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Original Article

Diagnostic Value of Non-contrast Lung CT in Evaluating Pulmonary Cavitary Lesions in Children and Adolescents: With a Specific Focus in Perforated Hydatid Cyst, Necrotizing Pneumonia, and Lung Abscess

Shokrollah Hafez Eftekhari[1], Anahita Azinfar[2], Masoud Mahdavi Rashed[1], Mahdi Abdollahi Karizno[1]

[1]Department of Radiology, Mashhad University of Medical Sciences Faculty of Medicine, Mashhad, Iran
[2]Mashhad University of Medical Sciences School of Medicine, Mashhad, Iran

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ABSTRACT

OBJECTIVE: Accurate diagnosis of pulmonary cavitary lesions in children is essential for effective treatment and prevention of complications. While chest X-rays are commonly used, they lack the precision needed for detailed lesion characterization. Non-contrast high-resolution computed tomography (CT) scans offer superior imaging capabilities, particularly for cavitary lesions, though their use in pediatric patients must be balanced against radiation exposure risks. This study evaluates the diagnostic utility of non-contrast CT in distinguishing among hydatid cysts, necrotizing pneumonia, and lung abscesses by incorporating both clinical and imaging data.

MATERIAL AND METHODS: Conducted as a cross-sectional study at Akbar Hospital (Mashhad University of Medical Sciences) from 2021 to 2023, the study included pediatric patients who presented with pulmonary symptoms and underwent non-contrast lung CT. Statistical analyses involved chi-square tests for categorical variables and t-tests or non-parametric equivalents for continuous data. Diagnostic metrics such as sensitivity, specificity, predictive values, and accuracy were calculated.

RESULTS: Key radiological features that identify necrotizing pneumonia with high sensitivity and specificity include irregular lesion borders and fully aerated lesions. Additional indicators, such as pleural effusion heterogeneity and pneumothorax, further enhanced diagnostic accuracy. Hydatid cysts were reliably diagnosed by the presence of floating membranes and associated cystic structures, each demonstrating 100% specificity. In contrast, lung abscesses lacked distinctive imaging features, underscoring the need for further research.

CONCLUSION: Non-contrast CT is a valuable diagnostic tool for pediatric cavitary pulmonary lesions, particularly necrotizing pneumonia and hydatid cysts. The findings support the adoption of standardized imaging protocols to improve diagnostic precision and clinical outcomes.

KEYWORDS: Cavitary pulmonary lesions, non-contrast CT scan, necrotizing pneumonia, hydatid cyst, lung abscesses, children, adolescents

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INTRODUCTION

The accurate diagnosis of pulmonary cavitary lesions in children remains a clinical challenge. Chest radiography is typically the first-line imaging modality; however, its limited sensitivity and inability to adequately characterize complex lung lesions are well recognized. In contrast, computed tomography (CT) provides superior visualization of lung parenchyma and mediastinal structures and plays a key role in the evaluation of complicated pulmonary diseases.[1,2]

Corresponding author: Masoud Mahdavi Rashed, MD, e-mail: mahdavirm@mums.ac.ir

Pulmonary cavities most commonly result from infectious processes in children, including necrotizing pneumonia, lung abscess, and pulmonary hydatid disease. These entities differ significantly in their management and prognosis, making accurate differentiation essential. CT imaging offers high sensitivity for detecting cavitation and provides valuable morphological details such as wall thickness, air-fluid levels, and internal membranes, which aid in distinguishing among these conditions.[3,4]

Pulmonary hydatid disease, caused by Echinococcus granulosus, is particularly prevalent in endemic regions and commonly affects pediatric patients. Necrotizing pneumonia is a severe complication of bacterial infection and is characterized by parenchymal destruction and multiple irregular cavities, whereas lung abscess typically presents as a thick-walled cavity with an air-fluid level. CT findings are crucial for differentiating these entities and guiding appropriate treatment strategies.[5,6]

Despite the increasing use of lung CT in pediatric practice, concerns regarding radiation exposure necessitate careful evaluation of its diagnostic value, particularly when non-contrast protocols are used.[7]

Therefore, this study aims to assess the diagnostic value of non-contrast chest CT for differentiating cavitary pulmonary lesions in children at Akbar Hospital, Mashhad University of Medical Sciences between 2021 and 2023. To our knowledge, this is the first study in Iran focusing specifically on this topic.

