Mohammed *et al.*
*The Egyptian Journal of Bronchology* (2024) 18:34
https://doi.org/10.1186/s43168-024-00287-w

The Egyptian Journal of Bronchology

RESEARCH

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# Evaluation of MSCT severity scoring for prediction of mortality among patients with COVID-19

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## Abstract

**Background** Lung CT imaging may reveal COVID-19 abnormalities earlier than RTPCR. CT may be more sensitive than RT-PCR for diagnosing COVID-19-related pneumonia.

**Aim** This study assesses the accuracy of multi-slice computed tomography (MSCT) grading in predicting COVID-19 mortality.

**Methods** COVID-19 RT-PCR. For severity scores, all patients' clinical examinations, history, and chest MSCT data were collected.

**Results** According to the chest MSCT score, 102 (51.5%), 70 (35%), and 28 (14%) patients had mild, moderate, and severe illness. Out of the patients, 62 (31%) died, and 69% survived. Patients with severe MSCT scores showed a considerably greater mean age than other groups ($P < 0.001$). Moreover, this group had a considerably higher mean BMI ($P < 0.001$), and a majority (57.1%) were obese ($P < 0.001$). Compared to the mild group, the moderate and severe groups had significantly increased rates of diabetes, hypertension, and liver disease ($P < 0.001$). The moderate group had a greater rate of no comorbidities ($P < 0.001$). A severe MSCT score was linked to increased leucocytes, C-reactive protein, ESR, ferritin, d-dimer, HbA1c, and fasting blood sugar, as well as decreased mean lymphocytes ($P < 0.001$). Severe MSCT scores were linked to increased ICU admissions ($P < 0.001$) and increased demand for advanced mechanical ventilation and oxygen assistance ($P < 0.001$). A severe MSCT score was associated with the highest death rate, followed by a moderate MSCT score. Low mortality rates were observed in mild MSCT-scored patients ($P < 0.001$).

**Conclusion** MSC T score severity is a reliable and noninvasive way to predict COVID-19 mortality

**Keywords** COVID-19; MSCT; Morbidity; Complications

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## Background

Computed tomography (CT) has been extensively employed to identify and investigate suspected or affirmed cases of COVID-19 on a large scale [1]. Based on existing empirical evidence, it has been observed that lung CT imaging has the potential to detect abnormalities at an earlier stage compared to RT-PCR testing. Recent studies have indicated that MSCT may exhibit greater sensitivity compared to RT-PCR when diagnosing pneumonia associated with COVID-19. High-resolution computed tomography (HRCT) has become a dominant modality for initial diagnosis, screening, and assessment of disease intensity [2, 20].

According to recent studies, ground-glass opacity (GGO) is the most prevalent discovery in COVID-19-linked pneumonia. Most cases include both the lungs and peripheral subpleural distribution. The imaging findings are nonspecific; however, other radiological features have been described [3, 19].

Few studies have examined COVID-19 chest CT discoveries' short-term prognostic value. Individuals who were seriously ill exhibited a higher prevalence of consolidation patterns, air bronchograms, crazy paving, central lung involvement (peri-bronchovascular), and pleural effusion. These data may suggest COVID-19's severity and aggressiveness. Thus, these radiologic features may be predictive imaging indicators in COVID-19 pneumonia cases [4]. However, this research aimed to evaluate the MSCT score's predictive accuracy in COVID-19 patients.

## Methods

The current study is a retrospective and prospective observational investigation carried out in a university hospital and other quarantine hospitals for the duration of the study, spanning from November 2021 to May 2022. The study included a group of 200 individuals who had been diagnosed with COVID-19. The diagnosis was made by verifying the presence of COVID-19 nucleic acid using real-time reverse transcription-polymerase chain reaction (rRT-PCR) on swab specimens taken from the respiratory tract. Exclusion criteria include those without a prior CT scan, those with severe cardiac disease, or those with previous pulmonary disease.

All cases were subjected to the following:

I. *Complete history-taking*: It includes demographic and clinical data.

II. *Complete clinical examination*: A comprehensive clinical evaluation encompassing the assessment of overall status and vital signs, including blood pressure, pulse, temperature, and respiration rate, was performed. The medical practitioner conducted examinations of the abdomen, thorax, and heart. The researchers conducted the height and weight measurements and subsequently computed the body mass index (BMI) by dividing the weight (expressed in kilograms) by the height (expressed in $M^2$).

III. *Laboratory investigations*: Blood specimens were obtained from the patients and utilized to investigate the parameters listed below:

1. Complete blood count (CBC): CBC includes hemoglobin concentration (Hb%), white blood cells (WBCs), red blood cells (RBC), neutrophil count, lymphocyte count, and platelet count.
2. The study assessed fasting, random blood glucose levels, and HbA1c. The criteria for diagnosing diabetes included a fasting blood glucose level equal to or greater than 126 mg/dL, a glycated hemoglobin level equal to or greater than 6.5%, the use of hypoglycemic medications, or a self-reported history of diabetes.
3. Renal profile: Blood urea and creatinine (Cr) were evaluated.
4. Liver profile: Aspartate aminotransferase (AST), alanine transaminase (ALT), albumin, and serum total bilirubin were evaluated.
5. CRP, ferritin, and D-dimer were evaluated.

