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Original Article

Triaging of COVID-19 patients using low dose chest CT: Incidence and factor analysis of lung involvement on CT images

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ABSTRACT

Introduction: Despite an increase in CT studies to evaluate patients with coronavirus disease 2019 (COVID-19), their indication in triage is not well-established. The purpose was to investigate the incidence of lung involvement and analyzed factors related to lung involvement on CT images for establishment of the indication for CT scans in the triaging of COVID-19 patients.
Methods: Included were 192 COVID-19 patients who had undergone CT scans and blood tests for triaging. Two radiologists reviewed the CT images and recorded the incidence of lung involvement. The prediction model for lung involvement on CT images using clinico-laboratory variables [age, gender, body mass index, oxygen saturation of the peripheral artery (SpO$_2$), comorbidities, symptoms, and blood data] were developed by multivariate logistic regression with cross-validation.
Results: In 120 of the 192 patients (62.5%), CT revealed lung involvement.
The patient age (odds ratio [OR]; 4.95, 95% confidence interval [CI]; 0.93–26.49), albumin (OR; 4.66, 95%CI; 1.37–15.84), lactate dehydrogenase (OR; 5.79, 95%CI; 1.43–23.38) and C-reactive protein (OR; 8.93, 95%CI; 4.13–19.29) were selected for the final prediction model for lung involvement on CT images. The cross-validated area under the receiver operating characteristics (ROC) curve was 0.83.
Conclusions: The high incidence of lung involvement (62.5%) was confirmed on CT images. The proposed prediction model that includes the patient age, albumin, lactate dehydrogenase, and C-reactive protein may be useful for predicting lung involvement on CT images and may assist in deciding whether triaged COVID-19 patients should undergo CT.

1. Introduction

Coronavirus disease 2019 (COVID-19) was first encountered in a series of 41 individuals presenting with undetermined forms of pneumonia in Wuhan, China, in December 2019 [1]. The infection rapidly spread around the world. The World Health Organization (WHO) officially declared the outbreak a "public health emergency of international concern" on January 30, 2020. The disease was declared a pandemic on March 11, 2020.

While many individuals with COVID-19 infection are asymptomatic or develop only mild symptoms such as fever, cough, fatigue, and headache, in some the disease progresses and leads to respiratory distress (severe pneumonia, acute respiratory distress syndrome, multiple organ failure), and even death [1,2].

The pandemic and limited medical resources necessitated the triaging of patients with COVID-19 infection [3]. Although there were increasing positive evidences of CT scans to evaluate COVID-19 patients, further consideration for their indication in triage were required from

the risk of radiation exposure and the capacity of CT scanning. Regarding the risk of radiation exposure, low dose CT whose radiation dose is about one-fourth that of standard dose CT is used for lung cancer screening to reduce mortality rate from lung cancer [4]. Applied low dose CT to the triaging of COVID-19 patients, we can reduce the risk of radiation exposure from CT [5].

The purpose of our study was to investigate the incidence of- and analyzed factors related to lung involvement on CT images for establishment of the indication for CT scans in the triaging of COVID-19 patients.

2. Materials and methods

2.1. Subjects

This retrospective study was approved by our institutional review board; prior informed consent was waived. This triaging of COVID-19 patients with positive reverse-transcription polymerase chain reaction (RT-PCR) assays using low dose chest CT was conducted by the local government.

We initially enrolled 197 COVID-19 patients with positive RT-PCR assay triaged between December 23–26, 2020. Excluded were 5 patients; one was pregnant, in another joint contracture made blood tests impossible, and in 3 patients the body weight was not recorded on the interview sheet. Consequently, our study included 192 COVID-19 patients with positive RT-PCR assays; all had undergone both CT studies and blood tests for triage management.

Patient characteristics such as age, gender, body mass index (BMI), comorbidity, symptom and symptom onset were recorded.

2.2. Clinico-laboratory data

We recorded vital parameters such as body temperature and oxygen saturation of the peripheral artery (SpO_2) in each patient.

