Diagnostic Accuracy of Using Point-of-Care Lung Ultrasound for Early Triage of COVID-19 Patients

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ABSTRACT
Background: Early treatment of COVID-19 leads to better patient outcomes, highlighting the importance of early diagnosis. Diagnostic modalities include computed tomography (CT) and real-time polymerase chain reaction (RT-PCR).
Objective: This study aimed to evaluate the diagnostic accuracy of lung ultrasound for the diagnosis of COVID-19 infection.
Patients and Methods: This cross-sectional study was conducted in the emergency ward of Suez Canal University Hospital from December 2021 to July 2022. The study recruited patients with suspected COVID- 19 infection according to particular inclusion and exclusion criteria. Patients eligible for the study were subjected to detailed history taking, complete clinical evaluation, determining comorbidities, evaluation of the presenting symptoms, laboratory investigations, and imaging studies such as chest X-ray, lung ultrasound, and computed tomography. Patient outcome was reported.
Results: According to lung US, 68/80 (85%) were COVID-19 positive. The lymphocytic count differed significantly between COVID positive and negative patients (p-value of 0.026). There was a significant difference in PO_2, as demonstrated in the ABG analysis (p-value 0.046). The outcome of COVID- 19 positive patients was ICU admission (47.1%), inpatient admission (33.8%), or death in the emergency ward (19.1%) respectively. Lung ultrasound detected all positive cases diagnosed by CT. Lung US showed sensitivity, specificity, a PPV, an NPV, and diagnostic accuracy of 61.8%, 66.7%, 91.3%, 23.5%, and 62.5%, respectively, compared to PCR.
Conclusion: Lung ultrasound is a promising diagnostic tool for evaluating lung infection in patients suspected/infected with COVID-19.
Keywords: COVID-19; Diagnosis; Lung ultrasound; Sensitivity; Specificity.

INTRODUCTION
COVID- 19 (SARS-CoV-2; Severe Acute Respiratory Syndrome Coronavirus 2) outbreak resulted in significant harm and variable challenges to the world [(1)]. Clinically, it represents a challenge as it has many symptoms. It might be asymptomatic, symptomatic (fever, fatigue, and dry cough), or present with complications such as severe pneumonia [(2)], with lung failure considered the primary cause of intensive care unit admission [(3)]. Although the treatment is almost supportive, patients with pneumonia might benefit from other management lines such as anti-viral drugs, anti-inflammatory drugs, and respiratory supportive measures [(4)].

Early treatment results in good patient outcomes, which signifies the importance of early diagnosis [(4)]. The diagnostic modalities include computed tomography (CT) and real-time polymerase chain reaction (RT- PCR). However, RT-PCR has some disadvantages as false negative results with low viral load; a long time is needed to obtain the results, it gives no reflection about disease severity, and reagent shortage limits its utility [(5)]. This emphasizes the role of CT in the diagnosis of COVID-19 infection, even with negative PCR results [(6)]. However, CT is an expensive tool and might not be available in all healthcare centers representing a challenge to the healthcare team [(7)].

This necessitates the use of a cheap, easy-to-use diagnostic tool such as ultrasound, which proved to be more sensitive than a chest X-ray [(8)]. It showed usefulness in the diagnosis of respiratory failure and circulatory collapse. It can be used to monitor treatment efficacy in critically ill patients. It also detects possible complications such as pneumothorax and atelectasis [(9)]. It also correlated with CT findings, adding to its reliability as a substitute for CT [(10)]. The current study was conducted to evaluate the diagnostic accuracy of lung ultrasound in diagnosing COVID-19 infection.

PATIENTS AND METHODS
This cross-sectional study included 80 patients with suspected COVID-19 infection, who were recruited from the emergency ward of Suez Canal University Hospital between December 2021 and July 2022.
Inclusion criteria: Adults of both sexes and suspected COVID-19 infection based on clinical symptoms and signs [(11)].
Exclusion criteria: Refusal to participate in the study.

Patients eligible for the study were subjected to:
- **Personal data** (age, sex, geographic distribution, contact information),
- **Clinical evaluation** in the form of Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach, respiratory rate, and O_2 saturation.
- **Determination of comorbidities** such as diabetes, hypertension, ischemic heart disease, chronic obstructive lung disease, and others.

