# RESEARCH

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# Assessment of atypical pneumonia by chest ultrasonography



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# Abstract

**Background** Patients with pneumonia exhibit similar clinical presentations despite having different causative organisms; thus, a rapid and easy test is needed to differentiate between the diseases. Here, we use lung ultrasound to discriminate between causative organisms in correlation with other diagnostic modalities.

**Methods** This descriptive cross-sectional study was carried out on 67 patients diagnosed with atypical pneumonia admitted at Ain-Shams University hospitals in the period from July 2019 to June 2021. Study population was divided into three groups according to the causative agent based on the results of PCR: Group 1 included 23 patients (influenza A), group 2 included 30 patients (COVID-19), and group 3 included 14 patients (atypical organisms). Included patients underwent lung ultrasound scan via a 12-zone scanning protocol and CT scan with 24 h in between. The present study was approved by the ethical committee at our institution.

**Results** The mean age ranged from  $39.93 \pm 19.26$  SD to  $60.3 \pm 13.02$  SD years; 64.17% of them were males. There was also a highly statistically significant difference between the three groups as regard B-lines and thickened pleural line being higher among group 2; 100% of cases had B-lines in their chest ultrasound assessment, while thickened pleural line was found in 53.3% of cases. Dynamic air bronchogram was found with higher percentage in group 3 (71.4%) with a highly significant association. Higher mean Soldati score was associated with more severe disease among cases with viral pneumonia.

**Conclusions** Lung ultrasound may be used as an aiding tool to estimate the etiology of atypical pneumonia. It can be useful during pandemics of acute respiratory diseases for rapid triage and stratification of patients as through calculation of modified Soldati score and detection of the most common finding. Also, modified Soldati score correlates with disease severity.

Keywords Lung ultrasound, Influenza virus, Pneumonia, COVID-19, Atypical pneumonia

# Introduction

Pneumonia is an infection that affects one or both lungs. It causes the air sacs, or alveoli, of the lungs to fill up with fluid or pus, inflammatory cells, and fibrin

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[1]. Community-acquired pneumonia (CAP) is considered one of the most common infectious diseases and is caused by various infectious pathogens, including viruses, typical bacteria, and atypical pathogens. The vague clinical presentations of atypical CAP contribute to its under diagnosis and under reporting [2]. Given the high prevalence and potential severity of these disease processes, imaging modalities facilitating safe and rapid assessment of patients with respiratory complaints are indispensable. Current clinical approaches for pneumonia surveillance, early detection, and conventional culture-based



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microbiology in the critically ill are inadequate for optimal-targeted antibiotic treatment and stewardship. Novel rapid microbiological diagnostics, including nucleic-acid amplification, represent future promising approaches [3]. Lung ultrasound (LUS) has proved to be useful in the evaluation of many different acute and chronic pulmonary conditions, from cardiogenic pulmonary edema to acute lung injury, from pneumothorax to pneumonia, and from interstitial lung disease to pulmonary infarctions and contusions; the relative ease of bedside ultrasound examination and its availability have made chest ultrasonography an interesting and alternative investigating tool in various situations, because it offers accurate information that is of diagnostic and therapeutic value [4].

## Methods

# Participant selection and study design

Our study was a descriptive cross-sectional study that included 67 patients diagnosed with atypical pneumonia and admitted at Ain-Shams University hospitals in the period from July 2019 to June 2021. Study population were divided into three groups according to the causative agent: Group 1 included 23 patients (influenza A), group 2 included 30 patients (COVID-19), and group 3 included 14 patients (atypical organisms). All patients with clinical symptoms and signs suggesting pneumonia and confirmed to be caused by an atypical organism by doing PCR to samples collected from respiratory tract were included. Patients who refused to participate in the study were excluded, as well as pregnant females and patients who had samples positive for more than one organism. All the patients were subjected to full history taking and thorough clinical examination, assessment of comorbidities, respiratory tract sampling via sputum induction through hypertonic saline nebulizer or respiratory nasopharyngeal swabbing for PCR analysis (BioFire multiplex PCR array), chest ultrasound dividing the chest wall into ten scanning areas on both sides, and high-resolution CT scan of the chest without contrast with slice thickness 0.625–1.2 mm; the radiological modalities were done within 24 h in between.