IV. *Radiological investigations*: The radiologist reported an X-ray chest and a CT chest for all patients. During the chest examination using computed tomography (CT), all chest x-ray films and CT images were reviewed by the radiologists with more than 10 years of experience and blinded to the clinical data and laboratory indicators; a visual scoring system was employed to assess the condition of each of the five lung lobes. The scoring scale ranged from 0 to 5, with greater scores demonstrating greater severity or abnormality. The levels of involvement can be categorized as follows: 0 reveals no involvement, 1 indicates involvement of less than 5%, 2 indicates involvement of 25%, 3 indicates involvement ranging from 26 to 49%, 4 indicates involvement ranging from 50 to 75%, and 5 indicates involvement above 75%.

V. *MSCT severity scoring*: The primary objective of this study was to evaluate various computed tomography (CT) characteristics, including the spatial distribution of lesions (peripheral, central, or both), the extent of involvement in terms of the number of influenced lobes (one, two, three, four, or five), the morphological characteristics of lesions (patchy or nodular), the visual appearance of lesions (consolidation, ground-glass opacity (GGO), or GGO with consolidation), specific signs observed within the lesions (crazy paving pattern, vascular thickening, halo sign, air bronchogram sign, and fibrosis), the size of the largest lesion (less than 1 cm, 1–3 cm, and greater than 3 cm), and any additional manifestations outside the lungs (including enlargement of mediastinal and hilar lymph nodes, pleural thickening, and pleural effusion). The COVID 19-CT severity scoring was conducted for each unique incident using the methodology outlined by *Yang et al.* [5]. The scoring methodology was employed to calculate the severity of disease involvement in each of the five lobes present in both lungs. A score of zero indicates the lack of lung tissue involvement, whereas a score of one indicates participation of less than five percent. The 2, 3, 4, and 5 scores indicated progressively higher degrees of participation, encompassing 5–25% (Fig. 1), 26–50% (Fig. 2), 51–75%, and above 75% parenchymal involvement (Fig. 3), respectively. The aggregate global CT score was determined by totaling the individual lobar scores, encompassing a variation from 0 to 25. Scores varying from 0 to 1 were categorized as moderate. Scores ranging from 2 to 3 were categorized as moderate. Scores of 4 or 5 were categorized as indicative of a significant condition.

VI. *All patients received medical treatment* following Egypt's Ministry of Health and Population guidelines.

## Sample size

The sample size calculation was performed using EpI-Info 2002 software statistical package designed by World Health Organization (WHO) and by Centers for Disease Control and Prevention (CDC). The sample size was calculated based on the following considerations: 95% confidence level, and the prevalence of mortality was 30% according to a previous study [6] ± 5% confidence limit. Six cases were added to overcome dropout. Therefore, we will recruit 200 cases.

## Statistical analysis

For data analysis, SPSS version 24 for Windows was utilized. Numerical data with normal distributions had means and standard deviations. The numerical variable distribution's normality was validated with Kolmogorov-Smirnov. The chi-square test examined categorical variable associations. In cases of assumption violations, the fissure exact test was applied. An independent sample *t*-test was employed to compare parametric numerical variables across different groups. A *P*-value of less than 0.05 was deemed to be statistically significant.

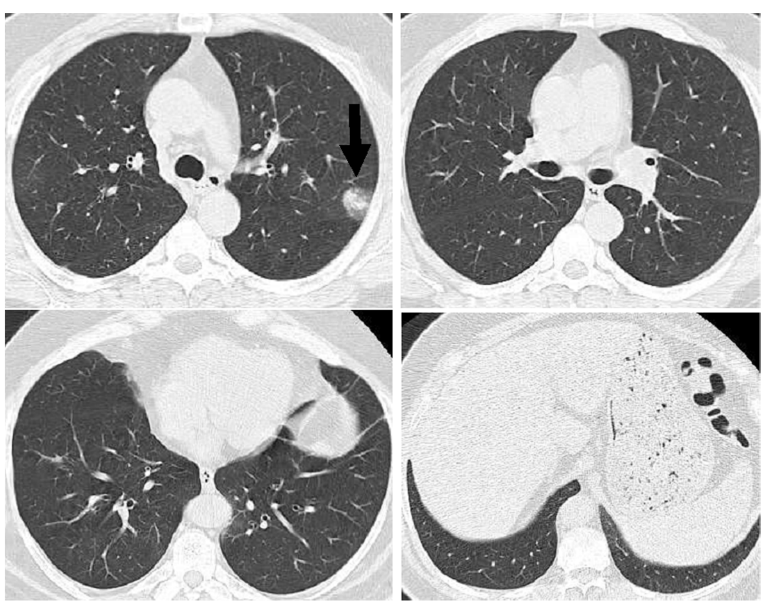

**Fig. 1** MSCT scans of lung window at different lung lobes show solitary subpleural area of ground-glass opacity at the left upper lung lobe (CORAD 3)

