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Original Research Article

A COMPARATIVE ANALYSIS OF CHEST ULTRASONOGRAPHY AND HIGH-RESOLUTION CT IN THE DIAGNOSIS AND EVALUATION OF INTERSTITIAL LUNG DISEASES

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Abstract

Background: Recent findings indicate the potential utility of lung ultrasound (LUS) in detecting interstitial lung disease (ILD) through the assessment of B-lines, a sonographic indicator of pulmonary interstitial syndrome. However, there is a lack of prospective studies comparing LUS to chest X-ray (CXR) for ILD evaluation. Additionally, consensus on specific echographic diagnostic criteria for defining ILD remains elusive. The current study aimed to determine the role of transthoracic LUS in diagnosing and assessing ILD and to correlate its findings with HRCT.

Methods: A total of 40 Patients with interstitial lung disease (ILD), meeting clinical, laboratory, or radiological criteria and consenting to participate, were enrolled in the current study. Clinical evaluations, including history, physical examination, and a questionnaire covering personal data, medical history, environmental and drug exposure, and symptoms (Borg test dyspnea score and Borg test for pre- and post-effort fatigue), were conducted. Participants underwent chest ultrasound and high-resolution computed tomography (HRCT), categorized by Warrick's score into mild, moderate, and severe ILD groups.

Results: Chest ultrasound revealed a total B-lines score of 71.24 ± 31.25 and the mean positive chest areas score of 6.69 ± 2.62. Concurrently, significant HRCT findings indicated that ground-glass opacification (GGO) was observed in 20 (50%) patients, and a reticulonodular interstitial pattern (RNP) was observed in 15 (37.5%) patients. There is an increased prevalence of cases exhibiting elevated B-lines scores in the lower lung areas (Area 3 and Area 4) in comparison to the upper lung areas (Area 1 and Area 2). The correlation between Warrick score and B-lines distance with a coefficient of -0.910, indicates a strong negative correlation.

Conclusion: In conclusion, while no imaging modalities can fully replace the comprehensive information provided by chest HRCT, which remains the gold standard for assessing pulmonary fibrosis, LUS in ILD presents itself as a useful, cost-effective, accessible, and radiation-free investigative tool.

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Keywords: Interstitial Lung Disease, Lung Ultrasound High-Resolution, Computed Tomography, B-line.

Introduction

Interstitial lung disease (ILD) is characterized by the thickening of the pulmonary interstitium the spaces between the alveolar epithelium and capillary endothelium resulting in impaired gas exchange. [1] This condition typically arises from various etiologies. ILD encompasses a group of disorders marked by combinations of inflammation and fibrosis, which may be idiopathic or triggered by exposure to organic and inorganic substances (e.g., pneumonitis and pneumoconiosis), medical conditions (e.g., connective tissue diseases [CTDs], multisystem diseases, drugs, infection, and radiation therapy). The understanding of the epidemiology of interstitial lung diseases (ILDs) in India is still evolving due to limited data available from national registries. Nevertheless, available studies indicate that ILDs constitute a significant cause of morbidity and mortality in the country. Current estimates suggest that the prevalence of ILDs in India falls within the range of 49.0 to 98.1 cases per 100,000 population, with an annual incidence ranging from 10.1 to 20.2 cases per 100,000 population. [2] While these figures are lower than those reported in developed countries, they underscore a considerable burden of disease. The most common causes of ILDs in India differ from those in developed countries. Sarcoidosis emerges as the predominant ILD in India, followed by hypersensitivity pneumonitis (HP), connective tissue disease (CTD)-ILD, and idiopathic pulmonary fibrosis (IPF). [3] This contrasts with developed countries, where IPF is the most prevalent ILD. Similar to other regions, the risk factors for ILDs in India encompass exposure to environmental pollutants, occupational hazards, and smoking. [4] However, there are specific risk factors more prevalent in India, such as exposure to indoor air pollution resulting from biomass fuel use and exposure to silica dust in occupational settings.