Blood tests for triage management were performed and the following parameters were evaluated: white blood cell (WBC), red blood cell (RBC), hemoglobin (Hb), platelet (PLT), albumin (ALB), aspartate aminotransferase (AST), lactate dehydrogenase (LDH), creatinine (Cre), C-reactive protein (CRP) and D-dimer. Blood test parameters were kept to a minimum required due to limited medical resources.

2.3. CT imaging

All scans were performed on a mobile CT unit with a 16 detector CT scanner (ECLOS 16, Hitachi Medical Corporation, Japan).

Reduced radiation dose helical scans were acquired at a tube voltage of 120 kV; the tube current was regulated by automatic exposure control (AEC) and the preset noise level was 30 Hounsfield units. The range of tube current was 20–25 mA in adults and 10–25 mA in children. Other scan parameters were: rotation time, 0.8 s; beam collimation, 16×1.25 mm; helical pitch, 1.3; reconstructed slice thickness, 5 mm; and reconstructed kernels, Lung and Soft tissue.

The $CTDI_{vol}$ calculated by dose calculator (CT-Expo version 2, SAS-CRAD, Germany) was 1.3 mGy for adults and 0.5 mGy for pediatrics, respectively.

The median interval between PCR positive and CT scans was 3 days (range; 1–11).

2.4. Outcome of triage management

For triage, the 192 patients were divided into four groups; mild (asymptomatic or mild cough, $SpO_2 \geqq 96\%$), moderate I (shortness of breath or pneumonia, $96\% > SpO_2 > 93\%$), moderate II (requiring oxygen, $SpO_2 \leqq 93\%$) and severe (admitted to the intensive care unit or requiring ventilation). The applied classification was based on the Japanese medical guidelines for COVID-19, v4.1. Based on this protocol,

with their consent, patients were discharged home, quarantined in hotels, or admitted to hospitals.

2.5. Image analysis

Two board-certified radiologists with 10 and 12 years of experience independently reviewed axial chest CT images of the 192 patients and recorded the incidence of lung involvement, the CT features, the distribution pattern of lung involvement, and the CT severity score. Discrepancies between the readers were solved by consensus readings.

The features of lung involvement by COVID-19 were recorded based on the CT patterns, i.e. ground glass opacity (GGO), crazy-paving pattern, and consolidation [6]. The distribution pattern of lung involvement was classified subjectively as peripheral, central, or both peripheral and central.

A semi-quantitative CT severity score was calculated based on the extent of lobar involvement where 0 = 0%, 1 = < 5%, 2 = 5–25%, 3 = 26–50%, 4 = 51–75%, 5 = > 75% involvement. The resulting global CT severity score was recorded as the sum of each individual lobar score (0–25) [7,8].

2.6. Statistical analysis

Continuous variables were expressed as the median and the range. The frequency of demographic and clinical data, and the incidence of lung involvement on CT images were expressed in terms of numbers and percentages, and the blood test results as the mean and the standard deviation (SD).

Interobserver agreement for the incidence of lung involvement on CT images was assessed with the Cohen kappa coefficient of concordance. Kappa values of 0–0.20 indicate poor-, 0.21–0.40 fair-, 41–0.60 moderate-, 0.61–0.80 good-, and 0.81 or greater very good agreement [9].

A multivariate logistic regression model is used to predict the incidence of lung involvement on CT image as a linear function of a set of clinico-laboratory variables: age, gender, BMI, SpO_2, comorbidity, symptom and blood data (WBC, RBC, Hb, PLT, ALB, AST, LDH, Cre, CRP and D-dimer). The patient age was dichotomized; patients aged 60, 65, and 70 years were the threshold candidates. Blood and SpO_2 data were categorized as normal, abnormal low or high based on the reference values. The body temperature was not used because only two patients were febrile ($\geqq 37.5\,^{\circ}$C). The final prediction model was developed using the backward elimination method successively dropping those variables with a multivariable p-value above 0.1. The diagnostic ability of the final prediction model was evaluated using receiver operating characteristics (ROC) analysis. The sensitivity and specificity of the prediction model for various cut-off values of the risk score were plotted in a ROC curve. To adjust the bias due to overfitting of the prediction model, internal validation method using 5-fold cross-validation, in which number of repetitions was 1,000, was performed. Statistical analysis was performed using SAS version 9.4 (SAS Institute Inc, Cary, NC). P values were two-sided. P value less than 0.05 were considered statistically significant.