MATERIAL AND METHODS

This descriptive-analytical study was conducted on pediatric patients who were referred to Akbar Hospital, Mashhad University of Medical Sciences, between 2021 and 2023 for evaluation of respiratory symptoms and who underwent non-contrast chest CT. The study was approved by the Ethics Committee of Mashhad University of Medical Sciences (IR. MUMS.IRH. REC.1403.115, date: 2024/08/05) and carried out in accordance with ethical principles, with confidentiality ensured and informed consent obtained from parents or legal guardians prior to patient enrollment. During the study period, a total of 2,225 chest CT examinations in pediatric patients were retrospectively reviewed. Among these, 300 patients were identified as having cavitary pulmonary lesions on CT imaging. These patients were evaluated retrospectively to determine their clinical course and final diagnoses. Of the 300 patients with cavitary lung lesions, 125 were children who underwent surgical intervention, which provided definitive pathological confirmation of the diagnosis. All 125 surgically treated patients were included in the final study population and constituted the study cohort.

Main Points

- Non-contrast lung computed tomography (CT) provides valuable diagnostic information for evaluating pulmonary cavitary lesions in children and adolescents.
- Specific CT findings, including irregular lesion borders and complete intralesional aeration, demonstrate high sensitivity and specificity for diagnosing necrotizing pneumonia.
- The presence of floating membranes and associated cystic structures on CT is highly specific for the diagnosis of a perforated pulmonary hydatid cyst.
- Lung abscesses do not show sufficiently distinctive imaging features on non-contrast CT, which indicates the need for further diagnostic evaluation and research.
- Standardized interpretation of CT imaging features can improve diagnostic accuracy and guide appropriate clinical management of pediatric cavitary lung lesions.

Exclusion criteria included patients without cavitary lesions on CT; patients with cavitary lesions who did not undergo surgical intervention; individuals with incomplete clinical or follow-up data (including outpatients); patients unwilling to participate; and cases in which a definitive diagnosis could not be established.

The final diagnoses of the included patients were confirmed by surgical intervention followed by histopathological examination. Among the 125 included patients, 38 were diagnosed with hydatid cysts, 63 with necrotizing pneumonia, and 24 with lung abscesses.

Although necrotizing pneumonia is primarily managed conservatively, surgical intervention was performed in selected cases due to failure of medical treatment or the development of complications. Indications for surgery in patients with necrotizing pneumonia included a lack of clinical or radiological improvement despite appropriate antibiotic therapy, persistent or enlarging cavitary lesions, suspicion of alternative diagnoses, development of complications such as lung abscess formation, bronchopleural fistula, empyema, or massive hemoptysis. Therefore, the necrotizing pneumonia cases included in this study represent a selected subgroup of surgically managed patients and do not reflect the overall population of children with necrotizing pneumonia.

Data collection was performed using a standardized and validated checklist designed to capture demographic information, clinical presentations, and imaging findings. Specific variables related to cavitary lesions were systematically evaluated, including wall thickness; aeration patterns (fully aerated, fluid-air level, or air-bubble pattern); presence of floating membranes or the "water lily sign"; presence or absence of soft tissue within the cavity; and communication between the cavity and the bronchus. Additionally, the presence of pleural effusion, laterality (unilateral or bilateral), and homogeneity or heterogeneity (heterogeneity assessed by densitometry) were assessed.

All CT scans were performed using a Canon Aquilion 16-slice CT scanner, manufactured by Toshiba. The scanning protocols, including kilovoltage and milliampere settings, were adjusted based on each patient's body weight to optimize image quality and minimize radiation exposure.