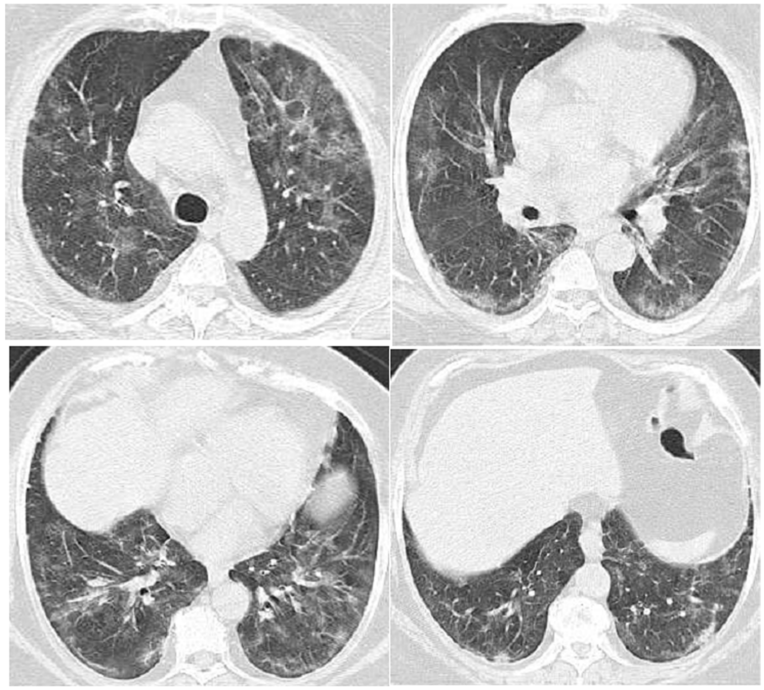

**Fig. 2** Chest CT scan at different lung levels of lung window shows multiple scattered subpleural peripheral distributed areas of ground-glass opacity and adhesive bands at the both lung field involving all lung lobes (CORAD 3)

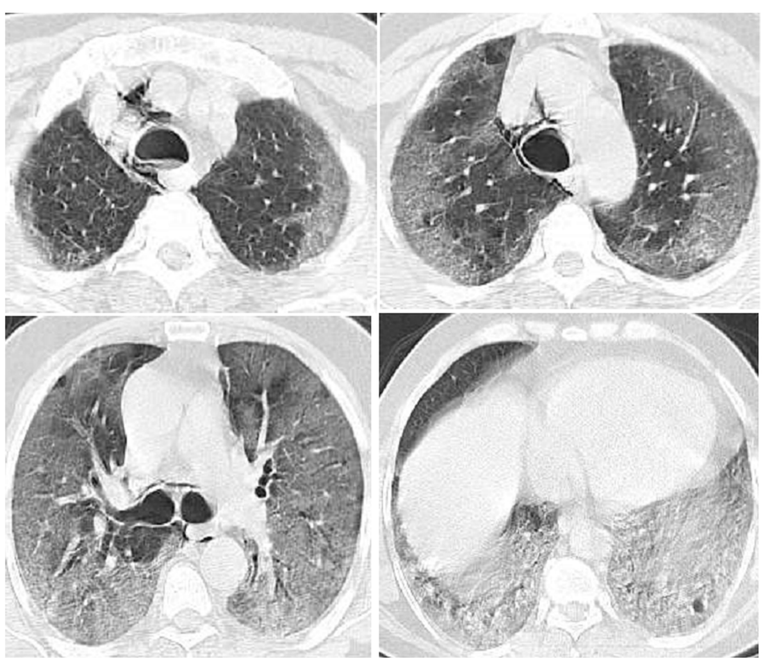

**Fig. 3** MSCT chest of lung window shows coalesces ground-glass opacities involving all lung lobes of peripheral distribution and at lung base predominance

## Results

The current study involved a cohort of 200 cases diagnosed with a verified case of COVID-19. According to the chest MSCT grading system, the distribution of disease severity among the patients was as follows: 102 individuals (51.5%) had a mild illness, 70 individuals (35%) had a moderate disease, and 28 individuals (14%) had a severe disease. Among the patients mentioned above, 62 individuals, including 31% of the sample, suffered death from the disease, while the remaining 69% of patients survived.

### Baseline characteristics of the studied cases dependent on BMI

The study revealed that the severe group had a statistically significant higher mean age ($M = 63.50$, $SD = 11.73$) when compared to the other categories. Furthermore, the group had a notably higher average BMI of 34.35 ± 13.62. Furthermore, most individuals (57.1%) within this group were classified as obese (Table 1).

The frequency of diabetes mellitus, hypertension, and liver disease was considerably greater in the moderate and severe groups compared to the mild group. In contrast, the mild group had a greater prevalence of individuals without comorbidities, amounting to 31.4% of the sample. No statistically significant differences were seen between the groups under investigation, as indicated by additional data (Table 1).

### Laboratory and clinical data of studied cases dependent on MSCT severity

No significant variations were observed in various clinical data across different groups of patients categorized based on chest MSCT score activity. The study revealed that the severe group exhibited significantly elevated levels of leucocytes, erythrocyte sedimentation rate, C-reactive protein, glycosylated hemoglobin, ferritin, d-dimer, and fasting blood sugar, while the results showed lower mean lymphocyte counts. Additional data indicated no statistically significant variations (Table 2).

### Nutrition index, hospital stay, and oxygen therapy in studied patients based on MSCT scoring severity

No significant differences were observed regarding hospital stay and nutrition ratio across various patient groups categorized based on MSCT score severity. However, it was found that the severe group had a much greater rate of admission to the ICU, with all patients in this group requiring ICU care (Table 2).

As illustrated in Table 3, a notable disparity was noticed among patient groups in terms of scoring activity as well as the mode of mechanical ventilation and oxygen support. The study revealed that a significant proportion of