3. Results

3.1. Patient characteristics

A summary of 192 COVID-19 patients characteristics of this study was shown in Table 1.

There were 192 COVID-19 patients [102 males, 90 females; median age 44.5 years (range 4–83), BMI 22.5 kg/m^2 (range 13.6–39.2)]. The median body temperature and SpO_2 were 36.5 $^{\circ}$C (range 35.4–37.6) and 98% (86–100), respectively.

Of the 192 patients, 56 (29.2%) were asymptomatic; 136 (70.8%) presented with symptoms. The most frequent symptoms were cough (n = 97, 71.3%), headache (n = 61, 44.9%), sore throat (n = 55, 40.4%),

Table 1

Summary of 192 COVID-19 patients characteristics.

Demographic data	
Median age [years old]	44.5 (range, 4–83)
<60/≥60	147 (76.6%): 45 (23.4%)
<65/≥65	158 (82.3%): 34 (17.7%)
<70/≥70	168 (87.5%): 24 (12.5%)
Gender [female, male]	90 (46.9%): 102 (53.1%)
Median BMI [kg/m^2]	22.5 (range, 13.6–39.2)
<25/≥25	156 (81.3%): 36 (18.8%)
Clinical data	
Median temperature [°C]	36.5 (range, 35.4–37.6)
Median SpO$_2$ [%]	98 (range, 86–100)
<96/≥96	14 (7.3%): 178 (92.7%)
Symptomatic	136 (70.8%)
Comorbidity	49 (25.5%)

COVID-19: coronavirus disease 2019.

BMI: body mass index.

SpO$_2$: oxygen saturation of the peripheral artery.

muscle pain and arthralgia n = 52, (38.2%), dyspnea (n = 22, 16.2%) and fatigue (n = 16, 11.8%); 25 patients (18.4%) presented with other symptoms. The symptom onset was unclear in 32 of the 192 patients. The median interval between symptom onset and CT scans was 5 days (range; 1–14).

In 49 of the 192 patients (25.5%) comorbidities were present. In descending order, they were hypertension (n = 22, 44.9%), asthma (n = 11, 22.4%), diabetes mellitus (n = 8, 16.3%), dyslipidemia (n = 7, 14.3%), chronic obstructive pulmonary disease (n = 3, 6.1%), and cardiovascular disease (n = 3, 6.1%); 10 patients (20.0%) presented with other comorbidities.

The results of blood tests are shown in Table 2. The mean of WBC, RBC, Hb and PLT level were 5.03 103/μL, 4.81 106/μL, 14.8 g/dL and 237.8103/μL; they were within normal limited. The decreased ALB level was obtained in 30.2% of 192 patients. The increased AST, LDH, Cre,

Table 2

Blood test results of 192 COVID-19 patients.

	Mean	SD
WBC (10^3/μL)	5.03	1.67
≤3.2/3.3–8.6/≥8.70	26 (13.5%): 160 (83.3%): 6 (3.1%)	
RBC (10^6/μL)	4.81	0.6
≤3.85/3.86–4.92/≥4.93	7 (3.6%): 111 (57.8%): 74 (38.5%)	
Hb (g/dL)	14.8	1.9
≤11.5/11.6–14.8/≥14.9	11 (5.7%): 85 (44.3%): 96 (50.0%)	
PLT (10^3/μL)	237.8	81.4
≤157/158–348/≥349	22 (11.5%): 155 (80.7%): 15 (7.8%)	
ALB (g/dL)	4.2	0.4
≤4.0/4.0<	58 (30.2%): 134 (68.8%)	
AST (U/L)	29.7	26.8
<31/≥31	140 (72.9%): 52 (27.1%)	
LDH (U/L)	197.6	74.5
<223/≥223	147 (76.6%): 45 (23.4%)	
Cre (mg/dL)	0.76	0.34
<0.80/≥0.80	113 (58.9%): 79 (41.1%)	
CRP (mg/dL)	0.96	1.84
<0.15/≥0.15	80 (41.7%): 112 (58.3%)	
D-dimer (μg/mL)	0.73	0.67
<1.00/≥1.00	169 (88.0%): 23 (12.0%)	

WBC: white blood cell.

