ORIGINAL ARTICLE

Novel coronavirus disease 2019: predicting prognosis with a computed tomography–based disease severity score and clinical laboratory data

Ali Sabri[1*], Amir H. Davarpanah[2*], Arash Mahdavi[3], Alireza Abrishami[4], Mehdi Khazaei[5], Saman Heydari[5], Reyhane Asgari[5], Seyyed Mojtaba Nekooghadam[6], Julian Dobranowski[1], Morteza Sanei Taheri[7]

1 Department of Radiology, McMaster University, Niagara Health, St. Catharines, Ontario, Canada
2 Department of Radiology, Emory University School of Medicine, Emory University Hospital, Atlanta, Georgia, United States
3 Department of Radiology, Shahid Beheshti University of Medical Sciences, Modarres Hospital, Tehran, Iran
4 Department of Radiology, Shahid Beheshti University of Medical Sciences, Labbafinejad Hospital, Tehran, Iran
5 Department of Radiology, Shahid Beheshti University of Medical Sciences, Tehran, Iran
6 Department of Internal Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran
7 Department of Radiology, Shahid Beheshti University of Medical Sciences, Shohada-e-Tajrish Hospital, Tehran, Iran

KEY WORDS

novel coronavirus, computed tomography–based disease severity scoring, mortality, pandemic, risk stratification

ABSTRACT

INTRODUCTION Currently, there are known contributing factors but no comprehensive methods for predicting the mortality risk or intensive care unit (ICU) admission in patients with novel coronavirus disease 2019 (COVID-19).

OBJECTIVES The aim of this study was to explore risk factors for mortality and ICU admission in patients with COVID-19, using computed tomography (CT) combined with clinical laboratory data.

PATIENTS AND METHODS Patients with polymerase chain reaction–confirmed COVID-19 (n = 63) from university hospitals in Tehran, Iran, were included. All patients underwent CT examination. Subsequently, a total CT score and the number of involved lung lobes were calculated and compared against collected laboratory and clinical characteristics. Univariable and multivariable proportional hazard analyses were used to determine the association among CT, laboratory and clinical data, ICU admission, and in-hospital death.

RESULTS By univariable analysis, in-hospital mortality was higher in patients with lower oxygen saturation on admission (below 88%), higher CT scores, and a higher number of lung lobes (more than 4) involved with a diffuse parenchymal pattern. By multivariable analysis, in-hospital mortality was higher in those with oxygen saturation below 88% on admission and a higher number of lung lobes involved with a diffuse parenchymal pattern. The risk of ICU admission was higher in patients with comorbidities (hypertension and ischemic heart disease), arterial oxygen saturation below 88%, and pericardial effusion.

CONCLUSIONS We can identify factors affecting in-hospital death and ICU admission in COVID-19. This can help clinicians to determine which patients are likely to require ICU admission and to inform strategic healthcare planning in critical conditions such as the COVID-19 pandemic.

Correspondence to:
Ali Sabri, MD, FRCPC, Department of Radiology, McMaster University, Niagara Health, 1200-4th Ave, St. Catharines, L2S 0A9 Ontario, Canada, phone: +1 905 616 0202, email: sabri.ali@gmail.com
Received: May 17, 2020.
Revision accepted: June 2, 2020.
Published online: June 5, 2020.
Pol Arch Intern Med. 2020; 130 (7-8): 629-634
doi:10.20452/pamw.15422

* AS and AHD contributed equally to this work.

INTRODUCTION Coronavirus disease 2019 (COVID-19), caused by the outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has recently been announced a global pandemic by the World Health Organization.[1] This infection can lead to severe respiratory distress requiring intensive care unit (ICU) admission. The World Health Organization estimated the COVID-19 mortality risk to be 3.4%.[2] The median time from symptom onset to radiological confirmation of this viral pneumonia is 5 days, whereas the median time from symptom onset to ICU admission is approximately 9.5 days.[3]

To identify predictors of clinical outcomes in patients with COVID-19 is essential in helping healthcare facilities in pandemic planning and

WHAT'S NEW?