# Lung ultrasound interpretation

All recruited patients underwent a complete sonographic examination using an institutional standard ten-zone protocol. The anterior chest lung zone is consistent of four zones: two anterior right chest zones and two anterior left chest zones. The axillary lung zone is divided into two zones, superior and inferior zones on both sides. The last two zones were posterior medial scapula lung zones of the right and left lungs. Each zone was assessed for the presence or absence of common features of LUS, including A-lines, B-lines, irregular pleural lines, subpleural consolidations, and pleural effusion. LUS severity score was calculated using a standardized modified scoring system originally described by Soldati for COVID-19 [5]. One lung zone could receive a maximum of two points. Individual lung zone scores were then summed up to generate a total patient lung severity score. A patient could receive a maximum severity score of 20 points (e.g., two points per each of the ten lung zones) (Fig. 1).

Score	LUS Findings	Example
0	Continuous, regular pleural line A-lines Pleural effusions present	
1	Pleural line indenting or irregularity 1-2 B-lines per clip	Mark and
2	Broken pleural line Subpleural consolidations 3 or more B-lines per clip	A

## CT scanning protocol

All patients were in supine position, performing a breath-hold after inhalation. The scanning range was from bilateral apex to base. Slice thickness is 0.625–1.2 mm. Lung changes were classified into the following seven subcategories: Ground-glass opacities, consolidation, crazy paving, tree-in-bud pattern, nodules whether being centrilobular micronodules (<3 mm) or solid nodule (well defined and >3 mm), pleural changes whether thickening of the pleura or pleural effusion, and interstitial thickening including subpleural lines and/or bands:

- Subpleural lines are 5- to 10-cm-long curvilinear opacities found within 1 cm of the pleura and parallel the chest wall. They are most frequent in the posterior portions of the lower lobes and remain unchanged on prone scans. They probably represent an early phase of lung fibrosis.
- Subpleural bands are non-tapering linear parenchymal opacities, 2 to 5 cm in length, which extend from the lung to contact the pleural surface. These fibrotic bands can be distinguished from vessels and thickened septa by their length, thickness, course, the absence of branching, and their association with regional parenchymal distortion.

## Data analysis and statistics

The collected data was revised, coded, tabulated, and introduced to a PC using Statistical Package for Social Science (IBM Corp. Released 2017, IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY, USA: IBM Corp.). Data was presented, and suitable analysis was done according to the type of data obtained for each parameter.

- i. Descriptive statistics
  - Shapiro–Wilk's test was used to evaluate normal distribution of continuous data. Mean, standard deviation (±SD), and range were used for parametric numerical data, while median and interquartile range (IQR) were used for nonparametric numerical data.
  - 2. Frequency and percentage of nonnumerical data.
- ii. Analytical statistics
  - ANOVA test was used to assess the statistical significance of the difference of a continuous variable between more than two study group means,

with Bonferroni post hoc test used for comparisons of all possible pairs of group means.

- 2 The Kruskal–Wallis test was used to assess the statistical significance of the difference of an ordinal variable between more than two study groups, with Dunn-Bonferroni post hoc test used for comparisons of all possible pairs.
- 3 Chi-square test was used to examine the relationship between two qualitative variables.
- 4 Fisher's exact test: Was used to examine the relationship between two qualitative variables when the expected count is less than 5 in more than 20% of cells.
- 5 Mann–Whitney test (U-test) was used to assess the statistical significance of the difference of an ordinal variable between two study groups.
- 6 Correlation analysis (using Spearman's method): To assess the strength of association between two quantitative variables. The correlation coefficient denoted symbolically "r" defines the strength and direction of the linear relationship between two variables.
  - P-value: Level of significance
    - *P*>0.05: Nonsignificant (NS)
    - *P* < 0.05: Significant (S)
    - *P*<0.01: Highly significant (HS)

# Results

Study was conducted on 67 patients in Ain-Shams University hospitals in the period from January 2019 to June 2021. The study population was divided into three groups: group 1 included 23 patients (influenza A group), group 2 included 30 patients (COVID-19 group), and group 3 included 14 patients (atypical organisms' group).

The atypical organisms' group included nine cases diagnosed with mycoplasma pneumonia, three cases with *Legionella pneumonia*, and two cases with *Chlamydia pneumonia*.

The mean age ranged from  $39.93 \pm 19.26$  SD to  $60.3 \pm 13.02$  SD years; 64.17% of them were males. Demographic and medical data for the three studied groups were illustrated in Table 1.