RBC: red blood cell.

Hb: hemoglobin.

PLT: platelet.

ALB: albumin.

AST: aspartate aminotransferase.

LDH: lactate dehydrogenase.

Cre: creatinine.

CRP: C-reactive protein.

SD: standard deviation.

CRP and D-dimer level were obtained in 27.1%, 23.4%, 41.1%, 58.3% and 12.0% of 192 patients, respectively.

3.2. Incidence of lung involvement on CT images

Of the 192 patients with positive RT-PCR assay, 120 patients (62.5%, 95%CI: 55.6–69.4%) presented lung involvement on CT images. GGO was observed in 118 (98.3%), the crazy-paving pattern in 23 (19.2%), and consolidation in 14 (11.7%). The distribution pattern was recorded as peripheral in 110 (91.7%), and as both peripheral and central in 10 (8.3%) patients. No central-only pattern was observed.

The inter-observer kappa value was 0.99 and which is consistent with very good agreement.

3.3. Prediction model for lung involvement on CT images

After backward elimination, the following four variables remained in the final prediction model were associated with an increased risk of lung involvement on CT images; the patient age (≥65 years old, odds ratio [OR]; 4.95, 95%CI; 0.93–26.49, p = 0.06), ALB (≤4.0 g/dL, OR; 4.66, 95%CI; 1.37–15.84, p = 0.01), LDH (≥223 U/L, OR; 5.79, 95%CI; 1.43–23.38, p = 0.01) and CRP (≥0.15 mg/dL, OR; 8.93, 95%CI; 4.13–19.29, p < 0.001) (Table 3). The unadjusted estimate of the area under the ROC curve for the multivariable model was 0.86; the cross-validated estimate after adjusting the bias due to overfitting was 0.83, suggesting reasonable discrimination capability (Fig. 1).

3.4. CT severity score

In 120 COVID-19 patients presented lung involvement on CT images, the median CT severity score was 4 (1–22) and 7 (5.8%) patients had CT severity score ≥16 which was previously reported as risk factors for poor prognosis [10] (Fig. 2).

3.5. Triage management

Of the 192 COVID-19 patients who had undergone both blood tests and CT studies, triaging assigned mild disease to 153 patients (79.7%) and moderate I andII disease to 37 (19.3%) and 2 (1.0%), respectively. There were no patients with severe disease. Among the 192 patients, 7 (3.6%) were hospitalized, the other 185 (96.4%) were discharged home or quarantined in hotels.

4. Discussion

In triaging of COVID-19 patients with positive RT-PCR assays using low dose chest CT, 120 of 192 (62.5%) patients presented lung involvement on CT images. The most frequent CT findings of lung involvement was GGO and it distributed peripheral dominant, which was well-established as feature of COVID-19 in earlier studies [8, 11–13].

Others [12,14,15] also identified a high rate of lung involvement on

Table 3

Odds ratio estimates for variables remaining in the final prediction model for lung involvement on CT images.

Variables	Odds ratio	95% CI	p-value
Age (≥65 years old)	4.95	0.93–26.49	0.06
ALB (≤4.0 g/dL)	4.66	1.37–15.84	0.01
LDH (≥223 U/L)	5.79	1.43–23.38	0.01
CRP (≥0.15 mg/dL)	8.93	4.13–19.29	<0.001

CI: confidence interval.

ALB: albumin.

LDH: lactate dehydrogenase.

