



Utility of lung radiodensity ratios in diagnosis of radiolucent foreign body aspiration in children: a practical approach

Emine Caliskan^{a,*}, Shamil Aliyev^a, Hatice Arioz Habibi^b, Zuhul Bayramoglu^a, Ravza Yilmaz^a, Ibrahim Adaletli^a

^a Istanbul Faculty of Medicine, Department of Radiology, Turgut Ozal Caddesi 118, Fatih, İstanbul, Turkey

^b Evliya Celebi Training and Research Hospital, Evliya Celebi Street, 43040 Kutayha, Turkey

ARTICLE INFO

Keywords:

Air-trapping
Chest X-ray
Foreign body aspiration
Radiodensity

ABSTRACT

Objective: To evaluate the utility of radiodensity ratio between lungs on chest X-ray for the diagnosis of radiolucent foreign body aspiration (FBA) in children.

Methods: X-rays of 33 patients with confirmed diagnosis of FBA by bronchoscopy were compared to 66 control patients. We divided the study group into three subgroups: symmetric (13-patients), right-oblique (RO;12-patients) and left-oblique (LO;8-patients).

Results: When we compared FBA-symmetric-subgroup to symmetric-control-group, FBA-RO-subgroup to RO-control-group and FBA-LO-subgroup to LO-control-group, radiodensity ratios were significantly higher in the FBA subgroups.

Conclusion: The calculated radiodensity ratio between lungs on X-ray would be a useful and practical tool for the diagnosis of radiolucent FBA in children.

1. Introduction

FBA can occur anywhere in the respiratory tract, usually in the first four years of life, and may result in accidental death or serious sequelae [1–4]. Aspirated foreign bodies can cause complete or partial obstruction of laryngeal, subglottic, tracheal and bronchial airways. The most common location of aspirated foreign bodies is the bronchial system [5]. Typical clinical symptoms of FBA are dyspnea, fever, hemoptysis, cough and wheezing. Sometimes symptoms can be nonspecific which may misdirect the clinician [6,7]. The role of imaging is crucial especially in patients with nonspecific symptoms.

In evaluation of radiolucent foreign bodies, unilateral air-trapping due to one-way valve mechanism in partial obstruction is a frequent radiological finding on chest radiography (X-ray) and computed tomography (CT) scan in the acute period [8,9]. Multidetector chest CT scan is a very sensitive modality for demonstrating radiolucent foreign bodies and air-trapping however high ionizing-radiation exposure is the major limitation in children [10,11]. Bronchoscopy is the gold standard for diagnosing FBA, but it is an invasive procedure which requires general anesthesia and occasionally can cause serious complications [12].

Chest X-ray is the initial study in the evaluation of FBA. It is a method utilizing minimal ionizing radiation which is quick, readily

available and inexpensive. Patient rotation causes asymmetry in radiodensity of the lungs which may mimic air-trapping and is thus a limitation of radiography in the evaluation for radiolucent foreign body aspiration [13,14]. Overall, X-ray is not a reliable tool in the diagnosis of radiolucent FBA and children may undergo CT scan before bronchoscopy. Therefore, adding new parameters to the assessment of chest X-ray in patients with FBA would increase the sensitivity of radiography for FBA, and potentially avoid further ionizing radiation exposure of CT.

The aim of this study is to evaluate the utility of radiodensity ratio between lungs on chest X-ray as a quantitative method to detect air-trapping seen in radiolucent FBA in children.

2. Materials and methods

2.1. Patients

Between September 2014 and February 2017, 52 patients were diagnosed with FBA both on bronchoscopy and CT at our institution. We excluded the patients with tracheal aspiration (n = 5), laryngeal aspiration (n = 2), chronic FBA who had atelectasis or pneumonia (n = 8) and patients without air-trapping on CT from the study (n = 4). An experienced radiologist evaluated air-trapping on CT, visually.

* Corresponding author.

E-mail address: eminecaliskanrad@gmail.com (E. Caliskan).



Fig. 1. Thorax CT demonstrates a foreign body in the left main bronchus (arrow) and air-trapping in the left lung.