The evaluation of ILD relies on a comprehensive analysis of clinical, functional, radiological, and histological data. High-resolution CT of the chest (HRCT) is the gold standard for diagnosing ILD. [5] However, lung ultrasound (LUS) has gained increasing importance in assessing various thoracic conditions and pleural effusions. Limited data are available on the use of LUS, both in monitoring patients with lung pathology and as a screening modality for assessing lung diseases. A key finding in LUS is the presence of B-lines, which can be unifocal or multifocal with variable arrangement. The identification of ≥3 B-lines between two ribs in the same scan is indicative of interstitial syndrome. [6] Overall, B-lines, consolidation, and pleural irregularities discovered by LUS suggest lung pathology. Given its relative affordability, portability, and safety, there is growing interest in using LUS for the diagnosis of various chest diseases, ushering in the era of LUS. However, its diagnostic efficacy needs careful consideration in comparison to standard available tools. The current study aimed to determine the role of transthoracic LUS in diagnosing and assessing ILD and to correlate its findings with HRCT considered the gold standard diagnostic modality.

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Material and Methods

This cross-sectional study was carried out in the Department of Respiratory Medicine in collaboration with the Department of Radiology, Navodaya Medical College Hospital and Research center, Mantralayam Road Navodaya Nagar Raichur, Karnataka. Institutional Ethical Committee approval was obtained for the study based on the Helsinki Declaration for Human research protocol. Written consent was obtained from all the participants of the study after explaining the nature of the study in the vernacular language. Participants provided informed consent, and their rights were protected, ensuring the confidentiality of collected data.

Patients with interstitial lung disease (ILD), who met clinical, laboratory, or radiological criteria and consented to participate, were enrolled in the current study. Exclusions comprised individuals with left-sided heart failure, bronchiectasis, aspiration pneumonia, and chronic kidney disease. Clinical evaluations, including history, physical examination, and a questionnaire covering personal data, medical history, environmental and drug exposure, and symptoms (Borg test dyspnea score and Borg test for pre- and post-effort fatigue), were conducted. A six-minute walk test assessed distance versus significant desaturation (>3%). Participants underwent chest ultrasound and high-resolution computed tomography (HRCT), categorized by Warrick's score into mild, moderate, and severe ILD groups.

Following diagnostic exams and HRCT, all patients underwent lung ultrasound (LUS) in 10 intercostal spaces, as previously described. Evaluation of B-line distribution and pattern was conducted, recording total numbers. The sum of B-lines in all lung areas constituted the total score, subsequently simplified by summing positive chest areas (where ≥3 B-lines were present). Both scores (total and simplified) were correlated with the HRCT score (Warrick's score). Respiratory functions were assessed using standard spirometry conducted with the RMS Helios 702 Portable Spirometer (PFT). Arterial blood gases were analyzed using the OPTI CCA-TS blood gas analyzer. *Statistical analysis:* The collected data were recorded, presented, and statistically analyzed using SPSS version 22 (SPSS Inc., Chicago, IL, U.S.A). Continuous variables were represented as mean standard deviations and percentages. The chi-square test, and Fisher's exact test for categorical data analysis, were employed. Independent two-sample t-tests or Mann-Whitney-U tests were applied to compare continuous variables between two groups, while a one-way analysis of variance was used for more than two groups with a P value equal to or less than 0.05 considered statistically significant.

Results

The distribution of cases of interstitial lung disease (ILD) included in the study, by age group and gender is depicted in Table 1. There were a total of 40 cases of ILD, with 24 males (60%) and 16 females (40%). The most

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common age group was 61-70 years, which accounted for 30% of cases. The range of age of the cohort was 20 - 78 years. The mean age was 55.3 ± 10.5 years. ILD is more common in males than in females. The disease is also more common in older adults, with the majority of cases occurring in people over the age of 60. These findings show that the disease is more common in men and older adults. One of the reasons for this is that age-related changes in the immune system may play a role.