CRP: C-reactive protein.
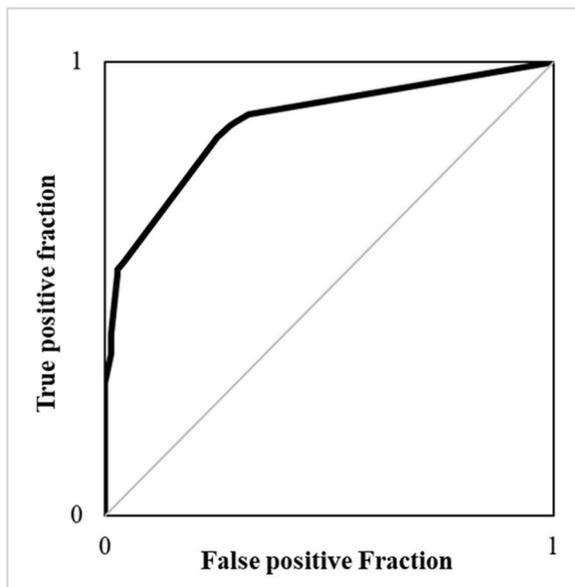
Fig. 1. The diagnostic ability of our final prediction model was evaluated using receiver operating characteristics (ROC) analysis. Its sensitivity and specificity for various cut-off values on the risk score derived by the final prediction model were plotted in a ROC curve. The cross-validated area under the ROC curve was 0.83.
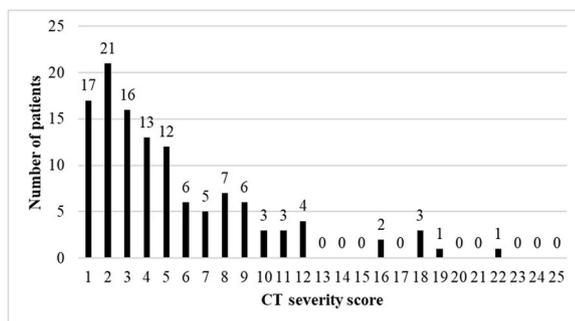
Fig. 2. The CT severity score of 120 COVID-19 patients.
The median CT score was 4 (1–22); in 7 patients (5.8%) it was 16 or higher.

CT images of even pauci-symptomatic and asymptomatic patients. A 54% incidence of bilateral GGO was reported in 82 asymptomatic carriers on the ship the Diamond Princess [15]. According to Varble et al. [12] and Castelli et al. [14], 48 of 74 (64.9%) asymptomatic- and 138 of 247 (55.9%) pauci-symptomatic COVID-19 patients presented with lung involvement on CT images. We confirmed the high incidence of lung involvement on CT images in our triaging which classified 153/192 (79.7%) patients as asymptomatic or mild.

Based on our final prediction model, the patient age (≥ 65 years), and the levels of ALB (≤ 4.0 g/dL), LDH (≥ 223U/L), and CRP (≥ 0.15 mg/dL) were associated with an increased risk of lung involvement on CT images. Among 34 patients 65 years or older, 32 (94.1%) did- and 88 of 158 (55.7%) patients younger than 65 did not manifest lung involvement on CT images. Meta-analyses that included more than 1500 individuals revealed that the age was a risk factor for mortality of COVID-19 [16,17]. Yang et al. [18] also reported that individuals from Wuhan, China who were ≥65 years old and had comorbidities were at increased risk of death. We suspect that the age is one of the most important factors for lung involvement on CT images of COVID-19 patients.

Earlier studies found that an increase in LHD and CRP and a decrease in ALB were predictive of a poor prognosis in COVID-19 patients [1,10, 19,20]. When ALB which is the index of the nutritional status of the body

decreases, the body loses resistance to the virus [20]. An elevation in LDH, one of the most important and significant prognostic indicators of severe idiopathic pulmonary fibrosis [21], reflects tissue destruction and elevated CRP levels are an important inflammatory index [20]. Therefore, it is reasonable to suspect that they are associated with an increased risk of lung involvement on CT images and our prediction model that includes the patient age and the ALB-, LDH-, and CRP levels may help to accurately predict lung involvement.

