 29, Chicago, IL, USA) and MedCalc (Version 20.104, MedCalc Software Ltd., Ostend, Belgium). Descriptive statistics were used to summarize the data, with categorical variables presented as counts and percentages, and continuous variables reported as means ± standard deviations or medians [interquartile range (IQR) 25th-75th percentile]. Data normality was assessed using the Shapiro-Wilk test and visual inspection of histograms.

For group comparisons, the Pearson chi-square test was used for categorical variables, with Fisher's exact test applied when the chi-square test assumptions were not met. Continuous variables were analyzed using either the Student's t-test or the Mann-Whitney U test, depending on the normality of the data.

Propensity score matching was conducted to reduce the impact of potential confounding variables, including age, gender, smoking status, and BMI. The balance of the matching process was assessed using balance tests, such as the Hansen and Bowers chi-square test for overall balance and the L1 statistic for multivariate imbalance.[13] The propensity score reduction indices demonstrated substantial improvement in balance between the matched groups, supporting the robustness of the matching process. The Coarsened Exact Matching (CEM) method, as described by Iacus, King, and Porro, was used for matching.[14] After matching, the single pneumothorax group and recurrent pneumothorax group each contained 91 patients, resulting in a total of 182 patients included in the final analysis. The Hansen and Bowers test confirmed a significant improvement in balance post-matching, and the L1 statistic indicated a reduction in multivariate imbalance.

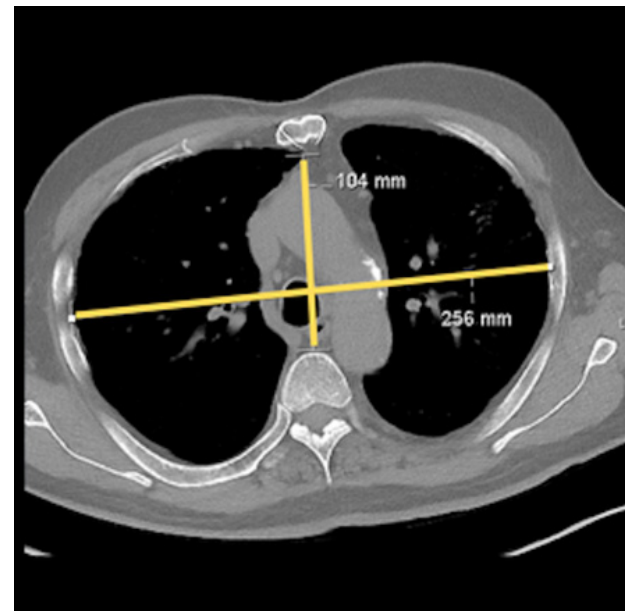

Figure 1. Measurement of the Haller index as the ratio of transverse to anteroposterior chest diameter on axial computed tomography.

The diagnostic performance of the Haller index in predicting recurrent pneumothorax was evaluated using Receiver Operating Characteristic (ROC) curve analysis. The area under the curve (AUC) was calculated to determine the overall discriminatory ability of the Haller index. The optimal cutoff value was identified using the Youden Index, with sensitivity, specificity, positive likelihood ratios (PLR), and negative likelihood ratios (NLR) reported.[15] A two-sided p value of <0.05 was considered statistically significant for all tests.

RESULTS

Propensity score matching was performed to control for potential confounders, including age, gender, smoking status, and BMI. The initial sample included 172 patients with single pneumothorax and 104 patients with recurrent pneumothorax. After matching, both groups consisted of 91 patients, resulting in the exclusion of 79 patients from the single pneumothorax group and 24 from the recurrent pneumothorax group as unmatched cases. No cases were excluded due to a lack of overlap in propensity scores.

The overall balance test indicated significant pre-matching imbalance, with a chi-square value of 58.656 and 5 degrees of freedom (p<0.001). The relative multivariate imbalance, measured by the L1 statistic, decreased slightly from 0.848 before matching to 0.835 after matching, indicating improved baseline comparability between the groups.

