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ORIGINAL ARTICLE

Early Diagnostic Value of Lung Ultrasound Compared with Chest Computed Tomography for Pleural Effusion and Pneumonia in Critically Ill Patients

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Abstract

Background: **Recently, lung ultrasound (LUS) has been touted as a modality that can diagnose pneumonia in a variety of settings while overcoming many of the shortcomings of other tools.**

Aim: **The aim of the study is to compare between diagnostic value of LUS and computed tomography (CT)-chest in evaluating pneumonia and pleural effusion in ICU patients. The primary study outcomes were the sensitivity and specificity of LUS and CT-chest in pneumonia and pleural effusion. The secondary study outcomes were the satisfaction of the patient.**

Patients and methods: **This was an observational study, which included 40 patients admitted to ICU Al-Azhar University hospitals.**

Results: **Its sensitivity was 93.33 %, specificity was 96 %, positive predictive value was 93.33 %, and negative predictive value was 96 % for chest US. Chest CT demonstrated 100 % sensitivity, 96 % specificity, 93.75 % positive predictive value, and 100 % negative predictive value.**

Conclusion: **In the early stages of diagnosing pneumonia and pleural effusion, LUS is a very useful tool. LUS is a reliable, highly accurate diagnostic technique for pleural effusion and pneumonia. It can supplement the use of clinical signs and symptoms in the bedside diagnosis and treatment of pneumonia and pleural effusion due to its capacity to offer real-time, inexpensive, quick images. It may be especially useful in places with poor access to conventional radiology and reduce ionizing radiation exposure.**

Keywords: Computed tomography, Pleural effusions, Pneumonia, Ultrasound

1. Introduction

Lung ultrasound (LUS) has recently been used as a technique that can circumvent many of the shortcomings of existing instruments in the diagnosis of pneumonia in a variety of circumstances.[1] Over the past 20 years, ultrasonography has demonstrated that it has the potential to be a key tool in both standard medical practise and the evaluation of the lung. Historically, the air barrier was thought to make the lung difficult to penetrate with US. However, a wealth of research supporting the use of LUS in a variety of situations has significantly altered this position.[2]

In critically ill patients diagnosis of pneumonia can be complex since the symptoms are nonspecific. The clinical presentation of the patient, including their medical history and physical examination, as well as radiological imaging, most commonly a chest radiograph [CXR; less frequently a computed

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tomography (CT) scan], are used to diagnose pneumonia in daily practise.[3]

Diagnosis of postoperative pulmonary complication is clinically suggested by findings like fever, cough, and crepitation, which was confirmed by thoracic imaging. For decades, thoracic imaging relied on routine bedside CXR, plus lung CT when its indication is justified.[4]

The gold standard for evaluating the lung structure and morphology is generally acknowledged to be chest CT. However, its application in critically ill patients is limited to a few reasons because to the risk of patient transfer and excessive radiation dosage. On the other hand, CXR is a simple widely available modality; it carries considerable technical defects that result in poor correlation between its findings and those of CT.[5]

The aim of the study is to compare between diagnostic value of LUS and CT-chest in evaluating pneumonia and pleural effusion in ICU patients. The primary study outcomes were the sensitivity and specificity of LUS and CT-chest in pneumonia and pleural effusion. The secondary study outcomes were the satisfaction of the patients.

2. Patients and methods

The protocol was applied for approval of Research Ethics Committee. Every participant was informed about the aim of the study, its benefit to him and to the community. Written consent was taken from all participants before including them in the study and they have the right to refuse without effect on their management.

This was an observational study, which included 40 patients admitted to ICU of Al-Azhar University hospitals and developed clinical data including one or more of the following: fever, cough, dyspnea, respiratory distress, and/or hypoxia. CT-chest is done to all 40 patients and bedside LUS were done to all 40 patients by another expert who was blinded to the result of CT-chest diagnosis on the day of admission.

2.1. Inclusion criteria

Patients accepted to join the study, age: between 21 and 60 years, BMI less than 30 kg/m^2, patients with postoperative pulmonary complications, and patients had one or more of the following: fever, cough, dyspnea, respiratory distress, and/or hypoxia.

2.2. Exclusion criteria

Patient refusal, patients with chest wall deformity, patients with thoracotomy, and pregnant patients.