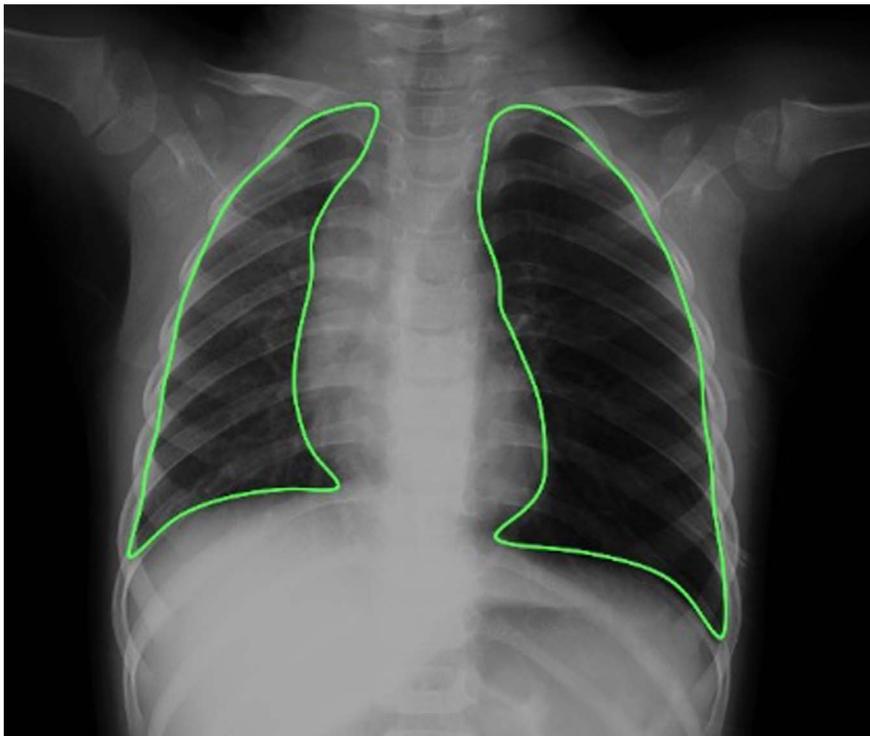


Fig. 2. Chest X-ray of the same patient with a radiolucent foreign body on CT shows the areas of radiodensity measurement. Air-trapping is observed in the left lung.

Thirty-three patients (age range: 5–46 months) who all had chest X-ray and CT scan with bronchial FBA and air-trapping were retrospectively evaluated. Multiplanar reconstructions images on CT were used in detecting airway foreign bodies and air-trapping. The study included only the patients with right or left acute bronchial FBA and air-trapping on CT (Fig. 1). On X-ray, a region of interest measuring mean Hounsfield units was drawn for each lung, using the cardiothymic silhouette, diaphragm, and the ribcage as borders (Fig. 2). Since different radiation doses were used in each patient, by using RD ratio between lungs we aimed to account for exposure dose differences. To obtain the radiodensity ratio we compared the ROIs on the side of the FBA to the ROIs on the contralateral side. Based on patient positioning on anterior-posterior (AP) supine X-rays, we divided the study group into three

subgroups as symmetric (13 patients), right oblique (RO, 12 patients) and left oblique (LO, 8 patients) on AP X-ray at supine position as standard protocol in young children. Inspiration and expiration differences were not considered. In the RO subgroup, the left lung was closer to the X-ray tube. In the LO subgroup, the right lung was closer to the X-ray tube. We defined the body rotation by measuring clavicular symmetry, also the distance between the medial aspect of the anterior costal arches and spine.

We compared our study group to 66 control patients who did not have FBA but had normal chest X-ray performed for various reasons. We selected the control group patients subsequently from the same time period and same age group. The control group also was divided into symmetrical (33 patients) and asymmetrical (33 patients) subgroups.

Table 1
Distribution of the patient in the subgroups

	Study group	Control group
Symmetric projection	13	33
Asymmetric projection		
RO	12	19
LO	8	14
Total	33	66

RO: Right oblique projection.

LO: Left oblique projection.

RD ratio was compared between 13 patients in the symmetric FBA group and 33 patients in the normal symmetric control group, 12 patients in the RO FBA group and 19 patients in the normal RO control group, 8 patients in the LO FBA group and 14 patients in the normal LO control group (Table 1).