Statistical Analysis

The reports were interpreted by an experienced radiologist, blinded to the patients' initial clinical diagnoses. Patients were followed up and their final diagnoses were recorded. The final diagnoses for all patients, encompassing necrotizing

pneumonia, hydatid cysts, and lung abscesses, were confirmed through surgical intervention followed by histopathological examination. All collected data were entered into SPSS software for analysis.

For statistical analysis, quantitative variables were summarized using the mean and standard deviation or the median and interquartile range, depending on the data distribution, while qualitative variables were reported as frequencies and percentages. Relationships between qualitative variables were analyzed using the chi-square test, while independent t-tests or their non-parametric equivalents were employed to compare quantitative variables. Additionally, diagnostic performance metrics of CT scans, including sensitivity, specificity, positive predictive value (PPV), negative predictive value, and overall diagnostic accuracy, were calculated, with statistical significance set at a *P* value of less than 0.05.

RESULTS

Evaluation of Wall Thickness in Differentiating Hydatid Cyst, Abscess, and Necrotizing Pneumonia

The descriptive statistical analysis of the study variables revealed significant differences in cavity wall thickness across different disease groups. The mean cavity wall thickness in patients with hydatid cysts was 5.637 mm, the highest among the groups. In patients with necrotizing pneumonia, the mean thickness was 4.45 mm, whereas in lung abscess cases it was the lowest at 3.621 mm. The overall mean thickness was calculated as 4.825 mm, with a range of 2 to 10 mm. This variation in wall thickness may indicate differing levels of tissue involvement and disease progression among these conditions (Table 1).

Receiver operating characteristic (ROC) curve analysis of wall thickness measurements for differentiating hydatid cysts, abscesses, and necrotizing pneumonia showed that the areas under the curve (AUCs) for abscess and necrotizing pneumonia were below 70%, indicating poor diagnostic performance. However, the AUC for hydatid cyst was 83%, suggesting good discriminative ability.

Based on ROC analysis, a wall thickness cut-off of 3.9 mm demonstrated a sensitivity of 90% and a specificity of 60.9%, whereas a cut-off of 4.15 mm yielded a sensitivity of 80% and a specificity of 74%. These findings suggest that increasing the wall thickness threshold enhances specificity but may reduce sensitivity, highlighting the importance of selecting an appropriate cut-off value for accurate differentiation of pulmonary cavitary lesions.

These results suggest that wall thickness can be a useful parameter in distinguishing hydatid cyst from abscess and necrotizing pneumonia, with an optimal threshold in the specified range providing a balance between sensitivity and specificity (Figure 1).

Analysis of Imaging Findings and Lesion Characteristics

In this study, 81.6% of cases presented with a single lesion, while 18.4% exhibited multiple lesions, suggesting that solitary cavitary lung lesions were the predominant pattern. Regarding lesion distribution, 11.2% of cases showed spread to other lung regions, indicating a more severe disease course in these patients. Regarding lesion borders, 61.6% had irregular margins, while 38.4% had regular margins, reflecting heterogeneity in the growth and evolution of these lesions. The location of lesions within the lung varied: 19.2% were centrally located, 31.2% were peripherally distributed, and 49.6% exhibited a mixed (central and peripheral) pattern. This distribution may suggest different pathogenic mechanisms for each condition.

Diagnostic Criteria for Necrotizing Pneumonia

The most reliable imaging indicators for necrotizing pneumonia were:

Irregular pattern, with 92.06% sensitivity and 69.35% specificity, making it the strongest predictor. Fully aerated lesion, with 82.54% sensitivity and 72.58% specificity, providing a well-balanced diagnostic marker. Pleural effusion heterogeneity, with a specificity of 80% and a PPV of 78.58%.