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- **Evaluation of the presenting symptoms** as cough, fever, dyspnea, weakness, thoracic pain, syncope, smell/taste loss, headache, vomiting/diarrhea, confusion, paresthesia, nasal obstruction, leg edemas, abdominal pain, leg pain, or hemoptysis [11].
- **Laboratory investigations:** complete blood count (CBC), coagulation profile, serum electrolytes (Na, K), random blood sugar, serum creatinine, C-reactive protein (CRP), D-dimer, and arterial blood gases (ABG).
- **Imaging modalities** such as chest X-ray (CXR), lung ultrasound, and CT.
- The same researcher performed a lung ultrasound using (type of machine). The evaluation included a comment on normal lung appearance or the presence of a thick pleural line, multiple B lines, lung comet, and lung rocket [12]. Abnormal CT findings included the presence of consolidation, GGO, crazy paving, GGO and consolidation, GGO and crazy paving, lymphadenopathy, and pleural effusion [13].

The Study outcomes:

Patient outcome was either one of the following: a) inpatient admission, b) ICU admission, c) death at the emergency department, d) transferred, or e) discharged.

Sample size estimation:

The sample size was calculated at significance and error levels of 95% and 10%, respectively. The prevalence of COVID- 19 infection in an Egyptian population was 56.67%, and the sensitivity of lung ultrasound was 88.2% [7]. A drop-out proportion of 10% was added to the raw result giving a count of at least 80 participants.

***Ethical Consideration*:**

This study was ethically approved by Suez Canal University's Faculty of Medicine Research Ethics Committee. Written informed consent of all the participants was obtained. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human subjects.

Statistical Analysis

The population was classified as either COVID positive or negative based on lung US results. When applicable, percentages and frequencies (number of cases) were used to statistically characterize the data. The statistical software SPSS edition 22.0 for Windows was used for all statistical computations. Continuous variables with normally distributed data were tested using the t test, whereas categorical variables were tested using the chi-square test. Fisher's exact for categorical variables and Mann-Whitney U tests for continuous variables were used to assess non-normally distributed data. Statistical significance was defined as P-values below 0.05.

RESULTS

The study recruited 80 patients with suspected COVID-19 infection. According to lung US, 68/80 (85%) were COVID-19 positive. They demonstrated the following ultrasound findings: thick pleural line (16/68, 23.5%), multiple B lines (25/68, 36.8%), lung comet (20/68, 29.4%), and lung rocket (7/68, 10.3%). There was no significant difference between COVID positive and negative patients in their primary demographic data **(Table 1).**

Table (1): Basic demographic data of the studied population according to their COVID status as evidenced by Lung US.

		Covid -ve (12/80)	Covid +ve (68/80)	P value
Age (years)	16- 25	0 (0%)	4 (5.9%)	0.151[a]
	26-35	1 (8.3%)	17 (25%)	
	35-45	3 (25%)	10 (14.7%)	
	46-55	4 (33.3%)	13 (19.1%)	
	56-65	0 (0%)	14 (20.6%)	
	>65	4 (33.3%)	10 (14.7%)	
Gender	Male	8 (66.7%)	45 (66.2%)	0.974[a]
	Female	4 (33.3%)	23 (33.8%)	
Residency	Rural	4 (33.3%)	32 (47%)	0.378[a]
	Urban	8 (66.7%)	36 (53%)	
Chronic illness	Diabetes	3 (25%)	27 (39.7%)	0.549[a]
	HTN	4 (33.3%)	21 (30.9%)	0.745[b]
	IHD	4 (33.3%)	8 (11.8%)	0.075[b]
	COPD	1 (8.3%)	19 (27.9%)	0.277[b]
	CLD	0 (0%)	1 (1.5%)	1.00[b]

[a] Chi-square test, [b] Fisher exact test

There was no difference in the clinical presentation, including standard, neurological, uncommon, and non-COVID symptoms, between both groups **(Table 2).** Also, the clinical evaluation showed a nonsignificant difference between both groups **(Table 3).**

Table (2): Clinical presentation of the recruited patients.