2.2. CT

All CT examinations were performed in emergency department without contrast by a 16-slice CT scanner in the supine position (The Philips Ingenuity CT 16-slice scanner, United States). The scanning parameters were 25–30 mA, 80–90 kV, depending on child age and weight, section thickness of 1 mm and reconstruction interval of 0.5 mm. The scan revolution time was 0.4 s. CT data was transferred from the archive to a workstation (Osirix MD 7 for MAC).

2.3. X-ray

In all patients, anterior-posterior screen-film chest X-ray was performed in the supine position (Us x-ray, SHF 835, Turkey). The examination parameters were 6–8 mA, 60–75 kV, depending on child age and weight. Radiographic data was transferred from the archive to a workstation (Osirix MD 7 for MAC). Radiodensity (Hounsfield unit; HU) of each lung was measured in ROI using borders of the cardiothymic silhouette, diaphragm and ribcage.

2.4. Statistical analysis

SPSS 22.0 was used for statistical analysis. The data was analyzed using independent samples *T*-Test. The parameters we used to compare the groups are the mean, standard deviation, maximum and minimum values of RD ratio. The data is expressed as mean \pm standard deviation of the mean.

3. Results

In the study group, there were 18 girls and 15 boys. Nineteen of 33 foreign bodies were detected in right bronchus and 14 in left bronchus on CT with air-trapping. In total 33 FBA patients, the RD ratio varied between 1.04 and 2.00 (1.18 ± 0.03) (Fig. 3). Thirteen of 33 FBA X-ray were symmetric (RD Ratio: 1.04–1.46; mean: 1.17 ± 0.05), 12 were right oblique (RD ratio: 1.05–1.36; mean: 1.11 ± 0.03), and 8 were left oblique (RD ratio: 1.16–2.00; mean: 1.29 ± 0.10).

In 33 symmetric control group, the RD ratio varied between 0.96 and 1.03 (mean: 1.00 ± 0.03). In 33 asymmetric control group (19 RO, 14 LO), the RD ratio varied from 0.84 to 1.08 (mean: 1.02 ± 0.01). Right/Left RD ratio was calculated in 19 normal RO control group (RD ratio: 0.92–1.08; mean: 1.01 ± 0.01) and Left/Right RD ratio was calculated in 14 normal LO control group (RD ratio: 0.84–1.07; mean: 1.04 ± 0.01) (Table 2).

When we compared the symmetric FBA group with the symmetric control group, the RD ratio was significantly higher in the study group (1.17 vs. 1.00 ; $p = 0.010$). The RD ratio increases in the presence of a foreign body in a symmetric radiograph. When we compared the RO

FBA group with the RO control group, the RD ratio was significantly higher in the study group (1.11 vs. 1.01 ; $p = 0.012$). When X-ray is right oblique, the RD ratio increases in the presence of a foreign body. When we compared the LO FBA group with the LO control group, the RD ratio was significantly higher in the study group (1.29 vs. 1.04 ; $p = 0.042$). When X-ray is left oblique, the RD ratio increases in the presence of a foreign body. In short, FBA changes aeration of affected lung and significantly increases the RD ratio not only on a symmetric radiograph but also on an asymmetric radiograph. There is not a significant difference in radiodensity ratio between the symmetric and asymmetric control groups ($p = 0.058$). Chest rotation in healthy people does not increase the RD ratio as much as in the study group.

4. Discussion

FBA is a common problem in children and may be life threatening. If the diagnosis is delayed or overlooked, many patients present with pneumonia, atelectasis or other complications. The radiologist plays an important role in the diagnosis. If radiologic findings are uncertain, expiratory images are of great help, as well as dynamic assessment of air-trapping with fluoroscopy that will show mediastinal shift toward the contralateral side during expiration. But, fluoroscopy is not always accessible in emergency department. Bilateral decubitus views have been used to simulate expiratory radiography. This technique may be helpful in the young non-cooperative children. Although bronchoscopy remains a very sensitive modality which makes possible both diagnosis and treatment, it is an invasive technique and has some complications such as hemorrhage, bronchial rupture or allergic reaction to anesthetic medications. CT can be performed in undiagnosed foreign body aspiration prior to bronchoscopy [6,14,15]. Main disadvantage of using CT is the additional ionizing radiation exposure which increases risk of future malignancy [11]. Therefore, we aimed to improve the diagnostic value of chest X-ray with a new radiographic method and suggest novel and practical approach also with numerical data on X-ray for the diagnosis of radiolucent FBA.

