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Quantitative Measurement of Lung Radiodensity on Chest X-ray Improves Diagnosis of Foreign Body Aspirations in Children

Direkt Akciğer Grafisinde Akciğer Radyodansitesinin Kantitatif Ölçümü Çocuklarda Yabancı Cisim Aspirasyonlarının Tanısını İyileştirir

Ayten Bilen[1], Fatma Ceren Sarıoğlu[2], Efil Aydın[1], Serra Sabuncu[1], Osman Zeki Karakuş[1], Oktay Ulusoy[1], Handan Güleryüz[2], Oğuz Ateş[1], Gülce Hakgüder[1], Mustafa Olguner[1], Miraç Feza Akgür[1]

[1]Dokuz Eylül University Faculty of Medicine, Department of Pediatric Surgery, İzmir, Türkiye
[2]Dokuz Eylül University Faculty of Medicine, Department of Radiology, Division of Pediatric Radiology, İzmir, Türkiye

Abstract

Introduction: Chest X-ray (CXR) is the primary imaging method for the diagnosis of foreign body (FB) aspiration (FBA) and the most common finding is ipsilateral hyperinflation due to air-trapping. FB related hyperinflation can be subtle and difficult to detect in the evaluation of the CXR. Radiodensity measurement of the lungs on CXR could be useful for the diagnosis of FBA. The aim of this study is to evaluate the diagnostic effectiveness of quantitative measurement of lung radiodensity in detecting hyperinflation on CXR of the patients with suspected FBA.

Methods: Records of patients who underwent rigid bronchoscopy for evaluation of FBA between January 2008 and June 2020 were reviewed retrospectively. Initial CXR of the patients were re-evaluated quantitatively by measuring lung radiodensity in FBA present and FBA absent groups.

Results: FB was detected in 154 patients, while FB was not detected in 87 patients during bronchoscopy. FB was in right lung in 89 patients, in left lung in 51 patients thus unilateral FB was present in 140 patients. Records of initial CXR evaluation of these 140 patients with unilateral FB showed unilateral lung hyperinflation in 60 patients (42.9%) and no unilateral hyperinflation in 80 patients (57.1%). Lung radiodensities of the FB-present lungs were statistically significantly less dense compared with radiodensities of the contralateral lungs. A 5.5% or more lung radiodensity difference compatible with hyperinflation were found in 113 out of 140 patients (80.7%) with unilateral FB during lung radiodensity measurements. During the initial CXR evaluation, the hyperinflation detection rate was 42.9%, with the lung radiodensity measurement, the hyperinflation detection rate increased to 80.7%

Öz

Giriş: Direkt akciğer grafisi (PA-AC grafisi), yabancı cisim aspirasyonu (YCA) tanısında birincil görüntüleme yöntemidir ve en yaygın bulgu hava yolu tıkanıklığına bağlı gelişen ipsilateral havalanma artışıdır. Yabancı cisim (YC) ile ilişkili havalanma artışının PA-AC grafisi ile değerlendirilmesi her zaman kolay olmayabilir. Akciğerlerin, PA-AC grafisi üzerindeki radyodansitelerinin ölçülmesi, YCA tanısı için yararlı olabilir. Bu çalışmanın amacı, şüpheli YCA olgularında PA-AC grafisinde havalanma artışının tespitinde akciğer radyodansitesinin kantitatif ölçümünün tanısal etkinliğini değerlendirmektir.

Yöntemler: Ocak 2008 ile Haziran 2020 tarihleri arasında YCA nedeniyle rijit bronkoskopi yapılan hastaların kayıtları geriye dönük olarak incelendi. YCA olan ve olmayan gruplarda akciğer radyodansitesi ölçülerek hastaların başlangıç PA-AC grafileri yeniden değerlendirildi.

Bulgular: Yüz elli dört hastada rijit bronkoskopi sonucunda yabancı cisim tespit edilirken, 87 hastada tespit edilmedi. Tek taraflı yabancı cisim tespit edilen 140 hastanın 89'unda yabancı cisim sağda, 51 hastada ise solda idi. Tek taraflı yabancı cisim saptanan hastaların PA-AC grafileri retrospektif olarak değerlendirildiğinde, 60 hastada (%42,9) tek taraflı havalanma artışı tespit edilirken, 80 hastada (%57,1) PA-AC grafisinde havalanma artışı izlenmemişti. Akciğer grafileri radyodansite ölçümü ile değerlendirildiğinde yabancı cisim bulunan akciğerlerin radyodansiteleri, karşı akciğer radyodansitelerine göre istatistiksel olarak anlamlı derecede daha az yoğundu. Rijit bronkoskopi ile tek taraflı yabancı cisim tespit edilen 140 hastanın 113'ünde (%80,7) akciğer radyodansitesi ölçümleri sırasında tek taraflı hava hapsi ile uyumlu en az %5,5'lik bir akciğer radyodansitesi farkı bulundu. Başlangıç PA-AC grafisi grafisi değerlendirilmesi ile radyodansite ölçümü sonrası yapılan