		Covid -ve (12/80)	Covid +ve (68/80)	*P value*
Symptoms	Cough	1(8.3%)	11 (16.2%)	0.681[b]
	Fever	0 (0%)	6 (8.8%)	0.584[b]
	Cough and fever	10 (83.3%)	38 (55.9%)	0.110[b]
	Dyspnea	4 (33.3%)	17 (25%)	0.723[b]
	Weakness	0 (0%)	3 (4.4%)	1.000[b]
	Chest pain	0 (0%)	6 (8.8%)	0.584[b]
Neurological symptoms	Syncope	4 (33.3%)	25 (36.8%)	0.820[a]
	Loss of smell/taste	8 (66.7%)	36 (53%)	0.532[b]
	Headache	2 (16.7%)	20 (29.4%)	0.495[b]
GIT symptoms	Vomiting	11 (91.7%)	47 (69.1%)	0.164[b]
	Diarrhea	4 (33.3%)	35 (51.5%)	0.247[a]
Uncommon symptoms	Confusion	12 (100%)	45 (66.2%)	0.058[a]
	Paresthesia	0 (0%)	10 (14.7%)	
	Nasal obstruction	0 (0%)	13 (19.1%)	
Non- COVID symptoms	Abdominal pain	5 (41.7%)	24 (35.3%)	0.190[a]
	Leg pain	7 (58.3%)	29 (42.6%)	
	Hemoptysis	0 (0%)	15 (22.1%)	

[a] Chi-square test, [b] Fisher exact test.

Table (3): Clinical evaluation of the studied population.

		Covid -ve (12/80)	Covid +ve (68/80)	*P value*
Airway	Patent	7 (58.3%)	42 (61.8%)	0.822[a]
	Obstructed	5 (41.7%)	26 (38.2%)	
Breathing	Equal	6 (50%)	4 (5.9%)	0.753[b]
	Assisted breathing	6 (50%)	28 (41.2%)	
Respiratory rate	<29	6 (50%)	24 (35.3%)	0.351[b]
	>29	6 (50%)	44 (64.7%)	
Pulse	<100	9 (75%)	31 (45.6%)	0.115[b]
	>100	3 (25%)	37 (54.4%)	
SBP	<90	4 (33.3%)	25 (36.8%)	0.575[a]
	90-100	6 (50%)	38 (55.9%)	
	100-110	2 (16.7%)	5 (7.4%)	
DBP	90-100	6 (50%)	40 (58.8%)	0.569[a]
	60-80	6 (50%)	25 (36.8%)	
	40-50	0 (0%)	3 (4.4%)	
O_2 saturation	95-100%	7 (58.3%)	26 (38.2%)	0.177[a]
	80-95%	0 (0%)	11 (16.2%)	
	70-80%	1 (8.3%)	17 (25%)	
	<70	4 (33.3%)	14 (14.7%)	
GCS	<8	1 (8.3%)	20 (29.4%)	0.066[a]
	9-11	8 (66.7%)	22 (32.4%)	
	12-15	3 (25%)	26 (38.2%)	

[a] Chi-square test, [b] Fisher exact test

The lymphocytic count differed significantly between both groups (p-value 0.026), with 38.2% of COVID-positive patients having a count of 500-700. Additionally, serum K levels differed significantly between them (p-value 0.043). Also, there was a significant difference in PO_2, as demonstrated in the ABG analysis (p-value 0.046) **(Table 4).**

Table (4): Laboratory evaluation of the studied population.