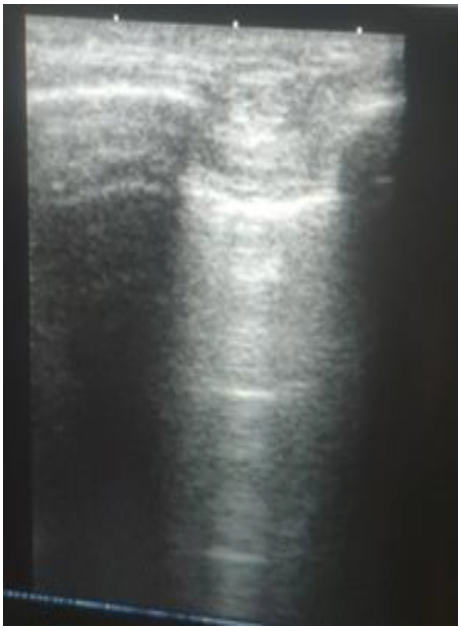

Fig. 1. Normal lung: pleura as whick white line horizontal (A line) and rips on both side of picuter and its shadow.

3. Methods

All patients were subjected to: an informed consent was taken from every patient, complete history taking, personal history, any complaint, past medical, family history, complete physical examination, and local chest examination.

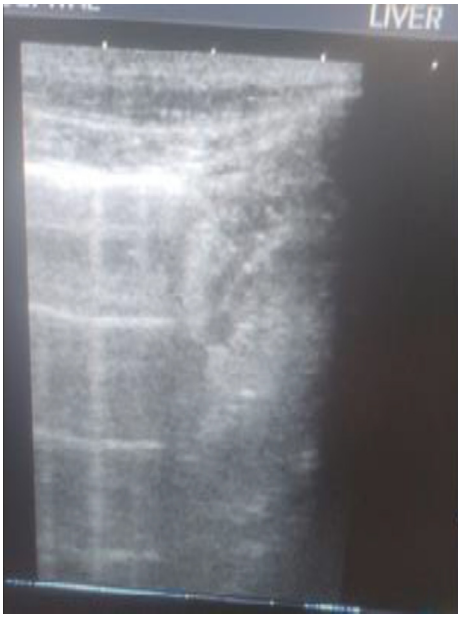

Fig. 2. Pneumonia stage of congestion: multiple vertical (B line).

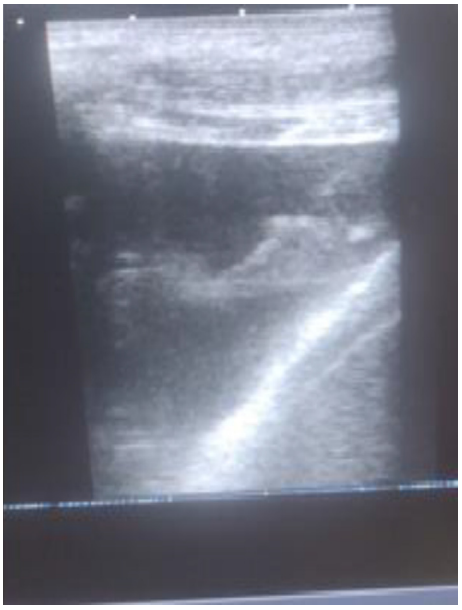

Fig. 3. Chronic peural effusion: liver in the right, diaphragm as thick white line, on the left massive pleural effusion, and adherence septa.

Table 1. Demographic characteristics among the study population.

	Study population ($N = 40$)
Sex [*n* (%)]	
Male	25 (62.5)
Female	15 (37.5)
Age (years)	
Mean ± SD	40.58 ± 7.8
Median (IQR)	39.5 (35–45.25)
Range (minimum–maximum)	31 (26–57)

IQR, interquartile range.

3.1. Lung ultrasound

A microconvex 5–9 MHz transducer suitable for transthoracic examination was used to visualize the lungs. It was possible to access images that were standardized (seashore signs, stratosphere signs). The normal lung generated lung sliding and A line (Fig. 1), consolidation isoechoic tissue-like structure and multiple B line in specific area (Fig. 2), pleural effusion was determined as a hypoechoic containing isoechoic particles or septations in inflammatory pleural diseases (Fig. 3). All data were documented as positive or negative and added to the patient-specific report. Expert thoracic US clinicians blinded to CT-chest findings carried out LUS in accordance with a methodical procedure advised by US guidelines. Based on the presence, distribution, and severity of abnormalities, the LUS score was determined.