Table 1: Distribution of cases of ILD included in the study

Age group	*Male*	*Female*	*Total (%)*
18 – 20	1	0	1(2.5%)
21 – 30	1	2	3(7.5%)
31 – 40	4	2	6(15.0%)
41 – 50	5	3	8(16.0%)
51 – 60	6	3	8(16.0%)
61 – 70	7	6	12(30.0%)
Total	24	16	40(100%)

The mean weight is 82.5 kg, with a standard deviation of 15.2 kg. The range of weights is from 51 kg to 110.5 kg. The mean height is 1.67 m, with a standard deviation of 0.082 m. The range of heights is from 1.48 m to 1.81 m. The mean BMI is 25.52 kg/m^2, with a standard deviation of 2.25 kg/m^2. The range of BMIs is from 18.99 kg/m^2 to 33.32 kg/m^2. These findings suggest that people with ILD tend to be overweight or obese.

Table 2: Chest ultrasound and high-resolution CT findings in cases of ILD patients

Category	*Variable*	*Value*
Chest ultrasound Findings	Total B-lines	71.24 ± 31.25
	Positive Chest areas [≥ 3 B-lines]	6.69 ± 2.62
	Pleural line (Thickened)	10 (25%)
	Pleural line (Smooth)	19 (47.5%)
	Pleural line (Irregular)	11 (27.5%)
High-resolution CT Findings	GGO	20 (50%)
	Reticulonodular interstitial pattern	15 (37.5%)
	Honeycombing	5 (12.5%)
	Crazy paving	3 (7.5%)
	Consolidation	8 (20%)

Table 2 summarizes the chest ultrasound and high-resolution CT (HRCT) findings among patients diagnosed with interstitial lung disease (ILD). Chest ultrasound revealed a total B-lines score of 71.24 ± 31.25 and the mean positive chest areas score of 6.69 ± 2.62. Concurrently, significant HRCT findings indicated that ground-glass opacification (GGO) was observed in 20 (50%) patients, and a reticulonodular interstitial pattern (RNP) was observed in 15 (37.5%) patients. These findings align with well-documented patterns of

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ILD on both chest ultrasound and HRCT. The presence of B-lines, pleural thickening, and pleural effusion on chest ultrasound suggests alveolar septal thickening and inflammation. Conversely, the presence of GGO, RNP, honeycombing, and crazy paving on HRCT indicates fibrosis and architectural distortion of the lung parenchyma. It's crucial to note that specific HRCT findings may vary depending on the particular type of ILD. For instance, honeycombing is more prevalent in idiopathic pulmonary fibrosis (IPF), whereas GGO is more commonly associated with nonspecific interstitial pneumonia (NSIP).