Pneumothorax had a specificity of 90.16% and a PPV of 80%, indicating that, while uncommon, its presence strongly

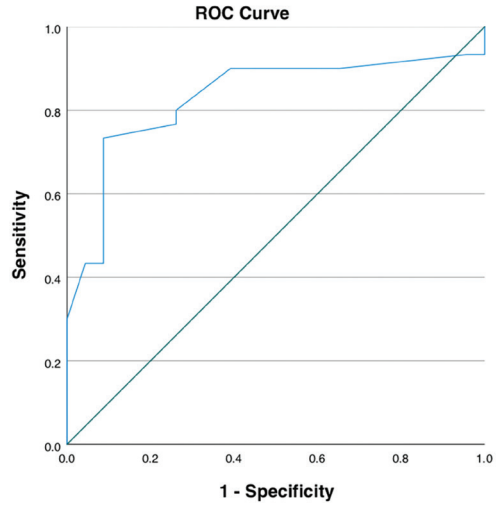

Figure 1. Receiver operating characteristic (ROC) curve analysis for the diagnostic performance of the proposed method. The area under the curve demonstrates high sensitivity and specificity in distinguishing wall thickness

Table 1. Diagnostic performance metrics for necrotizing pneumonia using the proposed imaging criteria

Variable	Group	Number (n)	Mean	Standard deviation	%95 confidence interval
Wall thickness	Hydatid cyst	30	5.637	1.8797	4.935–6.339
	Necrotizing pneumonia	4	4.450	1.6763	1.783–7.117
	Abscess	19	3.621	0.6152	3.325–3.918
	Total	53	4.825	1.7844	4.333–5.316

suggests necrotizing pneumonia. On the other hand, floating membranes and associated cysts had 0% sensitivity, confirming their irrelevance in diagnosing necrotizing pneumonia. The presence of a regular lesion pattern also had very low sensitivity (7.94%), making it an unreliable marker for this condition (Table 2).

Diagnostic Criteria for Hydatid Cyst

The most definitive diagnostic criteria for hydatid cysts included:

Floating membranes, with 100% specificity and PPV, confirming that when a membrane is observed, hydatid cyst is almost certain.

Associated cysts, also with 100% specificity and PPV, reinforcing its diagnostic reliability.

However, consolidation had high sensitivity (86.84%) but very low specificity (9.2%), indicating that while consolidation is commonly seen in hydatid cysts, it is also prevalent in other lung conditions. Similarly, diffuse involvement had only 19.95% specificity, making it an unreliable diagnostic feature for hydatid cysts (Table 3).

Diagnostic Criteria for Pulmonary Abscess

Key diagnostic indicators for lung abscess included:

No qualitative imaging attributes were identified as reliable diagnostic indicators for lung abscesses. Conversely, floating membranes and associated cysts were poor diagnostic features of abscess, with 0% sensitivity, indicating that these characteristics are not helpful in distinguishing abscess from other conditions. Additionally, bronchial communication and pneumothorax demonstrated low sensitivity, further confirming their limited role in the diagnosis of abscesses (Table 4).

Overall Diagnostic Implications

The findings of this study highlight the most effective imaging criteria for distinguishing between necrotizing pneumonia, hydatid cyst, and lung abscess:

For necrotizing pneumonia, irregular, fully aerated lesions, pleural effusion heterogeneity, and pneumothorax were the strongest markers, while associated cysts and floating membranes were irrelevant.

For hydatid cysts, floating membranes and associated cysts had the highest diagnostic accuracy, making them nearly definitive for diagnosis. Conversely, no distinct qualitative imaging characteristics were identified as reliable diagnostic markers for lung abscesses.

Imaging-based Diagnostic Highlights

Lesion margins, aeration patterns, and specific signs such as floating membranes and associated cystic lesions played crucial roles in differentiating among hydatid cysts, necrotizing pneumonia, and lung abscesses.