Although there were increasing positive evidences of CT to evaluate COVID-19 patients [3,7,22,23], it is not realistic way to perform CT scans for all huge COVID-19 patients in a pandemic. Radiation exposure of CT may be problematic even when using low dose in especially young patients. Therefore, the establishment of the indication for CT scans is urgent necessity in triaging of COVID-19 patients. In COVID-19 patients older than 65 years and in patients with abnormal ALB,- LDH-, and CRP levels, CT scanning may be indicated to evaluate the extend of lung involvement.

There is a major concern regarding a possible clinico-radiological dissociation in triaging of COVID-19 patients. Actually, some individuals died at home without treatment before hospitalization [24] and it became to be one of the largest social issues in management for COVID-19 patients. Therefore, the quantitative assessment based on CT scan is required for the triaging of COVID-19 patients. A CT severity score was firstly reported by Pan et al. [8] and it was subsequently used for disease classification and severity prediction [3,7,10]. Mozafari et al. [3] suggested that CT scores <10 and ≥ 10 were indicators for home-discharge and hospitalization, respectively. According to Zhou et al. [10], a CT score ≥ 16 was a risk factor for a poor prognosis and Francone et al. [7] reported that a CT score >18 was more highly predictive of patient mortality in the course of short-term follow. Among our 192 patients, 7 (3.6%) had a CT score ≥ 16 and 6 of them (85.7%) required immediate hospitalization. However, 5 of 7 patients whose CT score was ≥ 16 were assigned to moderate I based on the Japanese medical guidelines for COVID-19. This suggests that the CT severity score is useful for the objective identification of severe COVID-19 patients in case of clinico-radiological dissociation.

On the other hand, although our triaging using CT scans identified severe COVID-19 patients, most of the other patients were mild and did not require hospitalization. Since this triage was conducted in December 2020, when there was insufficient information on pathophysiology of the COVID-19, CT scans were performed on all patients. However, this might not be appropriate from standpoints of radiation exposure and cost-effectiveness. It is expected that our prediction model for lung involvements on CT and further studies would establish the more appropriate indication for CT scans in the triaging of COVID-19 patients.

Our retrospective study has some limitations. The interval between the acquisition of PCR-positive results and CT scans varied among patients. The symptom-onset was not detailed in some of our records and we have no long-term follow-up data including life and death, the severity when the disease was progressed the worst and treatment because our study focused on the triaging of COVD-19 patients. Also, because we included patients whose diagnosis was mild disease based on positive PCR assay results, this may have raised selection bias. In addition, the cut-off value of clinico-laboratory data used may have slightly affected the ROC curve of our prediction model.

In conclusion, our triage disclosed a high incidence (62.5%) of CT-confirmed lung involvement among our 192 COVID-19 patients. A patient age of 65 years or older, the levels of ALB≤4.0 g/dL, LDH≥223 U/L, and CRP≥0.15 mg/dL were associated with an increased risk of lung involvement on CT images. Our findings may assist in deciding whether triaged COVID-19 patients should undergo CT.

Author contribution

Kenichi Yoshimura were the chief investigator and responsible for the data analysis. Yuko Nakamura, Takahiro Sueoka, Fuminari Tatsugami and Naoyuki Kitamura developed the trial design. All authors contributed to the writing of the final manuscript.

Declaration of competing interest

Acknowledgements

References

[1] Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in wuhan, China. Lancet 2020;395:497–506.

[2] Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in wuhan, China: a descriptive study. Lancet 2020;395:507–13.

[3] Mozafari A, Miladinia M, Sabri A, Movaseghi F, Gholamzadeh Baeis M. The challenge of deciding between home-discharge versus hospitalization in covid-19 patients: the role of initial imaging and clinicolaboratory data. Clin Epidemiol Glob Health 2021;10:100673.

[4] National Lung Screening Trial Research T, Aberle DR, Adams AM, Berg CD, Black WC, Clapp JD, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. Engl J Med 2011;365:395–409.

[5] Sakane H, Ishida M, Shi L, Fukumoto W, Sakai C, Miyata Y, et al. Biological effects of low-dose chest ct on chromosomal DNA. Radiology 2020;295:439–45.