In this study, there is a significant difference between the RD ratios of FBA patients and both control groups. In patients with suspected FBA, the RD ratio increases in the presence of a foreign body because of air-trapping, regardless of whether the patient is rotated. In short, FBA changes aeration of affected lung and significantly increases the RD ratio not only on symmetric projection chest X-ray but also on asymmetric projection chest X-ray.

On X-ray, patient rotation can cause unilateral lung hyperlucency which mimics air trapping (Fig. 4). This is the most common cause of hyper-lucent lung and an important technical pitfall [13,16]. When the patient is rotated, the lung which is closer to the X-ray tube is exposed to high photon energy and can appear more lucent and be misinterpreted as more aerated. Inadequate X-rays in uncooperative children in the emergency department can further mislead the clinician. In our study, we used the RD ratio as a quantitative method to solve this problem. Our results show that, there is no significant difference between the RD ratios of symmetric and asymmetric X-rays in control group (RD ratio: 1.00 and 1.02, respectively). In other words, chest rotation does not affect the RD ratio in healthy people even if the X-ray is obtained with the patient in a rotated position.

Our results show that in all 3 subgroups of FBA patients the mean RD ratio was higher than 1.10 and we consider this could be the cut-off value to guide the clinician in the management of FBA patients. For patients with RD ratio ≥ 1.10 our suggestion is to proceed with bronchoscopy and to reserve CT scan for patients with RD ratio < 1.10 . By doing so, we can decrease number of children undergoing CT scan to avoid unnecessary ionizing radiation exposure.

To our knowledge, there is only one study in the literature which evaluated the utility of measuring lung radiodensity from chest X-ray for the diagnosis of foreign body aspiration [17]. Song, et al. measured lung radiodensity and radiodensity ratio (right/left lung radio density)

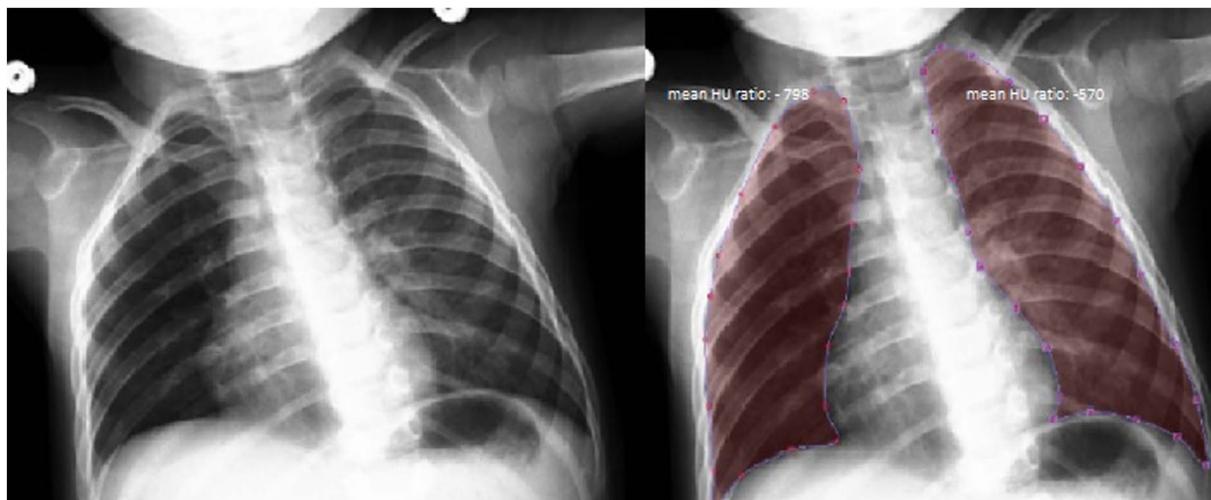


Fig. 3. AP X-ray of a patient with right bronchial FBA shows measurement of the mean HU in each lung. RD ratio is 1.4 (−798/−570).