The combination of computed tomography (CT) as well as clinical and laboratory data can help clinicians to predict the prognosis of novel coronavirus disease 2019. We established a CT scoring model to quantify disease severity. The extent of disease evaluated by CT has the potential to predict patient outcomes and, particularly, the need for intensive care unit admission.

accurate redistribution of highly valuable resources, such as ICU beds, toward the patients who may need these most during the course of their disease. The individual predictors of clinical outcomes have been already identified.[3]

Patient age is an important epidemiological factor associated with worse outcomes. The median age of deceased patients is significantly older than that of recovered patients. Patients over the age of 65 years account for the majority of COVID-19–related deaths.[3] Comorbidities such as diabetes, chronic lung disease, chronic hypertension and other cardiovascular diseases, chronic renal disease, and chronic liver disease are more frequent among deceased patients than among those recovered. Severe illness caused by COVID-19 is also more common in patients who are immunocompromised.[4]

Adverse outcomes are also related to patients' clinical status. Symptoms associated with hypoxemia, systematic inflammation, and multiorgan dysfunction were found more frequently in deceased patients than in those recovered.[5] In a retrospective cohort study from Wuhan, China, older age and a higher Sequential Organ Failure Assessment (SOFA) score were potential predictors of in-hospital mortality[6] in patients with COVID-19. So far, it has been known that the most important clinical criteria for COVID-19 severity include respiratory distress (respiratory rate [RR] ≥30; arterial oxygen saturation [SpO_2] <93% at rest; partial oxygen pressure [PaO_2] / fraction of inspired oxygen [FiO_2] ≤300 mm Hg) and rapid (within 24 to 48 hours) progression (>50%) of CT findings[7] and the extent of disease on CT scans.[7,8]

Some studies have suggested that CT may play a relevant role in predicting the outcomes of the patients. Patients with COVID-19 pneumonia at baseline CT who had ICU admission or who died had 4 or more lung lobes affected compared with patients without ICU admission or alive (16% versus 6% of patients).[9] The progression of abnormal imaging findings indicate a poor or fair response where the alleviated symptoms seen on CT suggest a good response.[10] A progressive deterioration of lesions on imaging despite medical treatment is thought to be associated with poor prognosis.[11]

The purpose of this study was to assess whether the extent of the disease on an initial CT scan (which was evaluated by a novel CT scoring method) in combination with laboratory and clinical characteristics has the potential to predict poor patient outcomes, ICU admission, and mortality related to COVID-19.

PATIENTS AND METHODS

Study design and participants This retrospective cohort study included adults (age ≥18 years) adults admitted in university hospitals in Tehran (Iran) between February 21, 2020 and March 17, 2020. All patients had positive results of the CoV-2 RNA real-time polymerase chain reaction test. The study was approved by the institutional review board and all patients signed informed consent on arrival. Ethical approval was obtained from Shahid Beheshti University of Medical Sciences, Tehran, Iran. All patients with incomplete medical records were excluded.

Data collection Demographic (age and sex), medical history (comorbidities), and clinical characteristics (including pulse rate, RR, temperature, and oxygen saturation) on admission were extracted from electronic medical records using a standardized data collection form. Chest CT scans were performed in all patients at the time of admission.

Definitions Fever was defined as a temperature greater than 38 °C; tachycardia as a heart rate greater than 100 bpm; tachypnea as a RR greater than 20/min; and abnormal oxygen saturation as a value equal to or lower than 93%.

Outcome Adverse outcomes were recorded based on 2 methods: first, a 2-point scale of non-ICU and ICU admission; second, a 2-point scale of survivors and nonsurvivors.

Image analysis Computed tomography examinations were retrieved from an image archiving and communication system.

Two investigators (AA and AM; with 5-year experience in chest imaging) independently evaluated chest CT examinations and scored lung parenchymal abnormalities. In case of disagreement, a third chest radiologist was consulted to reach the final score. Each lobe was evaluated for the percentage of lung involvement on a scale from 0 to 4 (0, 0% involvement; 1, less than 25% involvement; 2, 25% to less than 50% involvement; 3, 50% to less than 75% involvement; 4, 75% or greater involvement).[12] An overall CT score was a sum of scores from all 5 lung lobes. The maximum possible score was 20. The total CT score and the number of lobes involved were recorded. The distribution of abnormalities was evaluated as predominantly peripheral, central, or diffuse. Additionally, the presence of pleural and pericardial effusion was recorded.