[6] Hansell DM, Bankier AA, MacMahon H, McLoud TC, Muller NL, Remy J. Fleischner society: glossary of terms for thoracic imaging. Radiology 2008;246:697–722.

[7] Francone M, Iafrate F, Masci GM, Coco S, Cilia F, Manganaro L, et al. Chest ct score in covid-19 patients: correlation with disease severity and short-term prognosis. Eur Radiol 2020;30:6808–17.

[8] Pan F, Ye T, Sun P, Gui S, Liang B, Li L, et al. Time course of lung changes at chest ct during recovery from coronavirus disease 2019 (covid-19). Radiology 2020;295: 715–21.

[9] Svanholm H, Starklint H, Gundersen HJ, Fabricius J, Barlebo H, Olsen S. Reproducibility of histomorphologic diagnoses with special reference to the kappa statistic. APMIS 1989;97:689–98.

[10] Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with covid-19 in wuhan, China: a retrospective cohort study. Lancet 2020;395:1054–62.

[11] Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, et al. Correlation of chest ct and rt-pcr testing for coronavirus disease 2019 (covid-19) in China: a report of 1014 cases. Radiology 2020;296:E32–40.

[12] Varble N, Blain M, Kassin M, Xu S, Turkbey EB, Amalou A, et al. Ct and clinical assessment in asymptomatic and pre-symptomatic patients with early sars-cov-2 in outbreak settings. Eur Radiol 2020. https://doi.org/10.1007/s00330-020-07401-8.

[13] Ye Z, Zhang Y, Wang Y, Huang Z, Song B. Chest ct manifestations of new coronavirus disease 2019 (covid-19): a pictorial review. Eur Radiol 2020;30: 4381–9.

[14] Castelli M, Maurin A, Bartoli A, Dassa M, Marchi B, Finance J, et al. Prevalence and risk factors for lung involvement on low-dose chest ct (ldct) in a paucisymptomatic population of 247 patients affected by covid-19. Insights Imag 2020;11:117.

[15] Inui S, Fujikawa A, Jitsu M, Kunishima N, Watanabe S, Suzuki Y, et al. Chest ct findings in cases from the cruise ship diamond princess with coronavirus disease (covid-19). Radiol Cardiothorac Imag 2020;2:e200110.

[16] Grasselli G, Zangrillo A, Zanella A, Antonelli M, Cabrini L, Castelli A, et al. Baseline characteristics and outcomes of 1591 patients infected with sars-cov-2 admitted to icus of the lombardy region, Italy. JAMA 2020;323:1574–81.

[17] Wang B, Li R, Lu Z, Huang Y. Does comorbidity increase the risk of patients with covid-19: evidence from meta-analysis. Aging 2020;12:6049–57.

[18] Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, 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;8:475–81.

[19] Izcovich A, Ragusa MA, Tortosa F, Lavena Marzio MA, Agnoletti C, Bengolea A, et al. Prognostic factors for severity and mortality in patients infected with covid-19: a systematic review. PLoS One 2020;15:e0241955.

[20] Liu W, Tao ZW, Wang L, Yuan ML, Liu K, Zhou L, et al. Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease. Chin Med J 2020;133:1032–8.

[21] Liu L, Dong L, Zhang B, Chen X, Song X, Li S, et al. Early prediction model for progression and prognosis of severe patients with coronavirus disease 2019. Medicine 2021;100:e24901.

[22] Chen HJ, Qiu J, Wu B, Huang T, Gao Y, Wang ZP, et al. Early chest ct features of patients with 2019 novel coronavirus (covid-19) pneumonia: relationship to diagnosis and prognosis. Eur Radiol 2020;30:6178–85.

[23] Devie A, Kanagaratnam L, Perotin JM, Jolly D, Ravey JN, Djelouah M, et al. Covid-19: a qualitative chest ct model to identify severe form of the disease. Diagn Interv Imag 2021;102:77–84.

[24] Hubert H, Baert V, Beuscart JB, Chazard E. Use of out-of-hospital cardiac arrest registries to assess covid-19 home mortality. BMC Med Res Methodol 2020;20:305.