**Table 1** Baseline data of the studied cases dependent on chest MSCT scoring activity

| | | Severity based on chest MSCT scoring | | | *p*-value |
|---|---|---|---|---|---|
| | | **Mild ($n = 102$) Mean ± SD/count (%)** | **Moderate ($n = 70$) Mean ± SD/count (%)** | **Severe ($n = 28$) Mean ± SD/count (%)** | |
| **Age (years)** | | 55.74 ± 13.06 | 64.03 ± 13.78 | 63.50 ± 11.73 | **< 0.001** |
| **Sex** | Male | 52 (51%) | 38 (54.3%) | 18 (64.3%) | 0.45 |
| | Female | 50 (49%) | 32 (45.7%) | 10 (35.7%) | |
| **Body mass index (kg/m$^2$)** | **Mean ± SD** | 25.49 ± 7.37 | 28.47 ± 6.35 | 34.35 ± 13.62 | **< 0.001** |
| | **Class** | 6 (5.9%) | 6 (8.6%) | 4 (14.3%) | **< 0.001** |
| | Underweight | 48 (47.1%) | 10 (14.3%) | 4 (14.3%) | |
| | Normal | 30 (29.4%) | 32 (45.7%) | 4 (14.3%) | |
| | Overweight | 18 (17.6%) | 22 (31.4%) | 16 (57.1%) | |
| | Obese | | | | |
| **Residence** | Rural | 54 (52.9%) | 42 (60%) | 18 (64.3%) | 0.46 |
| | Urban | 48 (47.1%) | 28 (40%) | 10 (35.7%) | |
| **Smoking** | | 20 (19.6%) | 20 (28.6%) | 8 (28.6%) | 0.33 |
| **Comorbidities** | Diabetes mellitus | 28 (27.5%) | 31 (44.3%) | 12 (42.9%) | **0.04** |
| | Hypertension | 30 (29.4%) | 32 (45.7%) | 16 (57.1%) | **0.01** |
| | Chest disease | 29 (28.4%) | 28 (40%) | 10 (35.7%) | 0.27 |
| | Ischemic heart disease | 11 (10.8%) | 8 (11.4%) | 6 (21.4%) | 0.30 |
| | Chronic kidney disease | 4 (3.9%) | 4 (5.7%) | 4 (14.3%) | 0.12 |
| | Liver disease | 2 (2%) | 9 (12.9%) | 4 (14.3%) | **0.01** |
| | Malignant lesions | 2 (2%) | 4 (5.7%) | 2 (7.1%) | 0.30 |
| | No comorbidities | 32 (31.4%) | 6 (8.6%) | 2 (7.1%) | **< 0.001** |

Data are expressed as frequency (percentage) and mean (SD). *P*-value was significant if it was < 0.05. *MSCT* multi-slice computed tomography

**Table 2** Laboratory and clinical data of the tested cases dependent on MSCT scoring

| | | Severity based on chest MSCT scoring | | | *p*-value |
|---|---|---|---|---|---|
| | | Mild ($n = 102$) | Moderate ($n = 70$) | Severe ($n = 28$) | |
| **Symptoms Count (%)** | **Cough** | 94 (92.2%) | 66 (94.3%) | 26 (92.9%) | 0.86 |
| | **Dyspnea** | 100 (98%) | 70 (100%) | 26 (92.9%) | 0.07 |
| | **Sore throat** | 30 (29.4%) | 16 (22.9%) | 12 (42.9%) | 0.14 |
| | **Fever** | 74 (72.5%) | 50 (71.4%) | 24 (85.7%) | 0.30 |
| | **Diarrhea** | 28 (27.5%) | 10 (14.3%) | 8 (28.6%) | 0.09 |
| **Complete blood picture Mean ± SD** | **Leucocytes (10/μl$^3$)** | 5.59 ± 1.34 | 6.01 ± 1.22 | 11.76 ± 3.22 | **< 0.001** |
| | **Neutrophils (10/μl$^3$)** | 3.11 ± 0.76 | 4.44 ± 0.19 | 7.98 ± 3.09 | **0.02** |
| | **Lymphocytes (10/μl$^3$)** | 1.12 ± 0.21 | 1 ± 0.06 | 0.78 ± 0.22 | **< 0.001** |
| | **Hemoglobin (g/dl)** | 12.12 ± 2.18 | 12.01 ± 2.22 | 11.98 ± 0.87 | 0.64 |
| | **Platelets (10/μl$^3$)** | 240.19 ± 55.67 | 239.98 ± 60.11 | 242.87 ± 70.44 | 0.18 |
| **Inflammatory markers Mean ± SD** | **CRP (mg/dl)** | 16.87 ± 5.67 | 17.89 ± 4.44 | 70.87 ± 32.98 | **< 0.001** |
| | **ESR (ml/h)** | 22.87 ± 10.34 | 32.18 ± 7.09 | 67.98 ± 23.87 | **< 0.001** |
| | **Ferritin (ng/dl)** | 334.56 ± 87.98 | 355.99 ± 39.01 | 70.11 ± 12.09 | **< 0.001** |
| | **D-dimer (ng/ml)** | 2.98 ± 0.56 | 3.01 ± 0.80 | 4.17 ± 2.11 | **0.03** |
| **Liver functions Mean ± SD** | **ALT (U/l)** | 45.96 ± 9.45 | 47.98 ± 11.99 | 45.11 ± 8.17 | 0.19 |
| | **AST (U/l)** | 44.09 ± 11.34 | 40.11 ± 12.98 | 45.19 ± 9.54 | 0.11 |
| | **Bilirubin (mmol/l)** | 0.90 ± 0.22 | 1.01 ± 0.31 | 0.99 ± 2.22 | 0.16 |
| | **Albumin (mg/dl)** | 3.23 ± 0.76 | 3.30 ± 0.77 | 3.30 ± 1.19 | 0.06 |
| **Kidney functions** | **Creatinine (mg/dl)** | 1.56 ± 0.35 | 1.56 ± 0.22 | 1.70 ± 0.33 | 0.13 |
| | **Urea (mg/dl)** | 46.98 ± 12.87 | 48.99 ± 10.10 | 47.77 ± 5.44 | 0.12 |
| **Glycemic control Mean ± SD** | **HbA1c (%)** | 5.56 ± 0.59 | 6.01 ± 0.70 | 8.90 ± 2.22 | **< 0.001** |
| | **FBS (mg/dl)** | 101.98 ± 12.98 | 102.88 ± 11.11 | 199.11 ± 19.09 | **< 0.001** |
| **Lipid profile Mean ± SD** | **Cholesterol (mg/dl)** | 201.87 ± 34.87 | 212.12 ± 40.40 | 210.98 ± 40.15 | 0.10 |
| | **Triglyceride (mg/dl)** | 144.98 ± 34.98 | 145.56 ± 43.90 | 149.11 ± 50.50 | 0.24 |
| **Electrolytes Mean ± SD** | **Sodium (mmol/l)** | 134.98 ± 0.19 | 133.01 ± 0.17 | 132.11 ± 0.50 | 0.98 |
| | **Potassium (mmol/l)** | 4.76 ± 0.18 | 4.44 ± 0.22 | 4.48 ± 0.30 | 0.27 |