Statistical analysis All statistical analyses were performed using the JMP software, version 15 Pro (SAS, Cary, North Carolina, United States). A *P* value less than 0.05 was considered significant. Mean (SD) was calculated and reported for numeric covariates. Frequency and its

TABLE 1 Demographic, clinical, and imaging characteristics for coronavirus disease 2019 survivors and nonsurvivors

Variable		Total (n = 63)	Survivors (n = 54)	Nonsurvivors (n = 9)	*P* value
Age, y, mean (SD); range		54.1 (15.5); 23–86	52.9 (15.4); 23–84	61.3 (15.1); 37–86	0.15
Comorbidity	Hypertension	15 (23.8)	13 (24.1)	2 (22.2)	0.90
	Ischemic heart disease	10 (15.9)	13 (24.1)	2 (22.2)	0.59
	Diabetes	12 (19)	11 (20)	1 (11.1)	0.21
Respiratory rate >20/min		10 (17.5)	9 (18.8)	1 (11.1)	0.56
Pulse rate >100/min		19 (32.8)	16 (32.7)	3 (33.3)	0.96
Fever >38 °C		25 (43.1)	22 (44.9)	3 (33.3)	0.51
SaO_2 <88%		12 (20)	8 (15.4)	4 (44.4)	0.04
CT score, points, mean (SD)		7.4 (4)	7 (4.1)	9.8 (3.3)	0.04
Lobes involved, n, mean (SD)		4.2 (1.3)	4 (1.3)	4.9 (0.3)	<0.001
Ground-glass opacity		59 (93.6)	50 (92.6)	9 (100)	0.95
Consolidation		25 (39.7)	23 (42.6)	2 (22.2)	0.29
Pleural effusion		9 (14.3)	6 (11.1)	3 (33.3)	0.11
Pericardial effusion		5 (7.9)	3 (5.5)	2 (22.2)	0.13
Axial distribution	Peripheral	40 (63.5)	36 (66.7)	4 (44.4)	0.28
	Central	9 (14.3)	6 (11.1)	3 (33.3)	
	Diffuse	11 (17.5)	9 (16.7)	2 (22.2)	
Craniocaudal distribution	Upper	2 (3.2)	2 (3.7)	0	<0.01
	Mild	8 (12.7)	7 (13)	1 (11.1)	
	Lower	28 (44.4)	27 (50)	1 (11.1)	
	Diffuse	22 (34.9)	15 (27.8)	7 (77.8)	

Data are presented as number (percentage) unless otherwise indicated.

Abbreviations: CT, computed tomography; SaO_2, arterial oxygen saturation

percentage were given for categorical variables. To compare differences between patients who required ICU admission and those who did not, as well as survivors and nonsurvivors, we used the 1-way analysis of variance test and the Kruskal–Wallis test for numerical covariates and the χ^2 test or the Fisher exact test for categorical covariates where appropriate. To explore risk factors associated with ICU admission and in-hospital death, univariable and multivariable logistic regression models were used. We excluded variables from the univariable analysis if their between-group differences were nonsignificant, if the number of events was too small to calculate odds ratios, or if they were colinear with other included factors. A 2-sided *P* of less than 0.05 was considered significant.

RESULTS From 100 adult patients referred to our hospitals between February 21, 2020 and March 17, 2020 owing to suspicion of COVID-19, 63 with complete medical records were included in this study. The mean (range) age of the 63 patients was 54.1 (23–86) years (TABLE 1). Of these, 54 patients were discharged and 9 died in the hospital (mean [range] age, 52.9 [23–84] and 61.3 [37–86] years, respectively; *P* = 0.15). During the course of hospitalization, 18 patients were admitted to the ICU, and 45 patients were admitted to the general ward (mean [range] age, 51.2 [23–86] and 63.2 [40–80] years, respectively; *P* <0.01).

Comorbidities were present in 37 patients, with hypertension being the most common one (15 patients [23.8%]), followed by diabetes (11 patients [17.4%]), and ischemic heart disease (10 patients [15.8%]).

The most common symptom on admission was cough (49 patients [77.7%]) and fever (25 patients [43%]) followed by tachycardia (19 patients [30%]) and tachypnea (10 patients [15.8%]). Oxygen saturation on admission below 88% was noted in 12 patients (20%).