Table 2
Distribution of HU ratios in the subgroups

	Control groups		study group			
	Symmetric	Asymmetric	Symmetric	Asymmetric		
		RO	LO	RO	LO	
HU ratio (mean)	1,00	1,01	1,04	1,17	1,11	1,29

RO: Right oblique projection.
LO: Left oblique projection.

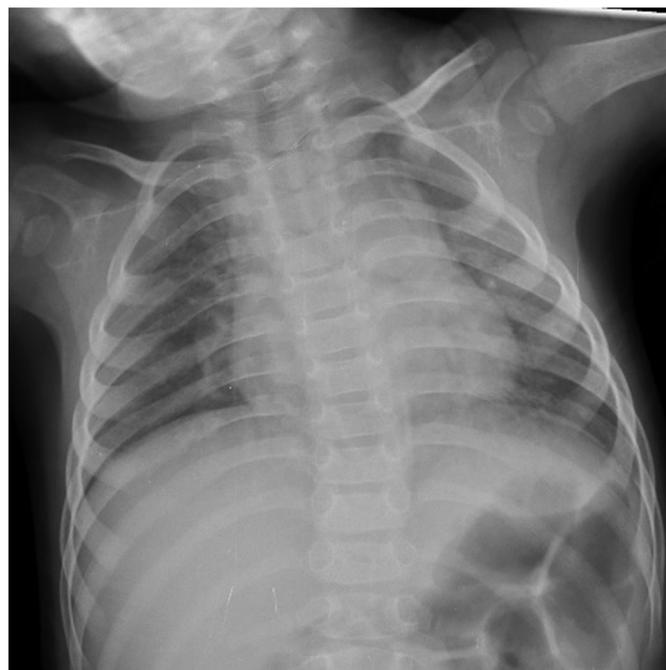


Fig. 4. Left oblique X-ray of a patient who doesn't have FBA mimics air-trapping in the right lung because of the chest wall rotation. But the RD ratio is 1.02 (< 1.10).

before and after foreign body removal. Radiodensity was calculated as the relative score compared with the tenth thoracic vertebra body (100 points) and the background (0 points). The change of radiodensity ratio (difference in radiodensity ratio of the second X-ray from that of first X-ray) was compared between 22 patients (foreign body group) and 22

normal subjects (control group). The mean radiodensity of the affected lung was lower than contralateral lung and it increased after foreign body removal. The change of radiodensity ratio in the foreign body group (17.8%) was higher than the control group (4.3%) ($p = 0.01$) and the cutoff value was 7.5%. They suggested that radiodensity of chest X-ray could be a useful tool like our study. However, we directly calculated the RD ratio of contralateral lungs. We think that drawing a ROI without using a formula may be simpler if it is used in cases of suspected air-trapping only. Also, they used 10th thoracic vertebra radiodensity as a fixed value but it isn't constant in every children which may change in some disorders such as osteopenia or osteosclerosis such as rickets, hypophosphatasia and osteopetrosis. In our study, we looked into the effect of body rotation which was emphasized as a limitation by Song, et al.

There are some limitations of our study. The numbers of patients were small especially among asymmetric radiographs. The major reason for that was we worked on patients who had just bronchial foreign body with air-trapping in acute period. Additionally, we chose the normal asymmetric control group which had minimal body rotation. Much more body rotation might change the parameters. Also, we didn't divide the radiographs as expiratory or inspiratory. Expiratory radiographs which are more sensitive to detect air-trapping can increase the RD ratio differences between study and control groups. Even in this situation, using RD ratio would be more valuable. Another limitation resides in the lung density discrepancy which is commonly encountered in normal children without FBA. In this scenario, one side of the film remains over-exposed whereas the other side under-exposed which leads to left-to-right lung gradient as a result of patient not being centered on X-ray beam. We did not consider the aforementioned artefactual effect in the results section. Further studies with controls are needed to draw a better conclusion.