Table 2. Information on ANOVA analysis for necrotizing pneumonia

Characteristics for predicting necrotizing pneumonia	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Accuracy %	%95 confidence interval
Solitary	87.30	24.19	53.92	65.22	56	46.84–64.86
Irregular border	92.06	69.35	75.32	89.58	80.80	72.79–87.29
Fully aerated	82.54	72.58	75.36	80.36	77.6	69.28–84.57
Associated cysts	0	77.42	0	43.24	38.40	29.84–47.52
Floating membranes	0	69.35	0	40.07	34.34	26.14–43.42
Heterogeneous effusion	48.89	80.0	78.57	51.06	61.33	49.38–72.36
Consolidation	96.83	17.74	54.46	84.62	57.60	48.44–66.39
Pneumothorax	38.1	90.16	80	58.51	63.71	54.6–72.15

Table 3. Comparison of sensitivity, specificity, and accuracy values across the study

Characteristics for predicting hydatid cyst	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Accuracy %	%95 confidence interval
Solitary	79.17	17.82	18.63	78.26	29.60	21.77–38.42
Diffuse	18.42	91.95	50.00	72.07	69.60	60.74–77.51
Regular border	63.16	72.41	50.00	81.82	69.60	60.74–77.51
Associated cysts	36.84	100	100	78.38	80.80	72.79–87.29
Floating membranes	50.00	100	100	82.08	84.80	77.29–90.59
Homogeneous effusion	83.33	47.06	42.55	85.71	58.67	46.70–69.92
Consolidation	86.84	9.20	29.46	61.54	32.80	24.67–41.77
Pneumothorax	16.22	72.41	20	67.02	55.65	46.45–64.56

ANOVA: analysis of Variance

Irregular lesion margins were reliable features of necrotizing pneumonia (Figure 2A), whereas smooth, regular margins were seen in hydatid cysts (Figure 2B) and lung abscesses (Figure 2C).

Complete aeration of the cavity was a dependable characteristic in necrotizing pneumonia (Figure 3A), although air-fluid levels and air bubbles were not effective qualitative indicators for distinguishing among these three diseases (Figure 3B and 3C).

Heterogeneous pleural effusion patterns were most notable in necrotizing pneumonia (Figure 4A), whereas homogeneous effusions were seen in hydatid cysts (Figure 4B) and abscesses (Figure 4C).

The presence of floating membranes and associated cystic lesions was highly specific for hydatid cysts and was not observed in other conditions. Floating membranes were visualized within the cystic cavity (Figure 5A), and associated cystic lesions with fluid-density areas were observed in different lobes (Figure 5B). These signs provide high diagnostic specificity for hydatid disease.

Additional Findings on Floating Membrane Presence

A notable finding in this study was the association between the floating membrane and disease type. The results of the chi-square test (P = 0.000) demonstrated a highly significant

Table 4. Statistical evaluation of diagnostic performance indices

Characteristics for predicting abscess	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %	Accuracy %	%95 confidence interval
Diffuse	0	86.14	0	78.38	69.6	60.74–77.51
Regular border	79.17	71.39	39.58	93.51	72.8	64.12–80.37
Air fluid level	75	71.29	38.30	92.31	72	63.27–79.66
Air bubble	8.33	93.07	22.22	81.03	76.80	68.41–83.88
Floating membranes	0	81.19	0	77.36	65.6	56.58–73.86
Associated cysts	0	86.14	0	78.38	69.6	60.74–77.51
Bronchial communication	0	89.11	0	78.95	72	63.27–79.66
Homogeneous effusion	66.67	37.68	8.51	92.86	40	28.85–51.96
Pneumothorax	0	70	0	74.47	56.45	47.26–65.33