			Covid -ve (12/80)	Covid +ve (68/80)	P value
CBC	Hb (g/dl)	7-9	3 (25%)	11 (16.2%)	0.847[a]
		9-10	5 (41.7%)	30 (44.1%)	
		10.1-11.5	3 (25%)	23 (33.8%)	
		11.5-13	1 (8.3%)	4 (5.9%)	
	WBCs (x10^9/L)	1.000-4.000	0 (0%)	10 (14.7%)	0.306[a]
		4.000-11.000	9 (75%)	37 (%)	
		11.000-15.000	3 (25%)	15 (22.1%)	
		>15.000	0 (0%)	6 (8.8%)	
	Lymphocytes (x10^9 /L)	0.100-0.500	0 (0%)	2 (2.9%)	0.026[a]
		0.500-0.700	2 (16.7%)	26 (38.2%)	
		0.700-0.1000	9 (75%)	20 (29.4%)	
		0.1000-0.4800	1 (8.3%)	20 (29.4%)	
	PLT (x10^9/L)	150000-200000	0 (0%)	10 (14.7%)	0.438[a]
		200000-350000	1 (8.3%)	4 (5.9%)	
		350000-450000	10 (83.3%)	52 (76.5%)	
		>450000	1 (8.3%)	2 (2.9%)	
Coagulation profile	PTT	25-35	4 (33.3%)	24 (35.3%)	0.896[a]
		>35	8 (66.7%)	44 (64.7%)	
	INR	1-1.2	8 (66.7%)	44 (64.7%)	0.896[a]
		>1.2	4 (33.3%)	24 (35.3%)	
Serum electrolytes	Na (mmol/L)	<135	0 (0%)	5 (7.4%)	0.593[a]
		135-140	4 (33.3%)	24 (35.3%)	
		140-145	8 (66.7%)	39 (57.4%)	
	K (mmol/L)	<3.5	1 (8.3%)	23 (33.8%)	0.043[a]
		3.5-4	10 (83.3%)	30 (44.1%)	
		4-5.5	1 (8.3%)	15 (22.1%)	
RBS (mg/dL)		110-200	3 (25%)	33 (48.5%)	0.307[a]
		200-350	8 (66.7%)	30 (44.1%)	
		>400	1 (8.3%)	5 (7.4%)	
LDH (mg/dL)		100-300	0 (0%)	17 (25%)	0.110[a]
		300-400	5 (41.7%)	27 (39.7%)	
		>400	7 (58.3%)	24 (35.3%)	
D- dimer (µg/dl)		<0.5	2 (16.7%)	16 (23.5%)	0.785[a]
		>0.5	10 (83.3%)	51 (75%)	
		3	0 (0%)	1 (1.5%)	
CRP (mg/dl)		0.8-1	0 (0%)	4 (5.9%)	0.319[a]
		1-10	7 (58.3%)	32 (47%)	
		10-100	4 (33.3%)	13 (19.1%)	
		>100	1 (8.3%)	19 (27.9%)	
Serum creatinine (mg/dl)		0.5-1	7 (58.3%)	32 (47%)	0.512[a]
		1-3	5 (41.7%)	30 (44.1%)	
		>3	0 (0%)	6 (8.8%)	
ABG	PO2 (mmHg)	95-100	3 (25%)	30 (44.1%)	0.046[a]
		80-95	6 (50%)	12 (17.6%)	
		70-80	1 (8.3%)	20 (29.4%)	
		<70	2 (16.7%)	6 (8.8%)	
	PO2/FiO2 ratio (mmHg)	300-200	3 (25%)	30 (44.1%)	0.198[a]
		200-100	6 (50%)	17 (25%)	
		<100	3 (25%)	21 (30.9%)	
PCR		Positive	4 (33.3%)	42 (61.8%)	0.111[b]
		Negative	8 (66.7%)	26 (38.2%)	

[a] Chi-square test, [b] Fisher exact test

Only one patient showed normal CXR findings while being COVID-19 positive as diagnosed by lung US. Variable CT findings were found as consolidation (7.4%), GGO (27.9%), crazy paving (22.1%), GGO+ crazy paving (27.9%), lymphadenopathy (2.9%), pleural effusion (7.4%), and lymphadenopathy + pleural effusion (4.4%) **(Table 5).**

Table (5): Imaging results

		Covid -ve (12/80)	**Covid +ve (68/80)**	***P value***
CXR	Positive	0 (0%)	67 (98.5%)	0.0001[b]
	Negative	12 (100%)	1 (1.5%)	
CT	Normal	12 (100%)	0 (0%)	0.0001[a]
	Consolidation	0 (0%)	5 (7.4%)	
	GGO	0 (0%)	19 (27.9%)	
	Crazy paving	0 (0%)	15 (22.1%)	
	GGO + crazy paving	0 (0%)	19 (27.9%)	
	Lymphadenopathy	0 (0%)	2 (2.9%)	
	Pleural effusion	0 (0%)	5 (7.4%)	
	Lymphadenopathy and pleural effusion	0 (0%)	3 (4.4%)	

[a] Chi-square test, [b] Fisher exact test

Among those who were COVID- 19, 32 (47.1%) patients were admitted to the ICU, 23 (33.8%) were admitted to the inpatient, and 13 (19.1%) died in the emergency ward **(Table 6)**.