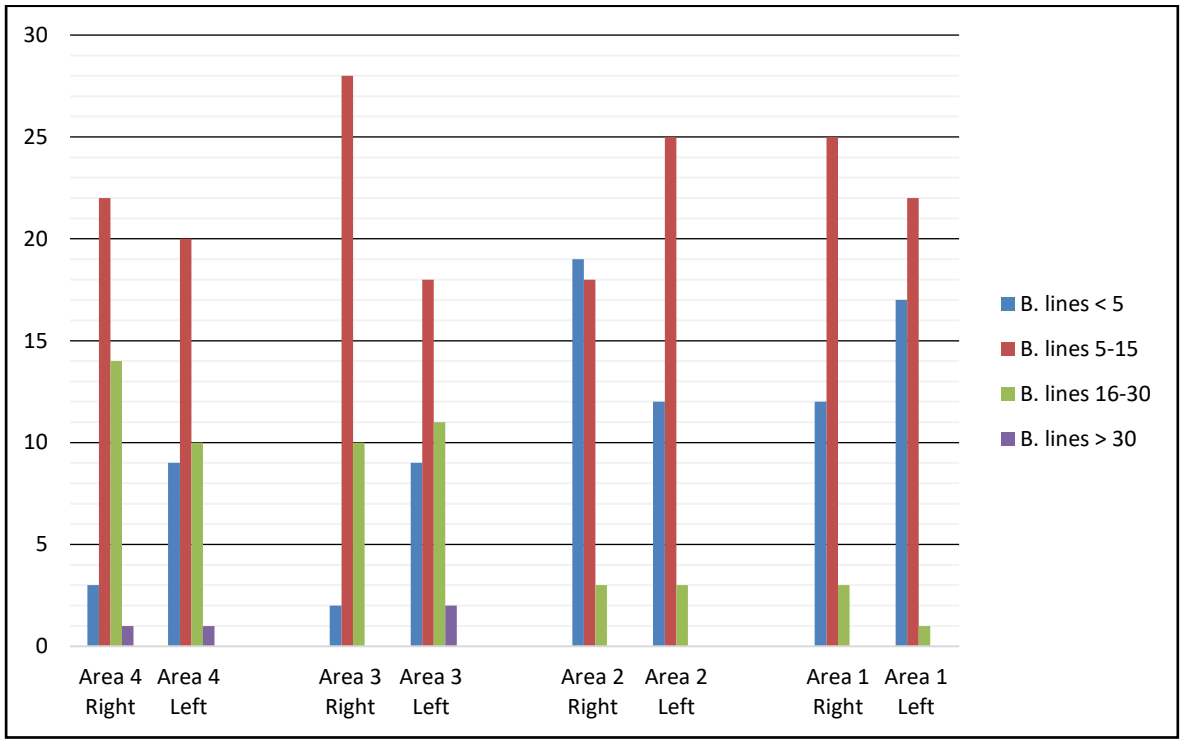

Figure 1: Showing distribution of the studied cases according to the LUS

Figure 1 illustrates the distribution of B-line scores among 40 cases of interstitial lung disease (ILD) based on lung areas (Area 1, Area 2, Area 3, and Area 4) and sides (right and left). The B-lines scores are categorized into four groups: <5, 5-15, 16-30, and >30. A notable observation is the higher prevalence of cases with elevated B-lines scores in the lower lung areas (Area 3 and Area 4) compared to the upper lung areas (Area 1 and Area 2). Additionally, there is a higher frequency of cases with increased B-lines scores on the right side compared to the left side. These findings align with established patterns of B-lines distribution in ILD, where B-lines are associated with thickening of the alveolar septa, a common characteristic of ILD. The lower lung areas are more susceptible to alveolar septal thickening due to gravitational effects. Moreover, the increased prevalence of B-lines on the right side is consistent with lung anatomy, as the right lung is slightly larger and has a more vertical orientation, potentially making it more susceptible to gravity-induced effects and alveolar septal thickening.

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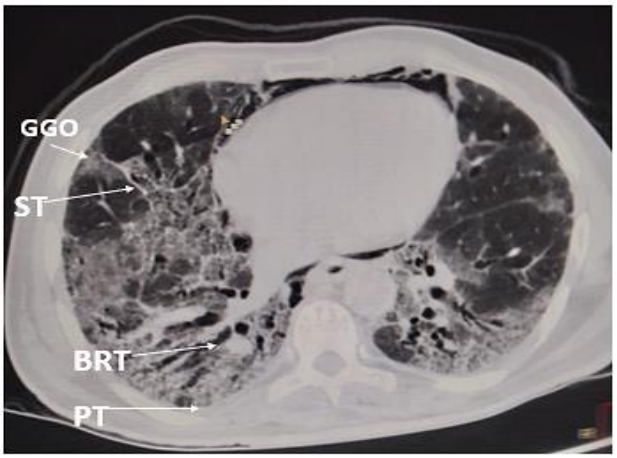

Figure 2: A chest CT scan showing GGO – ground glass opacity, ST – septal thickening, BRT – bronchiectasis changes, PT – Pleural thickening