Data are expressed as frequency (proportion) and mean (SD). *P*-value was significant if it was < 0.05. *MSCT* multi-slice computed tomography

individuals in the mild group (98%) and moderate group (54.3%) had improved and were subsequently discharged. Conversely, all patients in the severe group exhibited deterioration and ultimately succumbed to the illness.

### Different complications among the studied cases dependent on MSCT scoring severity

There were notable variations in the occurrence of different difficulties across numerous groups based on the severity of MSCT grading, except for neurological issues, where the difference was not statistically significant (*P* = 0.15). ARDS had a notably high prevalence within the severe group (64.3%) and the moderate group (22.9%) (Table 4).

Acute myocardial infarction, heart failure, atrial fibrillation, and uncontrolled hypertension were observed in 8 (11.4%), 2 (2.9%), 2 (2.9%), and 4 (5.7%) patients in the moderate group and 4 (14.3%), 2 (7.1%), 6 (21.4%), and 6 (21.4%) patients in the severe group, respectively. Six patients with modest severity experienced both heart failure and uncontrolled hypertension. Ten (35.7%), 8 (11.4%), and 6 (5.9%) patients of severe, moderate, and mild groups, respectively, developed acute hepatitis. Two patients in the mild group developed pancytopenia, and another four had thrombocytopenia. Thrombocytopenia occurred in four patients with moderate scores (Table 4).

Deep vein thrombosis (DVT) and thrombocytopenia occurred in four cases in the severe group. Two patients in the moderate group developed diabetes mellitus, while four patients in the severe group had subacute thyroiditis. Bed sores were absent in the mild group, whereas 10 (14.35) and 16 (57.1%) patients with moderate and severe illnesses, respectively, had bed sores (Table 4).

### Accuracy of MSCT scoring prediction of mortality among cases with COVID-19

It was found that MSCT scoring severity had 100% accuracy in predicting mortality in patients with COVID-19 with the area under the curve of 0.726 (Table 5 and Figs. 4, 5, and 6).

**Table 3** Nutrition index, hospital stay, and oxygen therapy in studied patients based on NSCT scoring severity

| | | Severity based on chest MSCT scoring | | | *p*-value |
|---|---|---|---|---|---|
| | | **Mild ($n = 102$)** Mean ± SD/count (%) | **Moderate ($n = 70$)** Mean ± SD/count (%) | **Severe ($n = 28$)** Mean ± SD/count (%) | |
| **Hospital stay (day)** | | 10.25 ± 4.46 | 10.48 ± 4.05 | 12.28 ± 5.47 | 0.10 |
| **Admission to the intensive care unit** | | 34 (33.3%) | 54 (77.1%) | 28 (100%) | **< 0.001** |
| **Nutrition index** | **< 3** | 12 (11.8%) | 8 (11.4%) | 4 (14.3%) | 0.92 |
| | **> 3** | 90 (88.2%) | 62 (88.6%) | 24 (85.7%) | |
| **Mode on mechanical ventilation** | **AC** | 2 (2%) | 6 (8.6%) | 2 (7.1%) | **< 0.001** |
| | **CPAP** | 0 | 4 (5.7%) | 0 | |
| | **NIV-PC** | 0 | 12 (17.1%) | 0 | |
| | **NIC-PS** | 0 | 2 (2.9%) | 2 (7.1%) | |
| | **SIMV** | 2 (2%) | 10 (14.3%) | 16 (57.1%) | |
| | **VC** | 2 (2%) | 4 (5.7%) | 8 (28.6%) | |
| **Oxygen support** | **Invasive MV** | 4 (3.9%) | 22 (31.4%) | 26 (92.9%) | **< 0.001** |
| | **NIV MV** | 2 (2%) | 16 (22.9%) | 2 (7.1%) | |
| | **Nasal prong** | 10 (9.8%) | 4 (5.7%) | 0 | |
| | **Venturi** | 66 (64.7%) | 28 (40%) | 0 | |
| **Outcome** | **Alive** | 100 (98%) | 38 (54.3%) | 0 | **< 0.001** |
| | **Died** | 2 (2%) | 32 (45.7%) | 28 (100%) | |

Data are represented as frequency (proportion) and mean (SD). *P*-value was significant if < 0.05. *MSCT* multi-slice computed tomography