Address for Correspondence/Yazışma Adresi: ssoc. Prof. Oktay Ulusoy, Dokuz Eylül University Faculty of Medicine, Department of Pediatric Surgery, İzmir, Türkiye
E-mail: oktay.ulusoy@deu.edu.tr **ORCID ID:** orcid.org/0000-0002-0992-8724
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Abstract

Conclusion: Quantative lung radiodensity measurement of CXR in patients with suspected FB aspiration could increase the efficiency of FB related hyperinflation detection.

Keywords: Chest X-ray, foreign body aspiration, radiodensity measurement

Öz

değerlendirmenin karşılaştırılmasında hava hapsinin tespit oranının %42,9'dan %80,7'ye yükseldiği görüldü.

Sonuç: Şüpheli YCA hastalarında PA-AC grafisi üzerindeki radyodansitenin kanitatif ölçülmesi, yabancı cisimle ilişkili hava hapsinin tespitini ve PA-AC grafisi tanısal etkinliğini artırabilir.

Anahtar Kelimeler: PA-AC grafisi, yabancı cisim aspirasyonu, radyodansite ölçümü

Introduction

Foreign body aspiration (FBA) is associated with morbidity and mortality related to diagnostic delay during childhood.[1] Delayed or missed diagnosis of FBA causes long-term complications, such as pneumonia, bronchiectasis, and atelectasis.[2,3] Diagnosis and early removal of the foreign body (FB) are vital for reducing potential complications and mortality.[4,5] Bronchoscopy is the gold standard for the diagnosis and treatment of FBA.[6,7]

Chest X-ray (CXR) is the primary and frequently used imaging modality for diagnosing FBA. The most common finding in CXR is ipsilateral hyperinflation due to air-trapping (34-71%).[8-10] FB-related hyperinflation can be subtle and difficult to detect during CXR evaluation. Radiodensity measurements of the lungs using CXR can be useful for diagnosing FBA.[10,11] This study aimed to evaluate the diagnostic effectiveness of quantitative lung radiodensity measurement for detecting hyperinflation on CXR in patients with suspected FBA.

Materials and Methods

Study Design and Population

The Institutional Clinical Research Ethics Review Board Dokuz Eylül University approved this study (approval no: GOA-5781, 2021/03-56, date: 01.02.2021). The records of patients who underwent rigid bronchoscopy for FBA evaluation between January 2008 and June 2020 were retrospectively reviewed. The reviewed parameters were age, sex, presenting symptoms, duration of symptoms, records of initial CXR findings, anatomic location of the FB as detected during bronchoscopy, complications, and length of hospital stay. Initial CXRs of patients were re-evaluated quantitatively by measuring lung radiodensity. Two groups were formed in the study.

1- FB-present group: This group comprised patients who underwent rigid bronchoscopy with suspected FBA and FB.

2- FB-absent group: Patients who underwent rigid bronchoscopy with suspected FBA but without FB detection.

Study Setting

(Radiographic density measurement of a CXR), posterior-anterior CXRs were obtained using M-Cabinet CXA (Phillips Medical System, Hamburg, Germany) and evaluated using Sectra Systems (Sectra Myrian, Expert 2.0/0502). Examination parameters were 6-8 mA, and 60-75 kV, depending on the patient's age and weight. Digital data from CXR were sent to a picture-archiving and communication system (PACS; Sectra, İzmir, Türkiye). For quantitative assessment, a radiodensity calculation system was used to measure the mean density on CXR. The radiologists worked blindly without knowing the bronchoscopy results during the radiodensity measurement on CXR. Radiodensity measurements were made using region of interest (ROI) drawings: ROIs for the entire right or left lung were drawn. The margin of the lung was delimited by the rib cage, cardiac border, and diaphragm (Figure 1).