A total of 182 patients were included in the study, equally divided into two groups: single pneumothorax (n=91, 50%) and recurrent pneumothorax (n=91, 50%). Table 1 summarizes the baseline characteristics of the groups. There were no statistically significant differences between the single and recurrent pneumothorax groups in terms of age (24.3±7.7 vs. 24.3±8.6, p=0.993), gender distribution (93.4% male in both groups, p=0.999), smoking status (39.6% vs. 44%, p=0.548), pneumothorax side (46.2% vs. 45.1% left-sided, p=0.882), BTS classification of pneumothorax size (53.8% vs. 61.5% small, p=0.294), tube thoracostomy (38.5% vs. 40.7%, p=0.880), operative intervention (7.7% vs. 6.6%, p=0.999), chemical pleurodesis (4.4% in both groups, p=0.999), and BMI (17.5±0.8 vs. 17.4±0.9, p=0.415).

In contrast, the Haller index was significantly higher in the recurrent pneumothorax group compared to the single pneumothorax group (2.72±0.47 vs. 2.15±0.34), with a mean difference of 0.56 (95% CI: 0.44-0.69, p<0.001).

Table 2 summarizes the diagnostic accuracy of the Haller index for predicting recurrent pneumothorax, demonstrating an AUC of 0.830 (95% CI: 0.768-0.882) (Fig. 2). The Youden

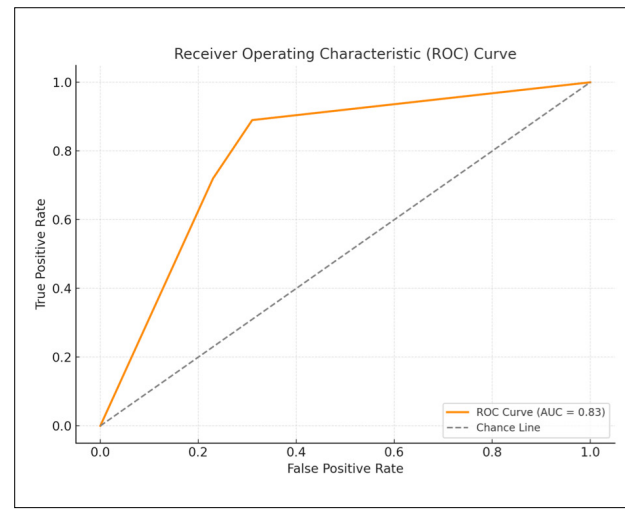

Figure 2. Receiver Operating Characteristic (ROC) curve demonstrating the diagnostic performance of the Haller index in predicting recurrence in primary spontaneous pneumothorax.

Table 2. Comparison of hemorrhage, edema, vasocongestion, inflammation, and Johnsen scores between rat groups

Variable	Single (n=91)	Recurrent (n=91)	p-value	Mean Difference (95% CI)
Age (years)	24.3±7.7	24.3±8.6	0.993	-
Gender (Male)	85 (93.4%)	85 (93.4%)	0.999	-
Smoking	36 (39.6%)	40 (44%)	0.548	-
Pneumothorax Side (Left)	42 (46.2%)	41 (45.1%)	0.882	-
BTS Classification (Small)	49 (53.8%)	56 (61.5%)	0.294	-
Tube Thoracostomy	35 (38.5%)	37 (40.7%)	0.880	-
Operative Intervention	7 (7.7%)	6 (6.6%)	0.999	-
Chemical Pleurodesis	4 (4.4%)	4 (4.4%)	0.999	-
BMI	17.5±0.8	17.4±0.9	0.415	-
Haller Index	2.15±0.34	2.72±0.47	<0.001	0.56 (0.44-0.69)

BMI: Body Mass Index; BTS: British Thoracic Society; "Small" indicates pneumothorax size per BTS guidelines.