There was a highly statistically significant difference between three studied groups as regard mean Soldati score with higher mean score among group 2 patients (mean Soldati score was 10.8) compared to the other two groups (mean Soldati score was 6.48 and 4.43 in group 1 and group 3, respectively). There was also a highly statistically significant difference between the three groups as regard B-lines and thickened pleural line being higher among group 2, 100% of cases had b-lines in their chest

		Group						Ρ	Sig
		Group 1 Influenza A (23 patients)		Group 2 COVID-19	9 (30 patients)	Group 3 Atypical o patients)	organisms (14		
		Mean	±SD	Mean	±SD	Mean	±SD		
Age		47.52	14.97	60.30	13.02	39.93	19.26	0.001	HS
Disease onset (days)		6.00	1.31	7.53	2.42	6.50	1.99	0.001	HS
Sex	Male	15	65.2%	20	66.7%	8	57.1%	0.822	NS
	Female	8	34.8%	10	33.3%	6	42.9%		
DM	No	14	60.9%	15	50.0%	12	85.7%	0.077	NS
	Yes	9	39.1%	15	50.0%	2	14.3%		
HTN	No	19	82.6%	15	50.0%	11	78.6%	0.026	S
	Yes	4	17.4%	15	50.0%	3	21.4%		
IHD	No	19	82.6%	27	90.0%	14	100.0%	0.260	NS
	Yes	4	17.4%	3	10.0%	0	0.0%		
CKD	No	20	87.0%	28	93.3%	12	85.7%	0.665	NS
	Yes	3	13.0%	2	6.7%	2	14.3%		
Malignancy	No	22	95.7%	28	93.3%	14	100.0%	1.0	NS
	Yes	1	4.3%	2	6.7%	0	0.0%		
Asthma	No	21	91.3%	26	86.7%	14	100.0%	0.402	NS
	Yes	2	8.7%	4	13.3%	0	0.0%		
Smoking	No	17	73.9%	18	60.0%	10	71.4%	0.525	NS
	Yes	6	26.1%	12	40.0%	4	28.6%		
Admission	Ward	2	8.7%	16	53.3%	2	14.3%	0.001	HS
	ICU	21	91.3%	14	46.7%	12	85.7%		
Нурохіа	No	13	56.5%	4	13.3%	10	71.4%	0.001	HS
	Yes	10	43.5%	26	86.7%	4	28.6%		

 Table 1
 Description of demographic and medical data among the three studied groups

DM Diabetes mellitus, HTN Hypertension, IHD Ischemic heart disease, CKD Chronic kidney disease, ICU Intensive-care unit

ultrasound assessment, while thickened pleural line was found in 53.3% of cases. Dynamic air bronchogram was found with higher percentage in group 3 (71.4%) with a highly significant association as described in Table 2.

Regarding CT findings in the three groups, there was a highly statistically significant difference between CT findings among three studied groups as regards GGOs and interstitial thickening which were higher in group 2. Also, there was a statistically significant association between crazy paving and group 2 population in comparison to the other two groups. There was a highly statistically significant difference between CT findings among three studied groups as regards consolidation, and treein-bud were higher among group 3 population as illustrated in Table 3.

Among the whole study population, a higher mean Soldati score was associated with development of hypoxia with a highly statistically significance as shown in Table 4. Also, there was a statistically significant association between higher mean Soldati score, smoking, DM, and IHD patients among group 1 patients (influenza group). Among group 2 subjects (COVID group), higher mean Soldati score was associated with DM and ICU admission in a high statistically significant association. Also, there was a statistically significant association between HTN, hypoxia, and patients with higher mean Soldati score, while group 3 patients (atypical bacterial organisms) showed a statistically significant association between higher mean Soldati score and patients with CKD, ICU admission, and development of hypoxia.

# Discussion

Each year, respiratory viruses run rampant throughout the global community. Patients with influenza and COVID-19 often present with similar symptoms, including cough, sore throat, myalgias, fatigue, fever, and shortness of breath [6]. Thus, differentiating these diseases based on clinical context alone can be challenging [7].

Some sonographic findings in the lung scan were found in distinct groups more than others in a statistically significant difference: B-lines were more common among viral pneumonia. They were found in all group 2 patients