Statistical Analysis

Data were analyzed using SPSS software for Windows version 22 (SPSS, Chicago, IL, USA). The compliance of the data to normal distribution was examined by visual (histograms and

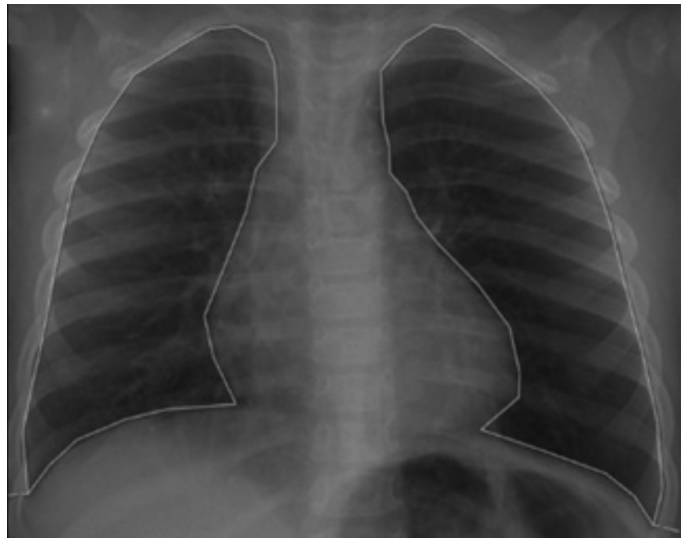

Figure 1. Chest X-ray showing lung regions of interest. The lung margin is delimited by the rib cage, cardiac border, and diaphragm

graphs) and analytical (Kolmogorov-Smirnov/Shapiro-Wilk tests). Because the data did not conform to the normal distribution, the parameters between the groups were evaluated by Kruskal-Wallis variance analysis. In cases of significant differences between groups, the Mann-Whitney U test was used for post-hoc pairwise comparisons. The statistical significance level was set as $p<0.05$.

Results

In total, 241 patients were hospitalized with a preliminary diagnosis of FBA. The female to male ratio was 93/148 (38.6/61.4%). The mean patient age was 30.6±1.6 months (range, 1-160 months).

The histories of 162 patients suggested FBA, 54 patients did not suggest FBA, and 25 patients' histories were inconclusive. Among these, 159 patients had a history of cough, 55 had a history of choking, 85 had wheezing, 60 had bruising, 36 had fever, and 31 had a history of chronic lower respiratory tract infection. The mean time from symptom onset to presentation to the emergency department was 178.423.1± hours (range, 24-1440 hours) (median 24 hours).

Bronchoscopy findings: FB was detected in 154 patients (63.9%) patients, whereas it was not detected in 87 patients (36.1%) during bronchoscopy. The FBs were located in the right lung in 89 patients, in the left lung in 51 patients, in both lungs in 5 patients, and in the trachea in 9 patients. Overall, 140 patients presented with unilateral FB. Average bronchoscopy conduction time averaged 10.9±0.4 minutes (range, 5-60 minutes). Nine patients (3.7%) required reintubation and intensive care monitoring after bronchoscopy due to airway edema and difficulty in spontaneous breathing. In 4 patients, bronchoscopy was repeated because the FB could not be removed completely during the first bronchoscopy. Thoracotomy was performed in three patients (1.2%) because the FB could not be removed during bronchoscopy. There is no mortality in our study.

Radiological evaluation: A unilateral bronchoscopy-proven FB was present in 140 patients. Records of the initial CXR evaluation showed hyperinflation on the right side in 37 patients and on the left side in 23 patients. Records of the initial CXR evaluation showed unilateral lung hyperinflation in 60 patients (42.9%) and no unilateral hyperinflation in 80 patients (57.1%) (Table 1). Hyperdense FB was detected in the right lung in 5 patients and the left lung in 1 patient.

Lung radiodensity measurements are presented in Table 2. The lung radiosensitizes of the FBs (ipsilateral lungs) were significantly less dense than the radiosensitizes of the contralateral lungs. The lung radiosensitizes of the FB-absent groups in both lungs were not significantly different. When the raw lung radiodensity measurements were analyzed individually, lungs with FB were 5.5% to 21.7% denser than contralateral lungs in patients with FB.