ANOVA: analysis of Variance

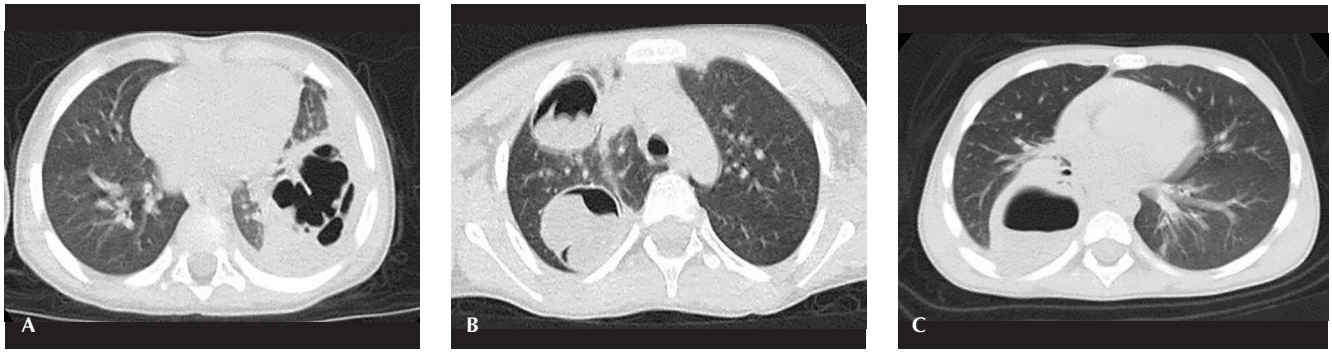

Figure 2. Cavity margin characteristics. (A) Irregular margin in a patient with necrotizing pneumonia. (B) Smooth and well-defined margin in a patient with hydatid cyst. (C) Smooth and defined margin in a patient with lung abscess

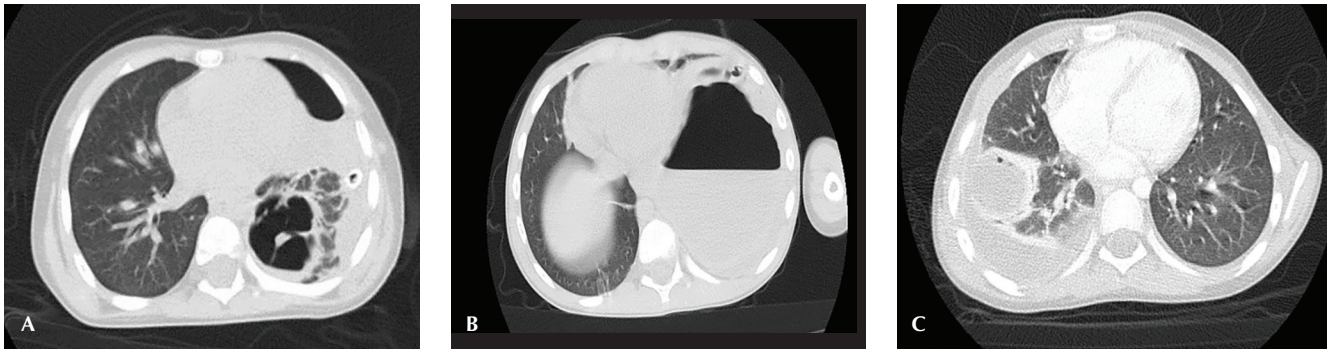

Figure 3. Air patterns within cavitary lesions. (A) Completely aerated cavity in necrotizing pneumonia. (B) Air-fluid level in a patient with diagnosis of hydatid cyst. (C) Presence of air bubbles in a patient with diagnosis of lung abscess