Chest CT showed ground-glass opacities in 59 patients (93.4%) and consolidations in 50 (92.6%). The majority of patients showed peripheral distribution of lung abnormalities (40 patients [63.5%]); central and diffuse opacities were seen in 9 (14.3%) and 11 (17.5%) patients, respectively. The lower or diffuse distribution of lung opacities were the most common pattern seen (in 28 [44.4%] and 22 [34.9%] patients) with the upper and mid lung distribution visualized only in 2 [3.2%] and 8 [12.7%] patients, respectively.

In univariable analysis, the odds ratios of death were higher in patients with oxygen saturation below 88% at presentation, a higher CT score, a higher number of involved lobes, and a diffuse pattern of lung involvement on CT. Higher odds ratios of ICU admission during hospitalization were found in older patients with a history of hypertension and ischemic heart disease, oxygen

TABLE 2 Demographic, clinical, and imaging characteristics by intensive care unit and non–intensive care unit admission

Variable		Total (n = 63)	Non-ICU admission (n = 48)	ICU admission (n = 15)	*P* value
Age, y, mean (SD); range		54.1 (15.5); 23–86	51.2 (15.7); 23–86	63.2 (10.6); 40–80	<0.01
Comorbidity	Hypertension	15 (23.8)	9 (18.7)	8 (53.3)	0.049
	Cardiac disease	10 (15.9)	7 (14.8)	8 (53.3)	0.03
	Diabetes	12 (19)	6 (12.5)	5 (33.3)	0.07
Respiratory rate >20/min		10 (17.5)	6 (13.6)	4 (30.7)	0.21
Pulse rate >100/min		19 (32.8)	15 (33.3)	4 (30.7)	>0.99
Fever >38 °C		25 (43.1)	16 (36.4)	9 (64.3)	0.12
SaO_2 <88%		12 (20)	7 (14.9)	6 (46.6)	0.03
CT score, mean (SD)		7.4 (4)	7 (4)	8.7 (3.9)	8.7 (3.9)
Lobes involved, n, mean (SD)		4.2 (1.3)	4 (1.3)	4.8 (0.8)	4.8 (0.8)
Ground-glass opacity		59 (93.6)	41 (91.1)	18 (100)	0.31
Consolidation		25 (39.7)	17 (37.8)	8 (44.4)	0.77
Pleural effusion		9 (14.3)	5 (10.4)	4 (26.7)	0.19
Pericardial effusion		5 (7.9)	2 (4.2)	4 (26.6)	0.03
Axial distribution	Peripheral	40 (63.5)	33 (73.3)	7 (38.9)	<0.01
	Central	9 (14.3)	3 (6.7)	6 (33.3)	
	Diffuse	11 (17.5)	6 (13.3)	5 (27.8)	
Craniocaudal distribution	Upper	2 (3.2)	1 (2.2)	1 (2.2)	0.51
	Mild	8 (12.7)	6 (13.3)	2 (11.1)	
	Lower	28 (44.4)	21 (46.7)	7 (38.9)	
	Diffuse	22 (34.9)	14 (31.1)	8 (44.4)	

Data are presented as number (percentage) unless otherwise indicated.

Abbreviations: ICU, intensive care unit; others, see TABLE 1

saturation below 88% at presentation, a higher number of involved lobes, pericardial effusion and peripheral and / or central pattern of distribution on chest CT (TABLE 2).

In a multivariable logistic regression model, we found that oxygen saturation below 88% on admission and the number of involved lobes on chest CT were associated with an increased odds ratio of death. There were higher odds ratios of ICU admission during the hospital course in patients with comorbidities (hypertension and ischemic heart disease), oxygen saturation below 88%, and pericardial effusion on CT.

DISCUSSION Risk stratification may prompt immediate supportive treatment. This retrospective study identified several risk factors for ICU admission and death in adults in Tehran, Iran, who were hospitalized for COVID-19. In particular, low SaO_2 on admission and the number of involved lobes on chest CT (4 or more) were associated with an increased odds ratio of death. Additionally, there were higher ICU admission rates during the hospital course in patients with comorbidities (hypertension and ischemic heart disease), low SaO_2, and pericardial effusion on chest CT.