5. Conclusion

The calculated radiodensity ratio between lungs on chest X-ray would be a useful and practical tool for the diagnosis of radiolucent FBA in children. For the patients with RD ratio ≥ 1.10 we would suggest bronchoscopy and we would reserve CT scan for patients with RD ratio < 1.10 . Children can be protected from relatively higher ionizing radiation exposure in CT compared to X-ray.

Conflict of interest

The authors declare that they have no conflicts of interest.

Funding source

No external funding was secured for this study.

Acknowledgments

We acknowledge Mr. Mehmet Ozturk in assisting to review the publications and Mr. Turker Acar for his assistance in the online literature search.

References

- [1] Bamber AR, Pryce J, Ashworth M, Sebire NJ. Fatal aspiration of foreign bodies in infants and children. *Fetal Pediatr Pathol* 2014;33:42–8.
- [2] Foltran F, Ballali S, Rodriguez H, Sebastian van As AB, Passali D, Gulati A, et al. Inhaled foreign bodies in children: a global perspective on their epidemiological, clinical, and preventive aspects. *Pediatr Pulmonol* 2013;48:344–51.
- [3] Goktas O, Snidero S, Jahnke V, Passali D, Gregori D. Foreign body aspiration in children: field report of a German hospital. *Pediatr Int* 2010;52:100–3.
- [4] Tang LF, Chen ZM. Fiberoptic bronchoscopy in neonatal and pediatric intensive care units: a 5-year experience. *Med Princ Pract* 2009;18:305–9.
- [5] Mantel K, Butenandt I. Tracheobronchial foreign body aspiration in childhood. A report on 224 cases. *Eur J Pediatr* 1986;145:211–6.
- [6] Arias Cruz A, González Dfáz SN, Galindo Rodríguez G, Canseco González C. Bronchial foreign body as a differential diagnosis for asthma. Report of a case and review of the literature. *Rev Alerg Mex* 2002;49:95–8.
- [7] Berk S, Uysal IO, Epozurk K, Altuntas EE, Dogan OT, Akkurt I. Laryngeal hirudiniasis as an unusual cause of massive hemoptysis. *J Otolaryngol Head Neck Surg* 2011;40:45–6.
- [8] Mortellaro VE, Iqbal C, Fu R, Curtis H, Fike FB, St Peter SD. Predictors of radiolucent foreign body aspiration. *J Pediatr Surg* 2013;48:1867–70.
- [9] Sink JR, Kitsko DJ, Georg MW, Winger DG, Simons JP. Predictors of foreign body aspiration in children. *Otolaryngol Head Neck Surg* 2016;155:501–7.
- [10] Bai W, Zhou X, Gao X, Shao C, Califano JA, Ha PK. Value of chest CT in the diagnosis and management of tracheobronchial foreign bodies. *Pediatr Int* 2011;53:515–8.
- [11] Martha S, Linet Kwang Pyo Kim, Rajaramanv Preetha. Children's exposure to diagnostic medical radiation and cancer risk: epidemiologic and dosimetric considerations *pediatr radiol.* 39. 2009. p. S4.
- [12] Paradis TJ, Dixon J, Tieu BH. The role of bronchoscopy in the diagnosis of airway disease. *J Thorac Dis* 2016;8:3826–37.
- [13] Crass JR, Cohen AM, Wiesen E, Shah Z. Hyperlucent thorax from rotation. *Anatomic Basis Invest Radiol* 1993;28:567–72.
- [14] Acharya Kunjan. Rigid bronchoscopy in airway foreign bodies: value of the clinical and radiological signs. *Int Arch Otorhinolaryngol* 2016;20:196–201.
- [15] Tong B, Zhang L, Fang R, Sha Y, Chi F. 3D images based on MDCT in evaluation of patients with suspected foreign body aspiration. *Eur Arch Otorhinolaryngol* 2013;270:1001–7.
- [16] Gronner AT, Ominsky SH. Plain film radiography of the chest: findings that simulate pulmonary disease. *AJR Am J Roentgenol* 1994;163:1343–8.
- [17] Song ES, Han DK, Cho HJ, Jeong IS, Yoon N, Ma JS, et al. Radiodensity on serial chest X-rays for the diagnosis of foreign body aspiration in children. *Indian Pediatr* 2015;52:663–7.