Table (6): Patient outcome.

	Covid -ve (12/80)	**Covid +ve (68/80)**	***P value***
Transferred	3 (25%)	0 (0%)	0.0001[a]
ICU admission	1 (8.3%)	32 (47.1%)	
Died at the emergency department	2 (16.7%)	13 (19.1%)	
Inpatient admission	5 (41.7%)	23 (22.8%)	
Discharged	1 (8.3%)	0 (0%)	

[a] Chi-square test

Lung ultrasound detected all positive cases diagnosed by CT. Lung US showed a sensitivity of 61.8%, a specificity of 66.7%, a PPV of 91.3%, an NPV of 23.5%, and a diagnostic accuracy of 62.5% compared to PCR **(Table 7).**

Table (7): Diagnostic performance of lung US compared to PCR.

	Sensitivity	**Specificity**	**PPV**	**NPV**	**Diagnostic accuracy**
LUS	61.8%	66.7%	91.3%	23.5%	62.5%

DISCUSSION

COVID-19, a world pandemic, affected middle age patients (26-35years), males, and diabetics greatly. This differed from previous research results where men and old age (+70) were high-risk factors for COVID- 19 infection [(14)]. Another study reported hypertension and diabetes as the most common comorbid conditions associated with COVID-19 infection, with many infections occurring in the middle-aged population [(15)]. Infection of men would be explained by the fact that infectious diseases of the respiratory system occur in men more than in women. Additionally, the SARS pandemic affected men more than women [(16, 17)].

It has variable presenting symptoms such as cough and fever, dyspnea, loss of taste and smell, syncope, vomiting, diarrhea, confusion, and other unrelated symptoms. This differed from the WHO interim clinical guidance [(18)]. It has been reported that COVID-19 has a wide range of symptoms that are altered by patients' age and general condition [(19)]. These include myalgia, sore throat, chest, and abdominal pain, and respiratory symptoms [(20)]. It also may be asymptomatic or present with severe lung infection associated with multiorgan failure [(21)]. Continuous update of the presenting symptoms is warranted, respecting geographic distribution [(15)]. PO_2 decreased significantly in the COVID positive group. This agreed with previous results where PO_2 was decreased in infected persons, especially those with severe infection and lung failure [(22)]. The lymphocytes were significantly reduced in the infected group. This was confirmed previously in multiple studies [(22, 23)]. Lymphopenia was explained by the viral effect on CD4+ and CD+8 T cells leading to decreased lymphocyte production [(24)].

Early diagnosis is of paramount importance. The CT chest, PCR, and lung US have been used. However, the availability of each one differs from one institute to another [(25)]. Lung ultrasound was presented early in the diagnosis of chest infection [(26)], and it provides results in a short time, with no increased risk of radiology exposure as with CT, and is easy to be done. However, it carries the same risk of infection transmission to the health care team [(27)]. CT findings were variable, with GGO and crazy paving occurring predominantly. Other studies reported the presence of patchy or segmental GGO with vasodilatation, GGO with consolidation, and consolidation alone [(7, 28)]. Lung ultrasound findings included a thick pleural line, multiple B lines, lung comet, and lung rocket. Another study reported lung US as a pleural thickening and subpleural consolidations with more significant predominance in patients with severe presentation and those who died [22].

In the current study, lung US detected positive cases diagnosed by the CT. However, it showed sensitivity and specificity of 61.8% and 66.7%, respectively, compared to PCR testing. Another reported lung ultrasound results were similar to CT in diagnosing COVID-19 infection. However, they reported a sensitivity of 88.2% and a specificity of 11.5% [7]. Additionally, an earlier study reported similarities in the results obtained by ultrasound and CT highlighting their role in diagnosing different chest conditions [29]. An additional one reported 89% and 59% sensitivity and specificity of lung ultrasound in diagnosing lung manifestations of COVID- 19 infection [30]. Inconsistent results reported by studies would be explained by the non-specific findings associated with COVID-19 infection [31]. B lines occurred with COVID-19, as well as pulmonary edema. Pleural effusions and consolidations occurred with COVID-19 infection, viral and non-viral pneumonia, and pulmonary embolism [32]. Accordingly, it would be difficult to discriminate between the cause of these findings, whether it was attributed to COVID infection or another underlying comorbidity [30]. Thirteen (19.1%) patients died in the emergency department. Another study reported a death rate of 29% [16]. Another one in China reported a fatality rate of 15% [33].