Table 2. Diagnostic accuracy of the Haller index for recurrent pneumothorax

Metric	AUC (95% CI)	Youden Index J	Associated Criterion	Sensitivity (95% CI)	Specificity (95% CI)
Haller Index	0.830 (0.768-0.882)	0.50	>2.38	72.53% (62.2-81.4)	76.92% (66.9-85.1)

AUC: Area Under the Curve; CI: Confidence Interval.

Index (J) was 0.50, with an associated criterion of >2.38. Sensitivity and specificity were 72.53% (95% CI: 62.2-81.4) and 76.92% (95% CI: 66.9-85.1), respectively.

DISCUSSION

The most significant finding of this study is that the Haller index demonstrates strong predictive value for recurrent pneumothorax in patients diagnosed with PSP. This finding suggests that the Haller index could be a useful tool for predicting the risk of pneumothorax recurrence in PSP patients and for aiding in the development of more personalized treatment strategies.

PSP is a common clinical condition frequently encountered in emergency departments. It typically affects young and otherwise healthy individuals, presenting with symptoms such as sudden chest pain and shortness of breath. PSP has a high recurrence rate, and untreated cases may result in severe complications.[16] The pathophysiology of PSP involves air leakage into the pleural space due to the rupture of subpleural blebs. While conservative treatment is often preferred for initial episodes of PSP, surgical interventions may be required for recurrent cases.[17,18] Thus, identifying predictors of recurrence in PSP is critical to optimizing the treatment process.

The Haller index is a parameter used to assess the degree of chest wall deformities and is calculated as the ratio of the anteroposterior chest diameter to the transverse chest diameter. In conditions such as pectus excavatum, elevated Haller index values indicate mechanical abnormalities in the chest wall. These abnormalities can impair the mechanical stability of the lungs, predisposing to the formation and rupture of subpleural blebs.

The role of the Haller index in PSP appears to be clinically significant, particularly in identifying patients with a high likelihood of recurrence. Chest wall deformities, as indicated by an elevated Haller index, may exert mechanical stress on the lung parenchyma. This stress can lead to the formation and subsequent rupture of subpleural blebs, especially in structurally compromised areas of the thorax. Furthermore, altered thoracic geometry may influence intrapleural pressure dynamics, increasing the likelihood of air leakage into the pleural space. These pathophysiological mechanisms provide a plausible explanation for the observed association between a high Haller index and an increased risk of PSP recurrence.

Although the literature suggests that the Haller index may be associated with PSP development, studies on this topic are limited. Lee et al.[11] reported that patients with a higher Haller index were more likely to develop PSP, proposing that structural predispositions in the thorax could increase the risk of pneumothorax recurrence. Similarly, Kılıçgün et al.[12] observed that patients with pectus excavatum had significantly higher Haller index values compared to controls, concluding that this deformity could be an etiological factor in PSP development. Additionally, in a study by Buz et al.,[22] the Haller index demonstrated high diagnostic validity in predicting the risk of recurrence in primary spontaneous pneumothorax patients, suggesting that it may serve as an effective tool for forecasting recurrence following an initial pneumothorax episode. Consistent with existing literature, out findings suggest that a higher Haller index indicates a predisposition to recurrent PSP. This supports the notion that thoracic structural abnormalities play a critical role in pneumothorax recurrence, highlighting the importance of evaluating such parameters in clinical practice.

Simultaneous surgical procedures, such as bullectomy performed during the minimally invasive repair of pectus excavatum (MIRPE), have been described in the literature. These cases often involve addressing bullae identified preoperatively to reduce the risk of pneumothorax recurrence. For instance, Bilgi et al.[23] and Bostancı et al.[24] reported successful outcomes of simultaneous video-assisted thoracoscopic surgery (VATS) bullectomy and MIRPE in patients with recurrent pneumothorax. While simultaneous procedures are not routine, they are considered in cases where pulmonary pathologies, such as bullae, coexist with chest wall deformities. Addressing these issues concurrently can optimize surgical outcomes and reduce the risk of future complications, particularly in patients with a high recurrence risk.