Contralateral lung FB-related hyperinflation detection rates during the initial CXR assessment and after lung radiodensity measurement are presented in Table 1. Of the 140 patients with unilateral FB, while hyperinflation was detected in 60 patients (42.9%), hyperinflation was not detected in 80 out of 140 patients (57.1%) during the initial CXR evaluation. However, 5.5% or more lung radiodensity differences compatible with hyperinflation were found in 113 out of 140 patients (80.7%) during lung radiodensity measurements (Table 1). During the initial CXR evaluation, the hyperinflation detection rate was

Table 1. Contralateral lung hyperinflation detection rates with initial CXR assessment versus quantitative radiodensity measurement (patients with bilateral and tracheal foreign bodies were excluded)

	Initial CXR assessment (n=140)		Lung radiodensity measurement* (n=140)	
	Hyperinflation (+) n (%)	Hyperinflation (-) n (%)	Hyperinflation (+) n (%)	Hyperinflation (-) n (%)
FB in right lung n=89	37 (41.5%)	52 (58.5%)	74 (83.1%)	15 (16.9%)
FB in left lung n=51	23 (45.1%)	28 (54.9%)	39 (76.5%)	12 (23.5%)
Total	60 (42.9%)	80 (57.1%)	113 (80.7%)	27 (19.3%)

*: 5.5% or more lung radiodensity difference between ipsilateral and contralateral lung was defined as presence of foreign body related hyperinflation, CXR: Chest X-ray, FB: Foreign body

Table 2. Lung radiodensity measurements of CXR (mean ± SEM)

	FB-present in right lung (n=89)	FB-present in left lung (n=51)	FB-absent group (n=87)
Right lung	979.5±60.1*	1076.8±63.6	1141.0±82.0
Left lung	1096.5±69.8	928.4±66.8*	1158.5±82.7

*: $p<0.01$ compared with contralateral lung, CXR: Chest X-ray, FB: Foreign body, SEM: Standard error of the mean

42.9%, and the lung radiodensity measurement revealed that the hyperinflation detection rate increased to 80.7% (Table 1).

Evident right hyperinflation on the CXR is shown in Figure 2A. The CXR of the patient with FB in whom no hyperinflation was detected in the initial CXR evaluation showed a 6.4% density difference compatible with hyperinflation detected in the lung radiodensity measurement of the CXR (Figure 2B).

On the other hand, the initial CXR findings of the five patients were not consistent with bronchoscopy findings. Although hyperinflation was detected on the left side in three patients and on the right side in two patients, FB was found on the contralateral side during bronchoscopy. However, CXR lung radiodensity measurements were consistent with bronchoscopy findings.

Postoperative management: In the postoperative period, 66 patients received nebulized salbutamol, 23 received nebulized budesonide, and 20 received nebulized adrenaline due to airway reactivity and dyspnea. In the postoperative period, 19 patients required 4-6 L/min O_2, and cold steam was applied to 40 patients. The length of hospital stay was 42.72.6± hours (range 7-96 hours) (median 41 hours).

Discussion

FBA is a preventable emergency pathology in childhood. Delayed diagnosis of FBA is associated with the risk of pneumonia, pneumothorax, respiratory failure, and mortality.[3] In a series of 11,000 pediatric patients with FBA, the overall mortality risk was 2.5%.[3] Bronchoscopy is the most effective method for the diagnosis and treatment of FBA.[6,7] The prognostic results of bronchoscopy are encouraging when FBs are removed properly. Therefore, an early diagnosis of FB and immediate intervention is important for the successful treatment of FBA.[5,12]

A significant history of FB is an indication for bronchoscopy alone.[9] In the present series, the major symptoms were cough (65.9%), choking (22.8%), and wheezing (35.3%). The sensitivity and specificity of symptoms at diagnosis were 75.3% and 50.6% for cough, 22.1% and 75.8% for choking, and 42.8% and 78.2% for wheezing, respectively.

The rate of negative bronchoscopy in the present study was 36.1%. Therefore, radiological imaging is crucial in patients with suspected FBA to reduce potential complications. CXR is the primary imaging modality for FBA evaluation. The most common finding in CXR after FBA is hyperinflation.[8-15] The determination of lung radiodensity is a quantitative measurement method that can be used during CXR evaluation.[10,11] Decreased ipsilateral lung radiodensity due to unilateral hyperinflation is a typical radiological finding in FBA.[10,11] Calculating the radiodensity ratio of both lungs in CXR is useful for the diagnosis of FBA.[10,11] Song et al.[10] measured CXR lung radiosensitizes in 22 children with bronchoscopy-proven unilateral FB and compared the radiodensities before and after bronchoscopic FB removal. Song et al.[10] found that the CXR radiodensity of the ipsilateral lung was lower than that of the contralateral lung and significantly increased after bronchoscopic FB removal. Caliskan et al.[11] measured CXR lung radiosensitizes in 33 children with bronchoscopy-proven unilateral FB and found that the presence of unilateral FB decreased the lung radiodensity of the ipsilateral lung. The present series is the largest in the literature, comprising 140 patients with bronchoscopy-proven unilateral FB. The current study is the first study to compare the hyperinflation detection rate during initial CXR assessment with the hyperinflation