**Table 4** Various complications in studied cases dependent on chest MSCT scoring severity

| | | Severity based on chest MSCT scoring | | | *p*-value |
|---|---|---|---|---|---|
| | | **Mild ($n = 102$)** Count (%) | **Moderate ($n = 70$)** Count (%) | **Severe ($n = 28$)** Count (%) | |
| **Respiratory** | **Alveolar hemorrhage** | 0 | 4 (5.7%) | 0 | **< 0.001** |
| | **ARDS** | 2 (2%) | 16 (22.9%) | 18 (64.3%) | |
| | **Severe asthma** | 2 (2%) | 4 (5.7%) | 0 | |
| | **Pulmonary embolism** | 0 | 2 (2.9%) | 0 | |
| **Cardiovascula** | **Acute myocardial injury** | 2 (2%) | 8 (11.4%) | 4 (14.3%) | **< 0.001** |
| | **Atrial fibrillation** | 0 | 2 (2.9%) | 2 (7.1%) | |
| | **Sinus tachycardia** | 0 | 2 (2.9%) | 2 (7.1%) | |
| | **Heart failure** | 6 (5.9%) | 2 (2.9%) | 6 (21.4%) | |
| | **Uncontrolled hypertension** | 6 (5.9%) | 4 (5.7%) | 6 (21.4%) | |
| **Neurological** | **Seizure** | 2 (2%) | 6 (8.6%) | 0 | 0.15 |
| | **Stroke** | 4 (3.9%) | 2 (2.9%) | 2 (7.1%) | |
| **Hematological** | **DVT** | 0 | 0 | 4 (14.3%) | **< 0.001** |
| | **Pancytopenia** | 2 (2%) | 0 | 0 | |
| | **Thrombocytopenia** | 4 (3.9%) | 4 (5.7%) | 4 (14.3%) | |
| **Endocrine** | **Diabetes mellitus** | 0 | 2 (2.9%) | 0 | **< 0.001** |
| | **Subacute thyroiditis** | 0 | 0 | 4 (14.3%) | |
| **Acute kidney injury** | | 8 (7.8%) | 20 (28.6%) | 16 (57.1%) | **< 0.001** |
| **Acute hepatitis** | | 6 (5.9%) | 8 (11.4%) | 10 (35.7%) | **< 0.001** |
| **Myalgia and bone pain** | | 2 (2%) | 8 (11.4%) | 2 (7.1%) | **0.03** |
| **Bed sores** | | 0 | 10 (14.3%) | 16 (57.1%) | **< 0.001** |

Data are represented as frequency (proportion) and mean (SD). *P*-value was significant if < 0.05. *MSCT* multi-slice computed tomography

### Univariate and multivariate regression of different complications versus chest MSCT scoring severity

In univariate regression, respiratory complications, cardiovascular complications, acute kidney injury, acute hepatitis, hematological complications, endocrine complications, and bed sores were independent predictors of chest MSCT scoring severity (*P*-value < 0.05).

**Table 5** Accuracy of MSCT scoring prediction of mortality among cases with COVID-19

| Indices | Value |
|---|---|
| Sensitivity | 45% |
| Specificity | 100% |
| Positive predictive value | 100% |
| Negative predictive value | 80.2% |
| Accuracy | 92.3% |
| Area under curve | 0.726 |
| *P*-value | **< 0.001** |

In multivariate regression, cardiovascular complications, acute kidney injury, acute hepatitis, endocrine complications, and bed sores were independent predictors of chest MSCT scoring severity (*P*-value < 0.05), while respiratory complications and hematological complications were not (Table 6).

## Discussion

A targeted viral diagnostic assay utilizing RT-PCR was quickly created to ascertain the diagnosis of COVID-19. While the diagnostic test is widely regarded as the gold standard, it is vital to find that certain individuals may experience false-negative outcomes [7]. The potential cause of this issue could be a lack of adequate cellular material for detection and the nucleic acid's unsuitable extraction