This study has several limitations that should be considered when interpreting the findings. First, the retrospective design may introduce potential biases, as data were collected from electronic medical records, and incomplete or inaccurate records could affect the results. Second, the study was conducted at a single center, which may limit the generalizability of the findings to other populations or healthcare settings. Third, the Haller index measurements were derived from chest computed tomography scans, and patients who did not undergo CT imaging were excluded from the study, potentially introducing selection bias. Finally, although pro-

pensity score matching was employed to minimize the effect of confounders, residual confounding factors may still exist and could influence the results.

CONCLUSION

This study demonstrates that the Haller index is a significant predictor of recurrent pneumothorax in patients diagnosed with primary spontaneous pneumothorax. The findings suggest that higher Haller index values are associated with an increased risk of recurrence, underscoring the potential value of incorporating this measurement into clinical decision-making for PSP management. Future studies are needed to validate these results and to further investigate the role of the Haller index in guiding treatment strategies for patients at high risk of recurrence.

Ethics Committee Approval: This study was approved by the İstanbul Yeni Yüzyıl University Clinical Research Ethics Committee Ethics Committee (Date: 04.11.2024, Decision No: 2024/11-1359).

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ORİJİNAL ÇALIŞMA - ÖZ

Primer spontan pnömotoraksta nüksü öngörme: Acil serviste Haller indeksinin rolü

AMAÇ: Primer spontan pnömotoraks (PSP), acil servislerde sıkça görülen ve genellikle genç ve sağlıklı bireyleri etkileyen bir durumdur. Nüks riski taşıyan hastaların belirlenmesi, yönetim stratejilerinin optimize edilmesi ve komplikasyonların önlenmesi açısından kritik öneme sahiptir. Bu çalışma, PSP tanısı konulan hastalarda nüks riskini belirlemede Haller indeksinin öngördürücü değerini değerlendirmeyi amaçlamıştır.

GEREÇ VE YÖNTEM: Ocak 1, 2019 ve Ocak 1, 2024 tarihleri arasında üçüncü basamak bir hastanenin acil servisinde PSP tanısı konulan hastalar üzerinde retrospektif bir analiz yapıldı. Hastalar tek PSP epizodu geçirenler ve tekrarlayan pnömotoraks yaşayanlar olarak iki gruba ayrıldı. Yaş, cinsiyet, sigara içme durumu ve vücut kitle indeksi (VKİ) gibi değişkenleri dengelemek için eğilim skoru eşleştirmesi kullanıldı. Haller İndeksi, toraks bilgisayarlı tomografi (BT) görüntülerinden hesaplandı ve nüksü öngörmedeki doğruluğu Alıcı İşletim Karakteristiği (ROC) eğrisi analizi ile değerlendirildi.

BULGULAR: Çalışmaya toplam 182 hasta dahil edildi ve her iki grupta da eğilim skoru eşleştirmesi sonrası 91 hasta yer aldı. Haller İndeksi, tekrarlayan pnömotoraks grubunda (2.72±0.47), tek pnömotoraks grubuna (2.15±0.34) göre anlamlı derecede yüksekti ve ortalama fark 0.56 (95% GA 0.44-0.69, p<0.001) olarak bulundu. ROC analizinde eğri altındaki alan (AUC) 0.830 (95% GA 0.768-0.882) olarak hesaplandı; >2.38 kesim değeri için Youden İndeksi 0.50, duyarlılık %72.53 ve özgüllük %76.92 olarak belirlendi.

SONUÇ: Haller indeksi, PSP hastalarında tekrarlayan pnömotoraksın güçlü bir öngördürücüsüdür. Klinik değerlendirmelere dahil edilmesi, yüksek nüks riski taşıyan hastaların belirlenmesine yardımcı olabilir ve tedavi stratejilerini buna göre yönlendirebilir.

Anahtar sözcükler: Haller indeksi; primer spontan pnömotoraks; rekürrens.

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