3.2. Chest computed tomography scans

A noncontrast chest multiple detectors CT scanning was performed and was evaluated by an independent radiologist. Interstitial syndrome defined as ground glass opacities, septal or nonseptal lines, or fibrotic changes. Consolidation was defined as presence of atelectasis, alveolar consolidation.

3.3. Measurements

Patient age, sex, and medical history was collected. Mode of oxygenation, LUS pathological findings as (A line, B line, lung sliding, lung point,

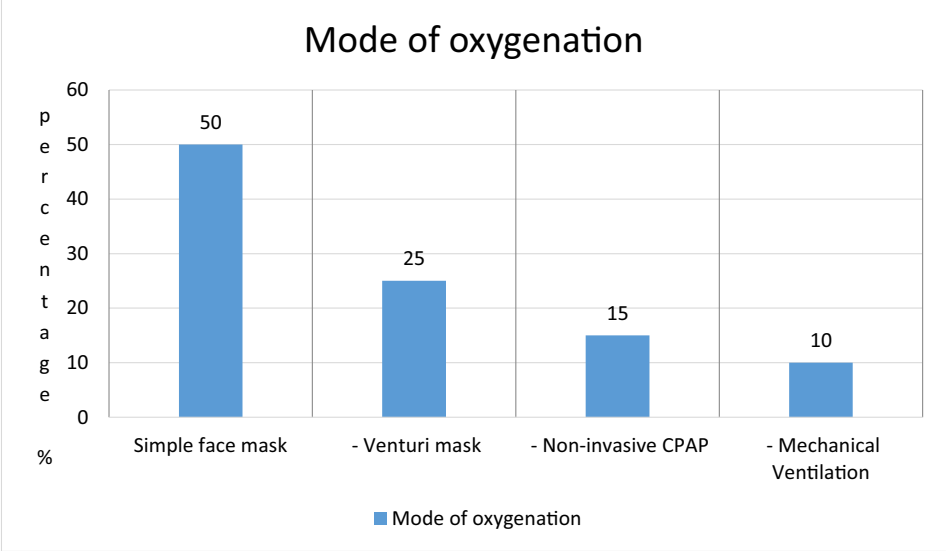

Fig. 4. Bar chart showing study population data regarding mode of oxygenation.

Table 2. Ultrasound pathological findings among the study population.

	Study population ($N = 40$) [n (%)]
Lung sliding	37 (92.5)
B lines	
Focal B line	2 (5)
Diffuse B line	7 (17.5)
A lines	39 (97.5)
Lung point	3 (7.5)
Interrupted pleural line	3 (7.5)
Consolidation	16 (40)
Air bronchogram	3 (7.5)
Pleural effusion	13 (32.5)
Alveolointerstitial syndrome	3 (7.5)

consolidation, pleural effusion), and diagnosis was documented, and CT chest diagnosis including pneumonia, atelectasis, effusion, and pneumothorax. LUS was compared with the lung CT, to calculate sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

3.4. Sample size

Utilizing the WHOs and the Center for Disease Control and Prevention's Epi-Info data program, the sample size was determined (Gadsden, USA version, 2002). With patients in one group and a 10 % loss to follow-up or death margin, the sample size was determined. The sample size was determined using the following criteria: 95 % confidence interval, 80 % power. The present study will involve 40 patients. All patients will have a CT-chest and LUS ordered on the day of arrival to rule out pneumonia and pleural effusion.[6]

3.5. Statistical analysis

All data were collected, processed, and statistically evaluated using SPSS 20.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Number and percentage were utilized to describe qualitative data. The range (minimum and maximum), mean, SD, and median were used to characterize quantitative data. The following settings for diagnostic tests were used: sensitivity (true positive rate): if a test yields a positive result. If a test will produce a negative result is known as specificity (true negative rate). The possibility that a person would truly have the disease for which the test was positive is known as PPV. The possibility that a person does not truly have the ailment for which they tested negative is known as NPV.