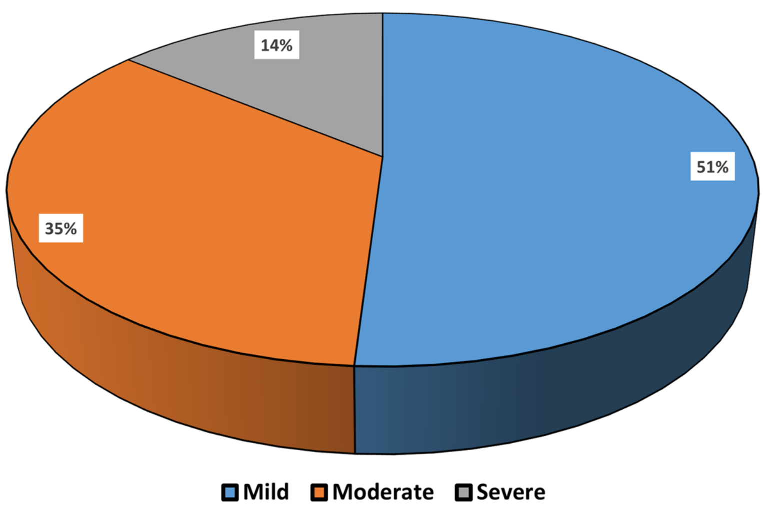


**Fig. 4** Distribution of studied patients based on chest MSCT scoring activity

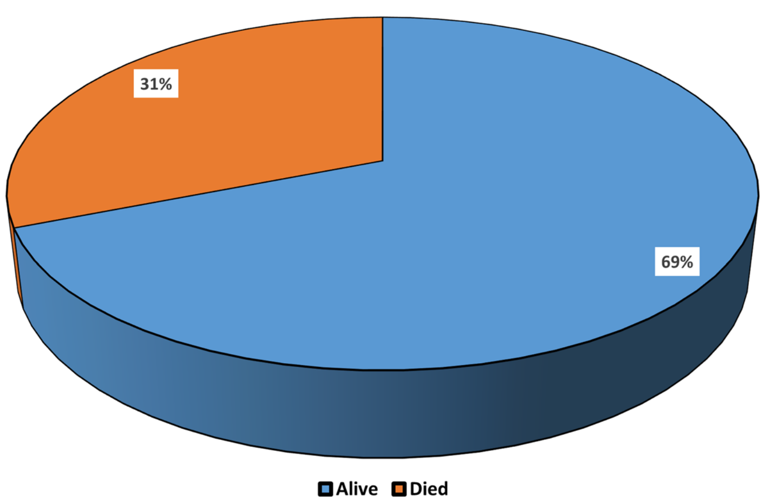


**Fig. 5** Distribution of studied patients based on outcome

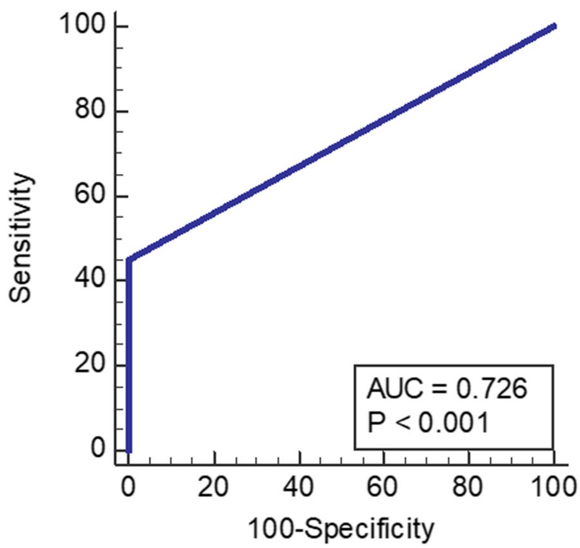


**Fig. 6** Accuracy of MSCT scoring prediction of mortality among cases with COVID-19

from clinical specimens. The variety in the RT-PCR data emphasizes the importance of using an adjunctive diagnostic methodology [8]. According to Ye et al. [7], chest CT images in COVID-19 cases may exhibit varying imaging characteristics or patterns, which can differ in terms of the time-related course and severity of the disease.

In the current investigation, an overall of 200 cases were investigated, of which 102 exhibited mild CT involvement (Fig. 4), 70 displayed moderate involvement (Fig. 5), and a mere 28 showed severe involvement (Fig. 6). In the study accomplished by *Faheem et al.* [9], the study documented that among the 300 individuals examined, 164 demonstrated slight to mild CT involvement, whereas 104 cases exhibited moderate involvement, and a mere 31 cases displayed noteworthy involvement.

Among our patient population, 62 individuals, constituting 31% of the sample, experienced mortality, while 69% of patients lived. *Magdy et al.* [10] observed a reduced mortality rate, with 3.8% of the 266 COVID-19 cases in the research succumbing to the disease.

The severe group was observed to have a substantially greater average age (63.50 ± 11.73) than the other groups.

This finding aligns with the findings revealed in the study performed by *Magdy et al.* [10] on a sample of 266 cases determined with COVID-19. It was determined that the mean age of individuals with severe and essential cases was notably greater than those with non-severe cases.

Additionally, *Farghaly and Makboul* [11] observed a strong and statistically significant positive association between the total CT lung score severity and the patient's age. A significant and robust association was seen between age and the severity of CT lung scores in both males and females. According to the findings of *Farghaly and Makboul* [11], the age's effect on the severity of COVID-19 is significant in individuals of both genders. Furthermore, it has been revealed that CT can be utilized as a helpful diagnostic technique for diagnosing COVID-19 and evaluating disease development and severity.

Furthermore, *Francone et al.* [12] performed a study with a sample of 1274 cases diagnosed with COVID-19. They revealed that the CT score was notably higher among those over 75 years than those aged 26–50. The CT score demonstrated a statistically significant elevation in the age group of 51–75 compared to the age group of 26–50.

Furthermore, a study done by *Ioannidis et al.* [13] demonstrated that advanced age is linked with a greater probability of experiencing a severe course of COVID-19 and an elevated risk of mortality. Therefore, it is crucial to prioritize senior COVID-19 cases with comorbidities during

**Table 6** Univariate and multivariate regression of different complications versus chest MSCT scoring severity

| | Univariate | | | Multivariate | | |
|---|---|---|---|---|---|---|
| | Odds ratio | 95% *CI* | *P* | Odds ratio | 95% *CI* | *P* |
| **Respiratory complications** | 9.257 | 3.87–22.15 | **< 0.001*** | 3.838 | 0.853–17.26 | 0.079 |
| **Cardiovascular complications** | 10.937 | 4.42–27.05 | **< 0.001*** | 6.618 | 1.46–29.91 | **0.014*** |
| **Neurological complications** | 0.868 | 0.186–4.04 | 0.857 | --- | --- | --- |
| **Acute kidney injury** | 6.857 | 2.93–16.06 | **< 0.001*** | 6.199 | 1.58–24.36 | **0.009*** |
| **Acute hepatitis** | 6.269 | 2.43–16.16 | **0.001*** | 32.599 | 4.95–214.85 | **0.001*** |
| **Hematological complications** | 5.333 | 1.95–14.62 | **0.001*** | 2.546 | 0.392–16.55 | 0.328 |
| **Myalgia and bone pain** | 1.246 | 0.258–6.012 | 0.784 | --- | --- | --- |
| **Endocrine complications** | 14.167 | 2.46–81.56 | **0.003*** | 130.96 | 8.59–1996.35 | **0.001*** |
| **Bed sores** | 21.6 | 8.075–57.78 | **< 0.001*** | 13.302 | 2.36–74.85 | **0.003*** |

[*] Significant as *P*-value ≤ 0.05, *CI* confidence interval

the entrance process in clinical settings to enhance their overall prognosis.