This difference would be due to variable causes of death (lung failure, bleeding, and sepsis) affecting infected patients in the ICU while our patients were only evaluated in the emergency department. Also, using PCR in some studies to diagnose COVID- 19 infection in patients with severe infection only is a cause of bias and results in altered results [15]. About one-third of the patients with COVID-19 infection required ICU admission. This was similar to the rates reported by **Huang *et al.*** [29], while lower rates were also reported (11.8%) [15].

STRENGTH AND LIMITATIONS

The study was carried out as a prospective cohort rather than a retrospective study. The sample size was small. The patients were classified according to their COVID-19 infection status without evaluating their severity, which might be more informative. The role of lung ultrasound in patient outcomes was not evaluated. Predictors of patient mortality were not evaluated.

CONCLUSION

In conclusion, Lung ultrasound is a promising diagnostic tool for evaluating lung infection in patients suspected/infected with COVID-19.

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REFERENCES

1. **WHO (2020):** Coronavirus disease 2019 (COVID-19). https://www.who.int/emergencies/ diseases/ novel-coronavirus-2019/situation-reports.
2. **Guan W, Ni Z, Hu Y *et al.* (2020):** Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med., 382(18):1708- 1720.
3. **Zhou F, Yu T, Du R *et al.* (2020):** Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet, 395(10229):1054–62.
4. **Chen J, Qi T, Liu L *et al.* (2020):** Clinical progression of patients with COVID-19 in Shanghai, China J Infect., 80(5):1-6.
5. **Corman V, Landt O, Kaiser M *et al.* (2020):** Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Euro Surveill., 25(3): 2000045. DOI: 10.2807/1560- 7917.ES.2020.25.3.2000045.
6. **Bassetti M, Vena A, Roberto Giacobbe D (2020):** The novel Chinese coronavirus (2019-nCoV) infections: challenges for fighting the storm. Eur J Clin Invest., 50: e13209. doi: 10.1111/eci.13209.
7. **Alrifai A, El-Raey F, Yousef A *et al.* (2020):** Ultrasound in Suspected Pneumonic COVID-19: Our Experience. IJMA., 2(4): 682-689.
8. **Vetrugno L, Bove T, Orso D *et al.* (2020):** Our Italian experience using lung ultrasound for identification, grading and serial follow-up of severity of lung involvement for management of patients with COVID-19. Echocardiography, 37:625–627.
9. **Mojoli F, Bouhemad B, Mongodi S *et al.* (2019):** Lung ultrasound for critically ill patients. Am J Respir Crit Care Med., 199(6):701–14.
10. **Danish M, Agarwal A, Goyal P *et al.* (2019):** Diagnostic performance of 6-point lung ultrasound in ICU patients: a comparison with chest X-ray and CT thorax. Turk J Anaesthesiol Reanim., 47(4):307–19.
11. **Struyf T, Deeks J, Dinnes J *et al.* (2022):** Signs and symptoms to determine if a patient presenting in primary care or hospital outpatient settings has COVID-19. Cochrane Database of Systematic Reviews, 5:CD013665. doi:10.1002/14651858.CD013665.
12. **Tirado A, Dabaja A, Nickels L *et al.* (2022):** Lung Ultrasonography. InAtlas of Emergency Medicine Procedures. Springer, Cham. pp. 151-157. doi:10.1007/978-3-030-85047-0_28
13. **Zhou J, Liao X, Cao J *et al.* (2021):** Differential diagnosis between the coronavirus disease 2019 and Streptococcus pneumoniae pneumonia by thin-slice CT features. Clinical Imaging, 69:318-23.
14. **Pijls B, Jolani S, Atherley A *et al.* (2021):** Demographic risk factors for COVID-19 infection, severity, ICU admission and death: a meta-analysis of 59 studies. BMJ Open, 11:e044640. doi:10.1136/ bmjopen-2020-044640
15. **Goshayeshi L, Akbari Rad M, Bergquist R *et al.* (2021):** Demographic and clinical characteristics of severe Covid-19 infections: a cross-sectional study from Mashhad University of Medical Sciences, Iran. BMC Infect Dis., 21(1):656. https://doi.org/10.1186/s12879-021-06363-6.
16. **Falagas M, Mourtzoukou E, Vardakas K (2007):** Sex differences in the incidence and severity of respiratory tract infections. Respir Med., 101:1845–63.