4. Results

Table 1 showed demographic characteristics among the study population. Number of male patients in the study population was 25 (62.5 %). Age in

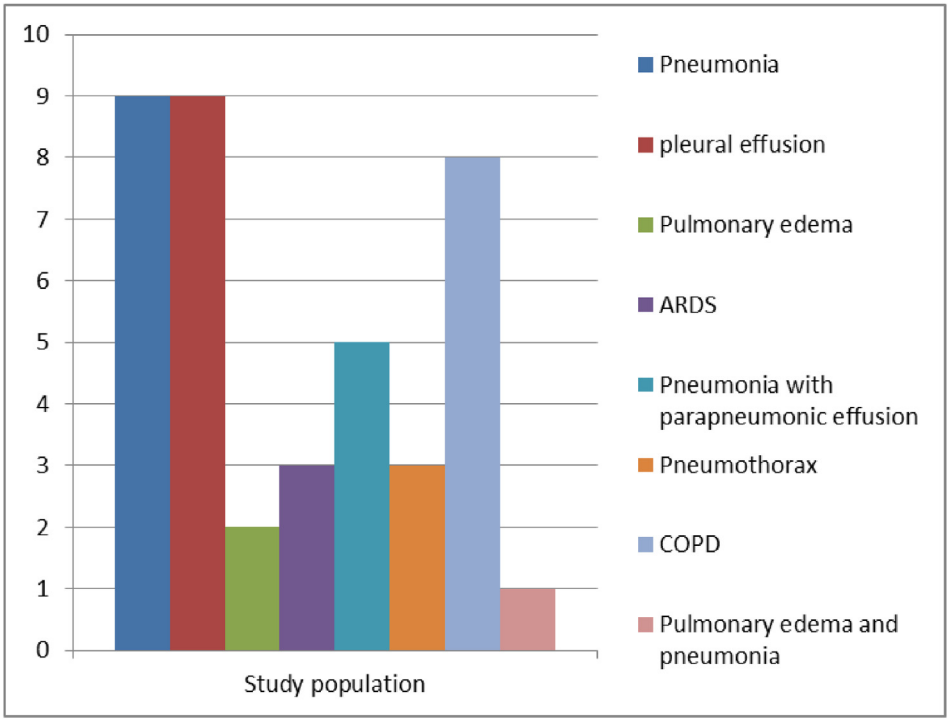

Fig. 5. Bar chart showing study population data regarding ultrasound diagnosis.

Table 3. Chest computed tomography of lung involvement findings among the study population.

	Study population ($N = 40$)
Right lung involvement (%)	
Mean ± SD	60.17 ± 9.11
Median (IQR)	61.75 (54.65–65.88)
Range (minimum–maximum)	34.2 (43–77.2)
Left lung involvement (%)	
Mean ± SD	55.06 ± 6.81
Median (IQR)	55.85 (51.75–60.42)
Range (minimum–maximum)	31.2 (38.8–70)

IQR, interquartile range.

the study population ranged from 26 to 57 years (40.58 ± 7.8 years) (Fig. 4).

Table 2 displayed the study population's US pathological results. Thirty-seven (92.50 %) patients of the study population had lung slipping. Thirty-nine individuals, or 97.50 % of the study population (A lines). There were three (7.50 %) patients with lung point in the study population. There were three (7.50 %) patients in the study population having an interrupted pleural line. Sixteen patients, or 40 % of the study sample, had consolidation. There were 13 (32.50 %) patients with pleural effusion in the study population.

Fig. 5 showed us diagnosis among the study population. Number of patients with pneumonia in the study population was nine (22.50 %).

Table 3 showed BMI among the study population. Right lung involvement percentage in the study population ranged from 43 to 77.2 (60.17 ± 9.11). Left lung involvement percentage in the study population ranged from 38.8 to 70 (55.06 ± 6.81).

Fig. 6 showed CT diagnosis among the study population. Number of patients CT pneumonia diagnosis in the study population was nine (23 %). Number of patients CT pleural effusion diagnosis in the study population was 10 (25 %).