Dependent on the findings of the current study, it was observed that the severe group exhibited significantly elevated levels of leucocytes, ferritin, C-reactive protein, D-dimer, HbA1c, erythrocyte sedimentation rate, and fasting blood sugar while displaying a lower mean count of lymphocytes. Consistent with *Francone et al.'s* [12] investigation, notable associations were seen between CT score and CRP and D-dimer levels. Furthermore, the CT score and lymphocyte count showed a negative, nonsignificant connection.

The current study indicated that a significant proportion of cases with light MSCT severity (98%) and moderate MSCT severity (54.3%) improved and were discharged, whereas all cases in the severe group demonstrated deterioration and ultimately succumbed. Furthermore, this study demonstrated a significant relationship between a higher severity of MSCT score and poorer clinical outcomes, specifically regarding complications, the requirement for ICU hospitalization, mechanical ventilation, and oxygen therapy.

In line with this study, the *Faheem et al.* [9] study, which was conducted on 300 COVID-19 patients, revealed that individuals with poor short-term clinical outcomes exhibited a statistically higher CT severity score ($P <$ 0.001). In addition, *Faheem et al.* [9] discovered that individuals with minimal, mild, and severe CT affections exhibited reduced morbidity and mortality rates. Nevertheless, individuals with significant CT involvement had elevated morbidity and mortality rates.

Moreover, *Magdy et al.* [10] found that the CT severity score in severe and serious cases was significantly higher than in mild cases.

Furthermore, *Liu et al.* [14] noted that COVID-19 cases with severe or critical disease had a higher CT severity score than patients with moderate disease in their study of 50 COVID-19 cases.

This is aligned with *Hefeda's* [15] study, which revealed that most patients with consolidation had a significant mortality rate. Crazy paving and consolidation are more likely in advanced-illness patients [15].

In addition, the *Parry et al.* [16] study found that clinically unstable patients had a higher crazy paving and consolidation appearance.

Moreover, *Francone et al.* [12] reported that GGO tends to be more prevalent in early cases, in contrast to crazy paving and consolidation patterns, which are more frequently noted in later stages.

Furthermore, *Feng et al.* [17] noted that individuals with a progressing condition have a radiographic finding known as a "crazy paving sign," which indicates interstitial thickness.

This study's results demonstrated that the severity of MSCT scoring demonstrated a 100% accuracy rate in anticipating the mortality of cases diagnosed with COVID-19. The area under the curve for this prediction was calculated to be 0.726.

In line with our study, the receiver operating characteristic (ROC) curve in the *Magdy et al.* [10] study showed that the CT severity score highly predicts short-term clinical outcomes in COVID-19 cases. A cut-off value of ≥ 19 was found to be particularly indicative of short-term death, with a sensitivity of 100%, a specificity of 91.9%, and an accuracy of 92.56%.

Furthermore, *Francone et al.* [12] asserted that a CT severity score equal to or greater than 18 out of 25 exhibits a strong predictive capability for death in COVID-19 patients throughout their immediate post-treatment monitoring period. Furthermore, *Zhou et al.* [18] have documented that a CT severity score cut-off value of 16.5/25 points yielded a sensitivity of 69.4% and specificity of 82.3% in prognosticating unfavorable outcomes among individuals diagnosed with COVID-19.

This study has limitations. The CT-SS assumes lung opacification, which indicates COVID-19 presence. These findings were not histologically confirmed. We also selected the first chest CT scan taken upon admission. Thus, the analysis was unaffected by symptom duration, which could influence scoring system interpretation. Our data show that severe patients had a considerably longer time between symptom onset and hospital admission than moderate patients.

## Conclusion

Overall, this study presents a simple yet effective way for evaluating the extent of COVID-19 severity based on the initial chest CT scans. In our sample, a CT-SS score shows 51.5% had a mild illness, 35% had a moderate disease, and 14% had a severe disease. CT-SS has the ability to accelerate the process of determining whether patients require hospital admission. We believe that this strategy could be valuable in situations where there are a large number of patients, limited healthcare resources, or restricted polymerase chain reaction testing capabilities. Moreover, it is worth noting that age can be determined as a significant risk factor for the severity of MSCT scoring in cases diagnosed with COVID-19.

**Abbreviations**

| | |
|---|---|
| CT | Computed tomography |
| RT-PCR | Reverse transcription polymerase chain reaction |
| MSCT | Multi-slice computed tomography |
| ESR | Erythrocyte sedimentation rate |
| HRCT | High-resolution computed tomography |
| GGO | Ground-glass opacity |

BMI Body mass index
ARDS Adult respiratory distress syndrome
DVT Deep venous thrombosis

**Acknowledgements**
Not applicable

**Authors' contributions**
TM, MB, and ME-b contributed in data collection, image revision, and final editing. H and H, share in data collection and editing. E-B, G, and MG, revision. All authors have read and approved the research and agree for the submission.

**Funding**
Not applicable

**Availability of data and materials**
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study was done after approval from the Al-Azhar University Hospital — Faculty of Medicine Assiut and after patient agrees verbal consent (as the patients not exposed to any type of surgical or intervention maneuver). The committee's reference number is as follows: the number of meeting code is 237, and the number of paper code is 4.

**Consent for publication**
All patients included in this research gave written informed consent to publish the data contained within this study.

**Competing interests**
The authors declare that they have no competing interests.

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Received: 19 December 2023 Accepted: 15 May 2024
Published online: 18 May 2024

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## Publisher's Note