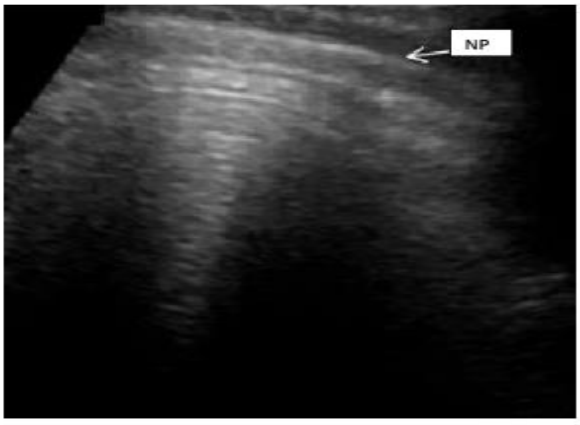

Figure 3: Lung ultrasound indicating Normal Pleura

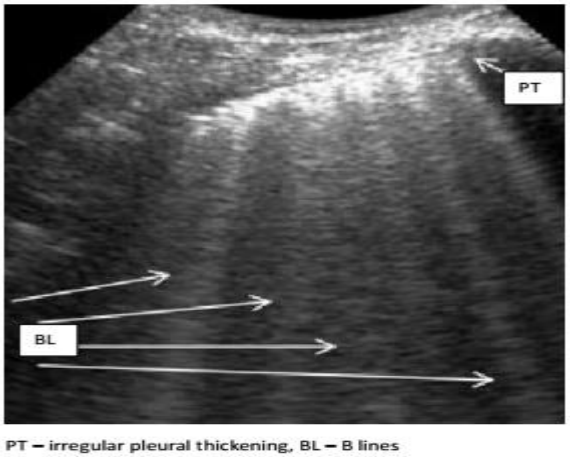

Figure 4: Lung ultrasound indicating irregular pleural thickening and existence of B-lines

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Table 4: Comparison of 40 cases according to Warrick score and severity of ILD

Parameters	*Mild (n=21)*	*Moderate (n=14)*	*Severe (n=3)*	*P value*
Warrick score	11.27 ± 3.19	21.22.15 ± 4.31	29.17 ± 0.82	0.012
6-min walk test	462.5 ± 110.2	425.5 ± 75.9	212.4 ± 40.22	0.040
B-lines distance	4.71 ± 1.21	5.32 ± 1.55	5.47 ± 1.29	0.002
PaO_2	69.95 ± 6.62	67.53 ± 6.74	65.21 ± 7.34	0.012
FVC	63.02 ± 7.15	58.33 ± 5.19	56.09 ± 7.92	0.011

Table 3 compares the Warrick score, 6-min walk test, B-lines distance, PaO_2, and FVC of 40 patients with interstitial lung disease (ILD) according to the severity of their disease. Patients experiencing severe ILD exhibit a higher Warrick score, reduced 6-minute walk test distance, increased B-lines distance, lower PaO_2, and diminished FVC in comparison to patients with mild or moderate ILD. The Warrick score gauges the severity of ILD based on chest X-ray findings. The data presented in this table indicate that the Warrick score, 6-minute walk test, B-lines distance, PaO_2, and FVC serve as valuable indicators of ILD severity. A discernible trend is observed, with the Warrick score rising, the 6-minute walk test distance decreasing, B-lines distance increasing, PaO_2 decreasing, and FVC decreasing as ILD severity increases. Although there is minimal overlap between the groups, indicating the measures' ability to distinguish between different ILD severities, the p-values for all parameters are below 0.05, underscoring the statistical significance of the differences among the three groups.

Discussion

The diagnosis of ILD is typically established through a combination of clinical, functional, radiological, and histological data. Chest X-ray (CXR) often serves as the initial imaging test for ILD. The British Thoracic Society recommends high-resolution computed tomography (HRCT) if the diagnosis remains uncertain following CXR and clinical assessment. In cases where the diagnosis remains unclear, additional diagnostic measures such as bronchoalveolar lavage, transbronchial lung biopsy, or surgical lung biopsy may be considered. [7] Complications associated with ILD include irreversible pulmonary fibrosis, respiratory failure, acute exacerbation, pulmonary artery hypertension, malignancy, and thromboembolic disease. This study has recorded the elevated diagnostic accuracy of Lung Ultrasound (LUS) in identifying Interstitial Lung Disease (ILD). Prior investigations exclusively compared LUS with High-Resolution Computed Tomography (HRCT), focusing on selected patients with rheumatologic disorders. [8-11] In some instances, these studies excluded patients with known cardiac and pulmonary comorbidities. [10, 11] In contrast, our evaluation of LUS was conducted under conditions reflective of routine clinical practice, where comorbidities and confounding factors are typically present, yielding encouraging data. The findings of the present study regarding patient characteristics align with those of Man et al. [12], where 58 patients were included, comprising 58.6% males and 41.4% females, with an average age of 58.97 ± 15.59 years. Cömert et al.