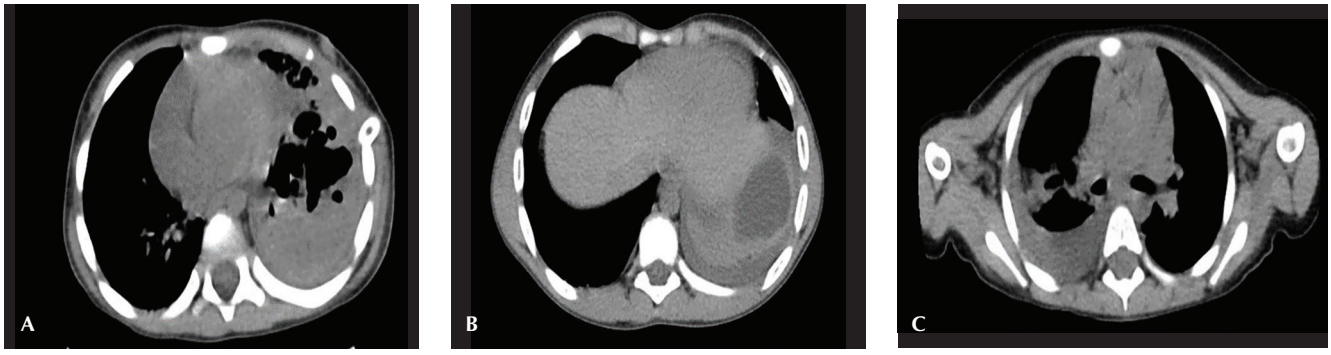

Figure 4. Pleural effusion characteristics. (A) Heterogeneous pleural effusion in necrotizing pneumonia. (B) Homogeneous pleural effusion in hydatid cyst. (C) Homogeneous pleural effusion in lung abscess

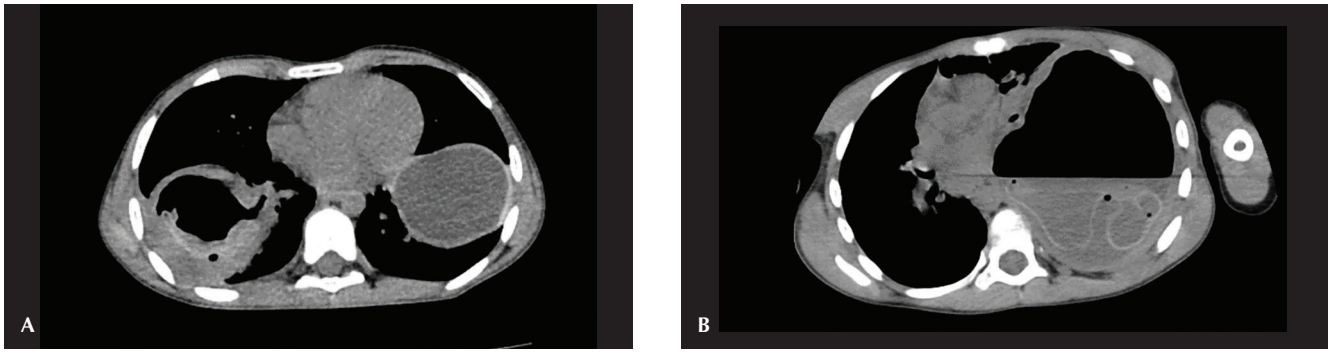

Figure 5. Hydatid-specific features. (A) Floating membranes within the cavity, highly suggestive of hydatid cyst. (B) A cavitary lesion in the right lung and an associated cystic lesion with fluid density in the left lung, suggestive of a hydatid cyst

relationship, confirming that the presence of a floating membrane is a strong indicator of a hydatid cyst, whereas none of the patients with necrotizing pneumonia or abscess exhibited membrane structures.

DISCUSSION

Summary of Key Findings

This study evaluated the diagnostic value of non-contrast chest CT in differentiating pediatric cavitary pulmonary lesions, focusing on hydatid cysts, necrotizing pneumonia, and lung abscesses. Our findings demonstrate that several CT features—including cavity wall characteristics, internal aeration patterns, the presence of floating membranes or associated cysts, pleural effusion, and pneumothorax—show distinct distributions among these entities. Non-contrast CT provided sufficient diagnostic information to reliably differentiate hydatid cysts from necrotizing pneumonia, whereas lung abscesses demonstrated more overlapping and non-specific imaging features. These results support the clinical utility of non-contrast CT as an effective first-line imaging modality in children with cavitary lung lesions.

Diagnostic Implications of Computed Tomography Findings

Accurate differentiation of cavitary lung lesions remains a diagnostic challenge due to overlapping clinical and radiological presentations. In our cohort, necrotizing pneumonia was more commonly associated with irregular lesion borders, fully aerated cavities, pleural effusion heterogeneity, and pneumothorax. In contrast, hydatid cysts demonstrated more specific imaging characteristics, including floating membranes and associated cystic lesions, which are well-recognized diagnostic indicators. Lung abscesses, however, lacked distinctive qualitative CT features, underscoring the need for further studies to establish more reliable imaging criteria for this subgroup. These findings highlight the value of pattern recognition on non-contrast CT in guiding accurate diagnosis and timely clinical management.