Our findings suggest that chest CT plays a crucial role, in addition to clinical and laboratory characteristics, to identify which patient is at higher risk and requires hospitalization. Based on our results, the only independent CT predictor of mortality was the number of involved lobes. In particular, the type of lung involvement (ground-glass opacity versus consolidation), the distribution of lung involvement as well as the CT score were not independent predictors of mortality. The presence of pericardial effusion was the only independent CT predictor of ICU admission.

The patients admitted to the ICU who died had a more diffuse or peripheral distribution of the disease on CT, which did not prove to be a key factor in prognosis in multivariable analysis; however, it is still a relevant finding.

Although older age has been reported to be an important independent predictor of mortality in COVID-19, it was not an independent predictor in our study, which might be explained by a relatively small sample size.

The most important laboratory characteristic that predicted patient outcomes was SaO_2 below 88% on admission. In our study, the common independent predictor of both ICU admission and mortality was low SaO_2 on admission. Previous studies have also shown the significance of SaO_2 evaluation in patients with a variety of respiratory and systemic disorders.[13,14]

Pericardial effusion is regarded as a particularly important contributing factor with regard to ICU admission, as this could be an indication of myocarditis or cardiomyopathy caused

TABLE 3 Multivariable analysis of factors affecting in-hospital death and intensive care unit admission

Outcome	Variable	*P* value	Multivariable OR (95% CI)
In-hospital death	Number of lobes involved	0.02	7.63 (1.58–13.68)
	SaO_2 <88%	<0.01	1.72 (1.07–2.37)
ICU admission	History of hypertension	<0.01	1.42 (1.13–1.71)
	History of cardiac disease	0.02	1.12 (1.08–1.14)
	Pericardial effusion	0.04	1.14 (1.11–1.7)
	SaO_2 <88%	<0.01	4.38 (3.78–9.73)

Abbreviations: OR, odds ratio; others, see TABLES 1 and 2

by COVID-19. However, we could not prove this hypothesis, as our patients did not have an echocardiogram performed.

We initially evaluated numerous other clinical factors including fever, RR, and heart rate as well as some other incidental findings on CT such as linear densities, reverse halo, and round opacities. Those did not prove to be significantly valuable in determining the prognosis of COVID-19.

At the beginning of the COVID-19 pandemic in China, owing to lack of sensitivity of the available diagnostic kits, CT proved to be a sensitive diagnostic tool and many studies were carried on to prove its vital role. It is now known that COVID-19 shows typical features on CT. However, the American College of Radiology and some other stakeholder organizations currently advise against the routine use of CT for screening patients with suspected COVID-19.[15] The trend is gradually shifting toward using CT only to assess the complication of this viral infection and to evaluate the prognosis. Despite the early role of chest CT for COVID-19 screening in countries having limited access to diagnostic kits, in our opinion, a CT scan is useful in predicting prognosis, such as a probability of ICU admission and mortality. Computed tomography findings combined with clinical and laboratory characteristics such as oxygen saturation proved to predict the prognosis of COVID-19 and patient outcomes, the need for ICU admission in particular.

Admittedly, our study had some limitations. A small sample size and treatment only in an advanced healthcare facility in the country could influence the results. We also did not have access to some laboratory data that were important in other studies, as described above. Further studies on larger samples are needed to establish a robust scoring system to allow multiple variables to predict the prognosis.

We can identify factors affecting in-hospital death and ICU admission in COVID-19. This can help clinicians to determine which patients are likely to require ICU admission and to inform strategic healthcare planning in critical conditions such as the COVID-19 pandemic (TABLE 3).

Delayed intubation is associated with poor patient outcomes. Identification of patients at high risk, using the described combination of a CT score together with clinical and laboratory data, can potentially lead to improvement in the quality of patient care.[16] These patients can be monitored and treated more aggressively.

This is of particular importance especially in jurisdictions with a potential shortage of hospitals and ICU beds. In our opinion, a combined scoring system can play an important role to help the healthcare system to accurately redistribute essential resources such as ICU beds toward the patients who may need these most during the course of their disease.

Conclusions Further studies on larger patient samples are needed to establish a robust scoring system to allow multiple variables to predict prognosis in COVID-19. Our small sample proved to be a good predictor of COVID-19 prognosis and may suggest the need for advanced care such as hospitalization and ICU admission. A score combining CT and clinical and laboratory data with an excellent negative or positive predictive value is needed and may help clinicians to determine which patients are unlikely to require ICU admission and to facilitate strategic healthcare planning in critical conditions such as the current COVID-19 pandemic.