17. **Leung G, Hedley A, Ho L *et al.* (2004):** The epidemiology of severe acute respiratory syndrome in the 2003 Hong Kong epidemic: an analysis of all 1755 patients. Ann Intern Med., 141:662–73.
18. **WHO (2020):** Interim clinical guidance for management of patients with confirmed coronavirus disease (COVID-19). https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html.
19. **Gao Z, Xu Y, Sun C *et al.* (2021):** A systematic review of asymptomatic infections with COVID-19. J Microbiol Immunol Infect., 54(1):12-16.
20. **Murat S, Dogruoz Karatekin B, Icagasioglu A *et al.* (2021):** Clinical presentations of pain in patients with COVID-19 infection. Irish Journal of Medical Science, 190(3):913-17.
21. **Guan W, Ni Z, Hu Y *et al.* (2020):** Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med., 382(18):1708–20.
22. **Stecher S, Anton S, Fraccaroli A *et al.* (2021):** Lung ultrasound predicts clinical course but not outcome in COVID-19 ICU patients: a retrospective single-center analysis. BMC Anesthesiol., 21: 178. https://doi.org/10.1186/s12871-021-01396-5
23. **Ibrahim M, Al-Aklobi O, Abomughaid M *et al.* (2021):** Epidemiological, clinical, and laboratory findings for patients of different age groups with confirmed coronavirus disease 2019 (COVID-19) in a hospital in Saudi Arabia. PLoS One, 16(4):e0250955. doi:10.1371/journal.pone.0250955.
24. **Chen N, Zhou M, Dong X *et al.* (2020):** Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet, 395:507–13.
25. **Yoon S, Lee K, Kim J *et al.* (2020):** Chest Radiographic and CT Findings of the 2019 Novel Coronavirus Disease (COVID-19): Analysis of Nine Patients Treated in Korea. Korean J Radiol., 21(4):494–500.
26. **Soldati G, Smargiassi A, Inchingolo R *et al.* (2020):** Is There a Role for Lung Ultrasound During the COVID-19 Pandemic? J Ultrasound Med., 39(7):1459-1462.
27. **Bass C, Sajed D, Adedipe A *et al.* (2015):** Pulmonary ultrasound and pulse oximetry versus chest radiography and arterial blood gas analysis for the diagnosis of acute respiratory distress syndrome: a pilot study. Crit Care, 19(1):282. DOI: 10.1186/s13054-015-0995-5.
28. **Hamer O, Salzberger B, Gebauer J *et al.* (2020):** CT morphology of COVID-19: Case report and review of literature. Rofo., 192(5):386- 392.
29. **Tierney D, Huelster J, Overgaard J *et al.* (2020):** Comparative performance of pulmonary ultrasound, chest radiograph, and CT among patients with acute respiratory failure. Crit Care Med., 48(2): 151-157.
30. **Haak S, Renken I, Jager L *et al.* (2021):** Diagnostic accuracy of point-of-care lung ultrasound in COVID-19. Emergency Medicine Journal, 38(2):94-99.
31. **Kraemer A, Staal S, López Matta J *et al.* (2020):** POCUS series: point-of-care lung ultrasound in patients with COVID-19. Neth J Crit Care, 28:162–64.
32. **Pierce C (2020):** Clarifying the role of lung ultrasonography in COVID-19 respiratory disease. CMAJ., 192: 436. doi:10.1503/cmaj.75311.
33. **Huang C, Wang Y, Li X *et al.* (2020):** Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet, 395(10223):497–506.