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[13] reported a mean age of 59.2 ± 14.2 years. Regarding high-resolution CT findings of the chest in the current study, they are consistent with the observations of Man et al. [12], who noted an HRCT score of 21.66 ± 7.79, a total number of B-lines score of 78.72 ± 44.3, and average positive chest areas score of 7.5. They concluded that LUS could serve as an appreciated diagnostic tool for chest assessment, given its bedside applicability, widespread availability, and cost-effectiveness. [14] The current study also identified a substantial correlation between the B-lines score and HRCT scores, consistent with findings by Man et al. [12], who demonstrated a good correlation between scores of both modalities. Their data supported the use of LUS as a diagnostic modality for ILD diagnosis and staging compared to HRCT. Gargani et al. [15], in ILD, associated with systemic sclerosis, introduced the B-line score and considered the test positive when the total B-lines in all scanning sites exceeded 10. Additionally, Gutierrez et al. [16], computed two different LUS scores and reported a statistically significant correlation between the two scores. The Warrick score, employed in the present study to assess disease severity (parenchymal extent of pathology), ranges from 0 (minimum) to 30 (maximum), with a higher score indicating severe disease and a high degree of change on the radiological study [17]. In this study, 46% had mild, 44% had moderate, and 10% had severe disease according to the Warrick score. Sarac et al. [17] reported a lower Warrick score, with their patients exhibiting mild to moderate disease. Farag et al. [18] found no association between B-line scores and different grades of disease severity revealed by HRCT. Our study found the correlation between Warrick score and B-lines distance is robust, with a coefficient of -0.910, indicating a strong negative correlation. This finding aligns with the established pathophysiology of ILD, where B-lines, visualized through chest ultrasound, are artifacts associated with ILD patients. The presence of B-lines is attributed to the thickening of alveolar septa, a common characteristic of ILD. The Warrick score, derived from chest X-ray findings, serves as a measure of ILD severity. The robust negative correlation between the Warrick score and B-lines distance aligns with ILD's known pathophysiology, emphasizing the potential utility of these measures as biomarkers for ILD. These results align with Ghanem MK et al. [19], who reported a positive correlation between the distance between each two adjacent B-lines and the Warrick score (r=0.693). Additionally, Cogliati et al. [20] reported a significant correlation between the B-line score and HRCT score (r=0.806), consistent with similar results reported by Mohammadi et al. [21] Furthermore, the study found a significant positive correlation between the Warrick score and B-lines distance, while there was a significant negative correlation between the Warrick score and the 6-minute walk test, PaO_2, and FVC. El-Fatah et al. [22] also reported a significant positive correlation between the Warrick score and the distance between B-lines, and a negative correlation between the Warrick score and the number of B-lines, PaO_2, 6-minute walk test, forced vital capacity, and pleural line thickness. Tardella M et al. [23] concluded that the identification of 10 B-lines serves as a strong indicator for the presence of significant Systemic Sclerosis-Interstitial Lung Disease (SSc-ILD) on High-Resolution Computed Tomography (HRCT). For individuals with Systemic Sclerosis (SSc),

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utilizing LUS as the initial imaging tool could potentially enhance the accuracy in determining the appropriate timing for chest HRCT. Presently, there is supporting evidence for incorporating Lung Ultrasound (LUS) in the screening of Interstitial Lung Disease (ILD), even in its initial stages and subclinical lung engagement. LUS demonstrates rapidity in examination, averaging 5–7 minutes, coupled with high sensitivity and specificity. While additional prospective studies involving larger populations are warranted, existing evidence suggests that thoracic ultrasound can be employed in therapeutic follow-up to complement clinical assessments due to its practicality, affordability, and absence of side effects. [24]

Conclusion

In conclusion, while no imaging modalities can fully replace the comprehensive information provided by chest HRCT, which remains the gold standard for assessing pulmonary fibrosis, LUS in ILD presents itself as a useful, cost-effective, accessible, and radiation-free investigative tool. The current study affirms the potential role of LUS as a significant standalone or adjunctive assessment tool for diagnosing and monitoring ILD patients, but further studies are essential for generalizing these results.

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