Table 4 showed that chest US and chest CT sensitivity and specificity regarding pneumonia. Regarding chest US, it had sensitivity 93.33 %, specificity 96 %, PPV 93.33 %, and NPV 96 %. Regarding chest CT, it had sensitivity 100 %, specificity 96 %, PPV 93.75 %, and NPV 100 %.

Table 5 showed the chest US and chest CT sensitivity and specificity regarding pleural effusion. Regarding chest US, its PPV was 100 %, its specificity was 100 %, and its NPV was 87.50 %. Chest CT had a sensitivity of 93.75 %, a specificity of 100 %, a PPV of 100 %, and a NPV of 96 %.

Overall patient satisfaction in the chest US was significantly higher than chest CT. The number of patient was only 36 because there were four patients on mechanical ventilation (Fig. 7).

5. Discussion

LUS has been marketed as a modality in the diagnosis of pneumonia in a variety of circumstances. Treatment of a number of pathological lung disorders, such as consolidation, and pleural effusion, has proven that LUS is more accurate than bedside CXR.[7] This observational study was conducted including 40 patients admitted to ICU Al-Azhar University hospitals. The results of the present study shows that there is no statistical difference. As regards to demographic characteristics

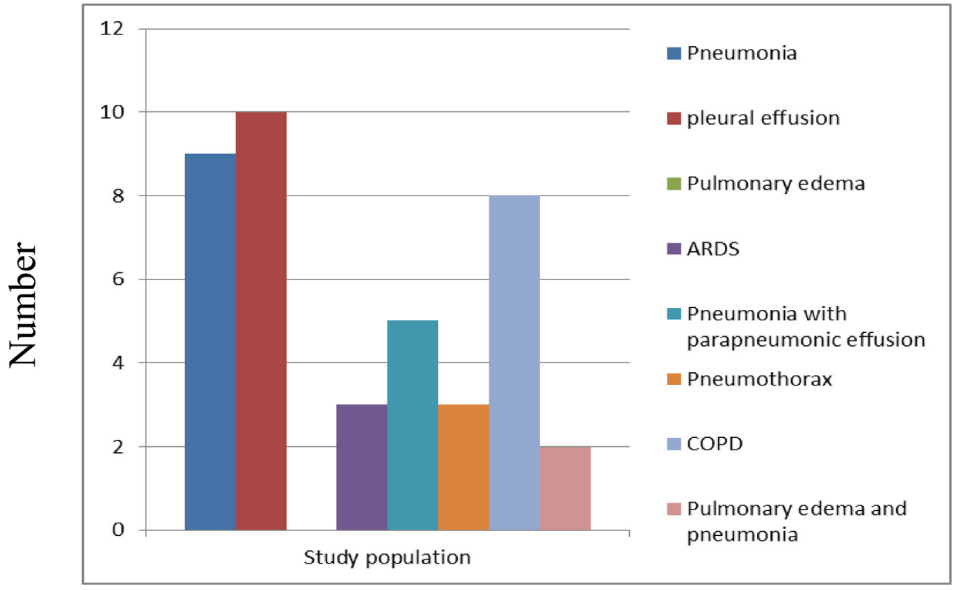

Fig. 6. Bar chart showing study population data regarding computed tomography diagnosis.

Table 4. Chest ultrasound and chest computed tomography sensitivity and specificity regarding pneumonia.

	Diagnostic parameters			
	Sensitivity	Specificity	PPV	NPV
Chest US %	93.33	96	93.33	96
Chest CT %	100	96	93.75	100

CT, computed tomography; NPV, negative predictive value; PPV, positive predictive value; US, ultrasound.

among the study population, the number of male patients in the study population was 25 (62.5 %). Age in the study population ranged from 26 to 57 years (40.58 ± 7.8 years). Regarding BMI among the study population, BMI in the study population ranged from 17.3 to 25.5 (22.73 ± 1.62). Also the results showed that chest CT and US were delicate and explicit for pneumonia. Its sensitivity was 93.33 %, specificity was 96 %, PPV was 93.33 %, and NPV was 96 % for chest US. Chest CT exhibited 100 % sensitivity, 96 % specificity, 93.75 % PPV, and 100 % NPV. As for pleural effusion on chest ultrasound

Table 5. Chest ultrasound and chest computed tomography sensitivity and specificity regarding pleural effusion.