		Group 1 Influenza (23 patients)		Group 2 COVID-19 (30 patients)		Group 3 Atypical organisms (14 patients)		Р	Sig
		Mean	±SD	Mean	±SD	Mean	±SD		
Soldati score		6.48	2.27	10.83	2.91	4.43	1.65	0.001	HS
		Ν	%	Ν	%	Ν	%		
B-lines	No	1	4.3%	0	0.0%	6	42.9%	0.001	HS
	< 3	6	26.1%	1	3.3%	4	28.6%		
	>3	11	47.8%	16	53.3%	4	28.6%		
	Confluent	5	21.7%	13	43.3%	0	0.0%		
Subpleural consolidation (< 0.5 cm)	No	16	69.6%	19	63.3%	11	78.6%	0.594	NS
	Yes	7	30.4%	11	36.7%	3	21.4%		
Dynamic air bronchogram (> 0.5 cm)	No	20	87.0%	29	96.7%	4	28.6%	0.001	HS
	Yes	3	13.0%	1	3.3%	10	71.4%		
Pleural effusion	No	20	87.0%	26	86.7%	11	78.6%	0.818	NS
	Yes	3	13.0%	4	13.3%	3	21.4%		
Fragmented pleura	No	16	69.6%	21	70.0%	14	100.0%	0.062	NS
	Yes	7	30.4%	9	30.0%	0	0.0%		
Thickened pleura	No	22	95.7%	14	46.7%	11	78.6%	0.0001	HS
	Yes	1	4.3%	16	53.3%	3	21.4%		
Blurred pleura	No	23	100.0%	28	93.3%	14	100.0%	0.688	NS
	Yes	0	0.0%	2	6.7%	0	0.0%		
A-lines	No	22	95.7%	24	80.0%	14	100.0%	0.097	NS
	Yes	1	4.3%	6	20.0%	0	0.0%		

# Table 2 Description and comparison of ultrasound findings among three studied groups

# Table 3 Description and comparison of CT findings between three studied groups

		Group	Group						
		Group 1 Influenza (23 patients)		Group 2 COVID (30 patients)		Group 3 Atypical organism (14 patients)			
		N	%	N	%	N	%		
GGOs	No	3	13.0%	0	0.0%	9	64.3%	0.001	HS
	Yes	20	87.0%	30	100.0%	5	35.7%		
Consolidation	No	18	78.3%	26	86.7%	1	7.1%	0.001	HS
	Yes	5	21.7%	4	13.3%	13	92.9%		
Crazy paving	No	22	95.7%	20	66.7%	13	92.9%	0.012	S
	Yes	1	4.3%	10	33.3%	1	7.1%		
Interstitial thickening	No	16	69.6%	11	36.7%	13	92.9%	0.001	HS
	Yes	7	30.4%	19	63.3%	1	7.1%		
Nodules	No	19	82.6%	30	100.0%	11	78.6%	0.218	NS
	Yes	4	17.4%	0	0.0%	3	21.4%		
Tree in bud	No	21	91.3%	30	100.0%	9	64.3%	0.001	HS
	Yes	2	8.7%	0	0.0%	5	35.7%		
Pleural effusion	No	20	87%	26	86.7%	11	78.6%	0.818	NS
	Yes	3	13%	4	13.3%	3	21.4%		

GGOs Ground-glass opacities

		Soldati score in group 1 Influenza					Soldati score in group 2 COVID				Soldati score in group 3 Atypical organisms			
		Mean	±SD	Ρ	Sig	Mean	±SD	Ρ	Sig	Mean	±SD	Ρ	Sig	
Sex	Male	6.07	2.31	0.288	NS	10.80	2.76	0.840	NS	4.50	2.00	0.894	NS	
	Female	7.25	2.12			10.90	3.35			4.33	1.21			
DM	No	5.43	1.95	0.005	HS	9.53	2.90	0.004	HS	4.42	1.44	0.851	NS	
	Yes	8.11	1.76			12.13	2.36			4.50	3.54			
HTN	No	6.37	2.36	0.647	NS	9.47	2.23	0.019	S	4.09	0.94	0.378	NS	
	Yes	7.00	2.00			12.20	2.93			5.67	3.21			
IHD	No	6.00	1.97	0.033	S	10.85	3.06	0.944	NS	4.43	1.65			
	Yes	8.75	2.50			10.67	1.15							
CKD	No	6.15	2.23	0.083	NS	10.89	2.96	0.766	NS	3.92	1.08	0.024	S	
	Yes	8.67	1.15			10.00	2.83			7.50	0.71			
Malignancy	No	6.41	2.30	0.486	NS	10.75	2.52	1.00	NS	4.43	1.65			
	Yes	8.00				12.00	8.49							
Asthma	No	6.67	2.29	0.217	NS	11.04	3.01	0.333	NS	4.43	1.65			
	Yes	4.50	0.71			9.50	1.91							
Smoking	No	5.88	2.03	0.031	S	10.78	2.94	0.897	NS	4.00	1.15	0.309	NS	
	Yes	8.17	2.23			10.92	3.00			5.50	2.38			
Admission	Ward	8.00	2.83	0.287	NS	8.79	1.76	0.001	HS	3.92	1.08	0.024	S	
	ICU	6.33	2.24			12.63	2.53			7.50	0.71			
Hypoxia	No	5.23	1.88	0.002	HS	8.00	.00	0.018	S	3.70	0.95	0.02	S	
	Yes	8.10	1.66			11.27	2.89			6.25	1.71			