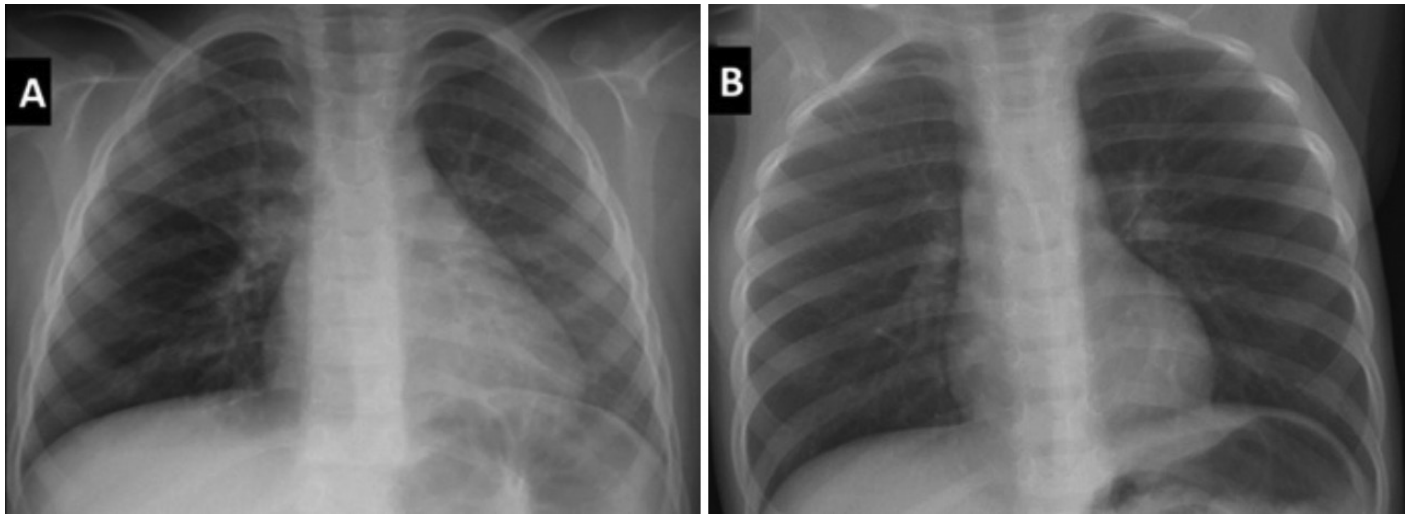

Figure 2. A) Evident right middle and lower lobe hyperinflation on the CXR of a 6-year-old boy, B) Normal CXR appearance without evident hyperinflation in a 7-year-old boy. Lung radiodensity measurements of this patient showed 6.4% less left lung radiodensity, indicating hyperinflation

CXR: Chest X-ray

detection rate during CXR lung radiodensity measurement. This study showed that quantitative evaluation of CXR through lung radiodensity measurement increased the detection rate of FB-related hyperinflation from 42.9% to 80.7%. We believe that quantitative measurement of lung radiodensity in patients with suspected FBA could decrease the misinterpretation rate of CXR due to individual or technical reasons.

Conclusion

We conclude that quantitative lung radiodensity measurement on CXR in patients with suspected FBA may increase the efficiency of FB-related hyperinflation detection.

Ethics

Ethics Committee Approval: The Institutional Clinical Research Ethics Review Board Dokuz Eylül University approved this study (approval no: GOA-5781, 2021/03-56, date: 01.02.2021).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.B., E.A., S.S., O.Z.K., O.U., O.A., G.H., M.O., M.F.A., Concept: A.B., O.Z.K., Design: A.B., O.Z.K., Data Collection or Processing: A.B., F.C.S., E.A., S.S., O.Z.K., O.U., H.G., Analysis or Interpretation: A.B., F.C.S., O.Z.K., Literature Search: A.B., O.Z.K., Writing: A.B., O.Z.K., O.U., O.A., G.H., M.O., M.F.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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