Role of Non-contrast Computed Tomography in Pediatric Imaging

Radiation exposure is a major concern in pediatric imaging, and minimizing dose without compromising diagnostic accuracy is a key priority. In this context, our study emphasizes that non-contrast CT can provide adequate diagnostic detail for evaluating cavitary lung lesions in children, potentially avoiding unnecessary contrast administration or repeat imaging. Dose optimization strategies—such as adjusting tube current based on body weight and using appropriate reconstruction techniques—allow CT to be performed safely while maintaining diagnostic confidence. Importantly, our findings do not argue against CT use, but rather support optimized and judicious CT utilization in pediatric patients.

Comparison with Other Imaging Modalities and Previous Studies

Alternative imaging modalities, such as lung ultrasound and magnetic resonance imaging (MRI), have been proposed as complementary tools in selected pediatric cases. Ultrasound

may be useful for assessing pleural complications, particularly in necrotizing pneumonia, while MRI offers superior soft-tissue contrast in complex lesions. However, both modalities have limitations in routine evaluation of air-containing lung parenchyma and are less practical in acute clinical settings. Therefore, CT—particularly non-contrast CT—remains the most informative and accessible modality for the initial evaluation of cavitary pulmonary lesions.

Our findings are consistent with previous studies, including Naggar et al.[3], who emphasized the importance of recognizing CT patterns in narrowing differential diagnoses of lung cavitation. Carrard et al.[8] reported that CT was superior to ultrasound in detecting parenchymal necrosis and cavitation, while Erdem and Erdem[9] demonstrated the superiority of CT over chest radiography in characterizing hydatid cysts. Collectively, these studies support the central role of CT in pediatric cavitary lung disease, aligning with our results.

Clinical Impact and Future Directions

By identifying reliable CT-based imaging markers, this study contributes to improved clinical decision-making and to more targeted patient management. Integrating radiological findings with clinical and pathological data can reduce diagnostic uncertainty and help avoid unnecessary contrast-enhanced or repeated CT examinations. Future research should focus on multicenter validation of these imaging criteria, the selective role of MRI in problem-solving scenarios, and the development of standardized diagnostic algorithms for pediatric cavitary lung lesions.

Strengths and Study Limitations

The strengths of this study include a well-defined pediatric cohort with surgically and histopathologically confirmed diagnoses, a blinded interpretation of CT images by an experienced radiologist, and an exclusive evaluation of non-contrast CT, reflecting real-world pediatric imaging practice.

Several limitations should be acknowledged. The retrospective design may introduce selection bias and result in incomplete data. The study was conducted at a single tertiary referral center, which may limit the generalizability of the findings. Additionally, only surgically managed cases were included, representing a subset of patients with more severe disease. Chest radiography findings were not systematically analyzed because variability in acquisition and reporting prevented direct comparison with CT. Finally, the relatively limited sample size may have reduced statistical power for subgroup analyses.

CONCLUSION

This study provides critical insights into the radiological evaluation of pediatric cavitary lung lesions, highlighting key diagnostic features that can improve clinical decision-making. By addressing current diagnostic challenges and proposing evidence-based solutions, such as radiation dose reduction, standardized diagnostic criteria, and alternative imaging techniques, this research contributes to enhancing pediatric imaging practices and optimizing patient care. Future studies should validate these findings through multicenter trials and exploring novel imaging techniques to ensure the best possible outcomes for pediatric patients.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of Mashhad University of Medical Sciences (IR. MUMS.IRH.REC.1403.115, date: 2024/08/05).

Informed Consent: Informed consent obtained from parents or legal guardians prior to patient enrollment.

Footnotes

Authorship Contributions

Concept: S.H.E., M.M.R., Design: S.H.E., M.M.R., Data Collection or Processing: A.A., M.A.K., Analysis or Interpretation: A.A., Literature Search: M.M.R., Writing: S.H.E., M.A.K.

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

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