	Diagnostic parameters			
	Sensitivity	Specificity	PPV	NPV
Chest US %	92.31	100	100	87.50
Chest CT %	93.75	100	100	96

CT, computed tomography; NPV, negative predictive value; PPV, positive predictive value; US, ultrasound.

and chest CT, chest US displayed sensitivity 87.50 %, specificity 100 %, PPV 100 %, and NPV 92.31 %. Chest CT displayed a sensitivity of 93.75 %, a specificity of 100 %, a PPV is 100 %, and a NPV is 96 %. The results of the present study agree with Berlet et al.[7] who performed everyday LUS in precisely ventilated patients and showed the worth of LUS in the early recognition and treatment of ventilator-associated pneumonia (VAP). For the determination of VAP, the presence of consolidation with an air bronchogram sign, whether static or dynamic, exhibited 100 % sensitivity and 60 % specificity. An alternate method for figuring out the cause of pulmonary consolidations is to use color Doppler US to analyze the vascular pattern within the consolidation. Bouhemad et al.[8] reviewed nine studies that assessed LUS and demonstrated a mean sensitivity of 97 % with a specificity of 94 % for LUS in the diagnosis of VAP. This also supports the result of the present study. Lichtenstein et al.[9] who considered CT as the gold standard in diagnosing VAP, found that the sensitivity and specificity of LUS in the diagnosis of VAP were 90 and 98 %, respectively. This is agreed to the results of the present study. Gleeson and Qureshi[10] and Froudarakis,[11] who demonstrated that LUS is accurate in detecting pleural fluid as low as 5–50 ml and is capable of detecting various stages of pleural effusion. LUS benefits include high learnability, strong diagnostic agreement, and lower radiation exposure in addition to its excellent diagnostic potential. Particularly in mechanical ventilation patients, the level of interpretation with LUS is more subjective than with CXR.

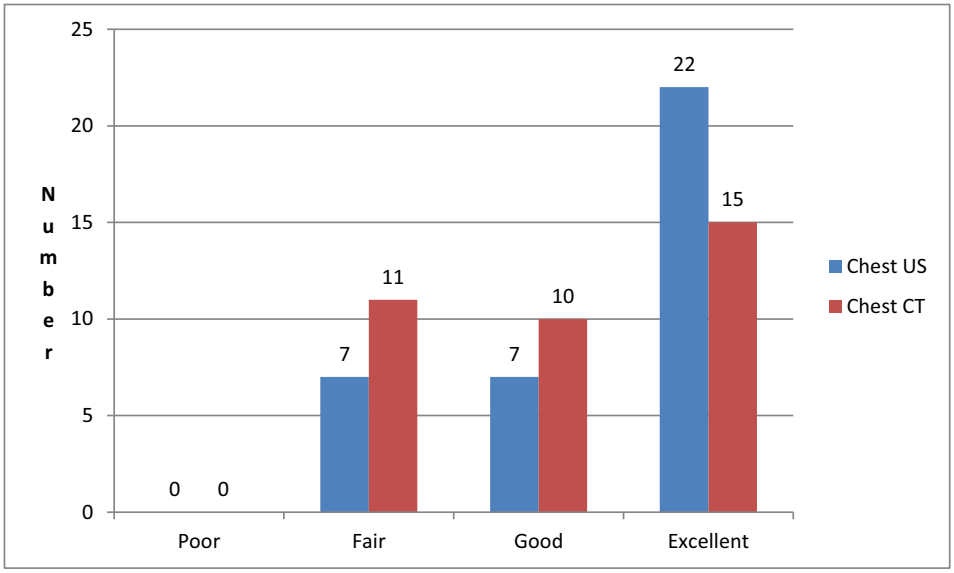

Fig. 7. Patient satisfaction regarding LUS higher than CT chest. CT, computed tomography; LUS, lung ultrasound.

6. Conclusion

LUS is an extremely supportive demonstrative strategy for pleural radiation and pneumonia in the beginning phases. Due to its ability to provide real-time, affordable diagnostic information, it can support the use of clinical signs and symptoms in the bedside diagnosis and treatment of pneumonia and pleural effusion, quick images. It might be especially useful as a way to reduce exposure to ionizing radiation.

Conflicts of interest

There are no conflicts of interest.

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