Table 4 Relation between personal and clinical factors and Soldati score among the three studied groups

DM Diabetes mellitus, HTN Hypertension, IHD Ischemic heart disease, CKD Chronic kidney disease, ICU Intensive-care unit

(100%) with variable numbers. Also, most patients in group 1 had B-lines in their scans (95.6% of patients). Dynamic air bronchogram showed a highly statistically significant association with group 3 patients (71.4% of patients). Thickened-pleural line was found with a significant association in group 2 more than other groups. More zones that have B-lines, subpleural consolidations, and irregular pleura resulted in a higher score. In agreement to the present study, Tsung et al. [8] and Kharasch et al. [9] showed that ultrasound findings of lung consolidation with sonographic air bronchograms correlated with bacterial pneumonia, and finding small subpleural consolidations and/or B-lines on ultrasound allowed the recognition of viral pneumonia.

Also, the work done by Buonsenso et al. [10] agreed with our study and stated that position of bronchogram showed to be a valid statistical parameter to distinguish bacterial from atypical pneumonia. Interestingly, the authors revealed that superficial air bronchogram (within 2 cm from the pleural line) was almost always present in atypical pneumonia (76.9%) which was not done in our work.

The chest CT features in the three studied groups were as follows: Ground-glass opacities (GGOs), interstitial thickening, and crazy paving were higher in group 2 (COVID) population in comparison to the other two groups, while consolidation and tree-in-bud were higher in group 3 (atypical bacterial organisms) in comparison to other studied groups. Pleural effusion was absent in most cases of viral pneumonia; however, it was associated in higher percentage of group 3 (atypical bacterial organisms) patients despite being non-statistically significant.

In disagreement with our results, Yin et al. [11] concluded that bronchiectasis and pleural effusion were more common among patients with influenza A pneumonia, whereas linear opacification, crazy-paving sign, vascular enlargement, and pleural thickening were more common among patients with COVID-19 pneumonia.

Also, the study done by Zarei et al. [12] had different findings; it showed that COVID-19 patients had more GGO and subpleural bands, whereas patients with influenza developed more consolidation and pleural effusion manifestations.

In our results, higher mean Soldati score was found in COVID patients (mean value of 10.8) compared to influenza patients and was associated with development of hypoxia in the same group.

Similarly, the study by Goldsmith et al. [13] showed that COVID-19 patients demonstrated higher severity scores when compared to influenza patients.

As well in accordance with our finding, M. Lugara et al. [14] revealed that higher LUS score corresponds to a higher mortality rate and a more severe COVID-19 phenotype.

In agreement to the present study, higher LUS score was more likely to have higher incidence of ARDS, higher invasive mechanical ventilation, and higher mortality in the study by Ji. et al. [15].

# Conclusion

LUS may be an important tool for clinical assessment and early diagnosis of pneumonia and differentiating between etiological organisms. Thus, it can play an important role in triaging pneumonia especially during pandemics and reduce the number of health care professionals exposed during stratification of the patients. Also, B-lines, thick irregular pleural lines, and subpleural consolidations are not specific to certain causative organism and can be observed in conditions such as viral pneumonias and ARDS. However, these findings, particularly when combined, can be an aid for diagnosis during epidemics when pretest probability is high, while dynamic air bronchogram identification by LUS correlates with bacterial causes of pneumonia rather than viral causes.

#### Abbreviations

ARDS	Acute respiratory distress syndrome
CAP	Community-acquired pneumonia
CKD	Chronic kidney disease
COVID-19	Coronavirus disease 2019
CT	Computed tomography
DM	Diabetes mellitus
GGOs	Ground-glass opacities
HTN	Hypertension
ICU	Intensive care unit
IHD	lschemic heart disease
LUS	Lung ultrasound
PCR	Polymerase chain reaction
SD	Standard deviation

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## Declarations

**Ethics approval and consent to participate** Approved by the local ethical committee.

#### **Consent for publication**

Not applicable.

#### **Competing interests**

The authors declare that they have no competing interests.

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