ARTICLE INFORMATION

NOTE Digital identifiers were assigned to AS (ORCID iD, http://orcid.org/0000-0002-4335-1770), AD (ORCID iD, https://orcid.org/0000-0003-0950-6772), SMN (ORCID iD, https://orcid.org/0000-0001-5243-3260), MK (ORCID iD, https://orcid.org/0000-0001-7852-7951), RA (ORCID iD, https://orcid.org/0000-0002-2052-2987), AM (ORCID iD, https://orcid.org/0000-0002-8083-697X), AA (ORCID iD, https://orcid.org/0000-0002-1330-6207), JD (ORCID iD, https://orcid.org/0000-0002-5613-3502), and MST (ORCID iD, https://orcid.org/0000-0002-8881-9058).

CONTRIBUTION STATEMENT AM, AA, MK, SH, RA, and MST collected the data. AS and AHD interpreted the data and drafted the manuscript. JD critically revised the manuscript for important intellectual content. All authors contributed to study conception and design as well as approved the final version of the manuscript.

CONFLICT OF INTEREST None declared.

HOW TO CITE Sabri A, Davarpanah AH, Mahdavi A, et al. Novel coronavirus disease 2019: predicting prognosis with a computed tomography–based disease severity score and clinical laboratory data. Pol Arch Intern Med. 2020; 130: 629-634. doi:10.20452/pamw.15422

REFERENCES

1 Song Z, Hu Y, Zheng S, et al. Hospital pharmacists' pharmaceutical care for hospitalized patients with COVID-19: Recommendations and guidance from clinical experience. Res Social Adm Pharm. 2020 Apr 3. [Epub ahead of print].

2 World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 – 3 March 2020. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--3-march-2020. Accessed April 21, 2020.

3 Yang X, Yu Y, Xu J, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med. 2020; 8: 475-481.

4 Preliminary estimates of the prevalence of selected underlying health conditions among patients with coronavirus disease 2019 – United States,

February 12–March 28, 2020. MMWR Morb Mortal Wkly Rep 2020; 69: 382-386.

5 Chen T, Wu D, Chen H, et al. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ. 2020; 368: m1091.

6 Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020; 395: 1054-1062.

7 World Health Organization. Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected: interim guidance, 13 March 2020. https://www.who.int/docs/default-source/coronaviruse/clinical-management-of-novel-cov. Accessed April 21, 2020.

8 Sabri A, Taheri MS, Mahdavi A, Dobranowski J. A 63-year-old man treated for coronavirus disease 2019. Pol Arch Intern Med. 2020; 130: 324-325.

9 Colombi D, Bodini FC, Petrini M, et al. Well-aerated lung on admitting chest CT to predict adverse outcome in COVID-19 pneumonia. Radiology. 2020: 201433. [Epub ahead of print].

10 Zhao W, Zhong Z, Xie X, et al. CT scans of patients with 2019 novel coronavirus (COVID-19) pneumonia. Theranostics. 2020; 10: 4606.

11 Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. Lancet Infect Dis. 2020; 20: 425-434.

12 Jin GY, Lynch D, Chawla A, et al. Interstitial lung abnormalities in a CT lung cancer screening population: prevalence and progression rate. Radiology. 2013; 268: 563-571.

13 Geelhoed GC, Landau LI, Le Souëf PN. Evaluation of SaO_2 as a predictor of outcome in 280 children presenting with acute asthma. Ann Emerg Med. 1994; 23: 1236-1241.

14 Millman AL, Payne B, Qu Z, et al. Oxygen saturation as a predictor of adverse maternal outcomes in women with preeclampsia. J Obstet Gynaecol Can. 2011; 33: 705-714.

15 American College of Radiology. ACR Recommendations for the use of Chest Radiography and Computed Tomography (CT) for Suspected COVID-19 Infection, 11 March 2020. https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT--for-Suspected-COVID19-Infection. Accessed April 15, 2020.

16 Thomas-Rüddel D, Winning J, Dickmann P, et al. Coronavirus disease 2019 (COVID-19): update for anesthesiologists and intensivists. March 2020. Der Anaesthesist. 2020: 1-10.