Tomographic score (RAD-Covid Score) to assess the clinical severity of infection with the novel Coronavirus

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Abstract

Objectives: The severity of pulmonary Covid-19 infection can be assessed by the pattern and extent of parenchymal involvement observed in computed tomography (CT), and it is important to standardize the analysis through objective, practical, and reproducible systems. We propose a method for stratifying the radiological severity of pulmonary disease, the Radiological Severity Score (RAD-Covid Score), in Covid-19 patients by quantifying infiltrate in chest CT, including assessment of its accuracy in predicting disease severity.

Methods: This retrospective, single-center study analyzed patients with a confirmed diagnosis of Covid-19 infection by real-time reverse-transcriptase polymerase chain reaction, who underwent chest CT at hospital admission between March 6 and April 6, 2020. The CT scans were classified as positive, negative or equivocal, and a radiological severity score (RADCovid Score) was assigned. Clinical severity was assessed upon hospital admission, with mild cases considered suitable for home treatment, moderate cases for hospital admission and severe cases for intensive care unit admission.

Results: 658 patients were included. Concordance correlation coefficient for the RAD-Covid Score was almost perfect among observers (0.833), with an overall agreement of 89.5%. The RAD-Covid Score was positively correlated with clinical severity and death, i.e., the higher the RAD-Covid Score, the greater the chance of a more severe clinical condition and mortality. This association proved independent of age and comorbidities. Accuracy of this score was 71%.

Conclusions: The RAD-Covid Score showed good accuracy in predicting clinical severity at hospital admission and mortality in patients with confirmed Covid-19 infection and was an independent predictor of severity.

Key Points

- Clinical severity of pulmonary infection by Covid–19 was assessed upon hospital admission and categorized into three groups: home treatment, hospitalization or intensive care unit admission.
- The severity of pulmonary infection by Covid–19 can be evaluated by the pattern and extent of pulmonary involvement in chest CT, and it is important to standardize the analysis through objective, practical, and reproducible systems.
- The Radiological Severity Score (RAD-Covid Score) showed good accuracy in predicting disease severity and mortality at hospital admission in patients with confirmed Covid–19 infection.

Introduction

The most serious clinical presentation of the global pandemic caused by the novel coronavirus disease (Covid–19) is severe acute respiratory syndrome coronavirus 2 (SARS-CoV–2).

The clinical spectrum of the disease is broad, with asymptomatic forms or mild flu conditions in most of the infected. Recent publications estimate that 15–20% of infected persons develop severe pneumonia and 5–10% require intensive care, with a mortality rate of 1 to 3.5%. [1,2]

Chest computed tomography (CT) has an important role in the initial diagnosis of Covid–19, as well as in assessing the severity of lung disease and treatment response, in addition to assisting in the search for complications and differential diagnoses. [3–20]

Some authors have proposed using chest CT in initial Covid–19 diagnosis. [12,19,21] Bai et al. found that CT shows high sensitivity in diagnosing the disease (97%, 95% confidence interval [CI]: 95–98%) and proposed using it as an initial diagnostic tool in high-incidence regions. [19] Assessing typical chest CT images, Barbosa et al. found sensitivity, specificity and accuracy of 64.0%, 84.8%, and 79.1%, respectively. However, when the images were typical or equivocal, the method's sensitivity, specificity and accuracy were 92.0%, 62.1% and 70.3%, respectively. They proposed including chest CT in the initial screening strategy for patients with clinical suspicion of the disease in settings with limited resources. [21]

Few studies have analyzed the correlation between the clinical severity of Covid–19 patients upon presentation and the severity of pulmonary involvement in their chest CT scans. Radiological severity has been assessed according to the pattern and extent of pulmonary involvement. The British Society of Thoracic Imaging proposed stratification by four degrees of pulmonary involvement (≤ 25%; 26 to 50%; 51 to 75% and > 75%) and defining disease severity as mild (up to 3 ground-glass opacities [GGO] with a diameter of up to 3 cm), moderate/severe (more than 3 GGO or focal opacities with a diameter > 3 cm and/or consolidation) and severe (diffuse or consolidated GGO with architectural distortion). [22]

In this study, we propose a simple method for quantifying parenchymal involvement through chest CT scans obtained upon presentation from patients with confirmed Covid–19 infection, thus stratifying the radiological severity of pulmonary disease. We evaluated the accuracy of this score in predicting clinical severity.

Materials And Methods

Participants and study design

This retrospective, observational and single-center study was approved by the institutional research ethics committee, although the consent requirement was waived due to its retrospective nature. Only patients (a) whose Covid–19 infection was confirmed by real-time polymerase chain reaction and (b) who underwent chest CT on admission between March 6 and April 6, 2020 were included. Patients (a) whose real-time polymerase chain reaction examinations were performed more than 7 days after chest CT and (b) who were under 18 years of age were excluded.

Clinical data and assessment of clinical severity

The patients' demographic data (age, gender), comorbidities, and outcome (death or recovery) were collected from the institution's electronic medical records. Clinical severity upon hospital admission was classified according to the institution's treatment protocol for patients with suspected Covid–19: mild (home treatment), moderate (hospitalization), or severe (intensive care unit [ICU] admission). The clinical criteria for medical decisions were:

- Home treatment: absence of SARS, with respiratory rate < 24 bpm and oxygen saturation > 93%.
- Hospitalization: presence of SARS (respiratory rate > = 24 bpm and/or oxygen saturation < 93%) with no signs of acute respiratory failure or severe hemodynamic instability and no need for orotracheal intubation.
- ICU admission: presence of SARS (respiratory rate > = 24 bpm and/or oxygen saturation < 93%), signs of acute respiratory failure requiring orotracheal intubation, and/or acute worsening of the respiratory pattern, and/or signs of end-organ and/or peripheral hypoperfusion (altered consciousness, elevated lactate, oliguria), and/or distributive shock.

Image acquisition and analysis protocols and RAD-Covid Score categorization

Chest CT scans were obtained through low-radiation-dose on a 160-MDCT (Aquilion Prime CT, Toshiba/Canon), 64-MDCT (Optma 660, GE), 16-MDCT (Somaton Scope,Siemens), 16-MDCT (Alexion, Toshiba/Canon) and 16-MDCT(BrightSpeed, GE Heathcare). The images were acquired during a deep inspiration, in the supine position, without contrast enhancement, and were reconstructed with 0.625 - 1.250 mm section thickness (with an identical increment) using a lung kernel.

Two radiologists, both with 8 years' experience in chest imaging and blinded to the clinical and laboratory data, performed a standardized review of all chest CT images at independent workstations. The images were evaluated using the Fleischner Society glossary as a reference [23], including lobar location, distribution, and lesion pattern.

The chest CTs were categorized into 3 diagnostic imaging groups: positive, equivocal, or negative for suspected Covid–19 pneumonia. For this classification we gather some definitions according to the Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings Related to Covid–19 [18], as well as other findings in the literature [19, 24, 25].

The following were considered positive CT findings for Covid–19 infection: GGO lesions with or without consolidation and predominantly peripheral and bilateral distribution; multifocal GGO lesions with a rounded morphology, with or without consolidations or “crazy-paving”; the reversed halo sign or other signs of organizing pneumonia. The following were considered equivocal CT findings: nonspecific pulmonary opacities lacking a typical pattern of involvement, such as GGO with diffuse or central distribution, neither rounded, unilateral, some overlapping with typical findings of other underlying pathologies (such as pulmonary fibrosis or emphysema), which sometimes limits diagnosis. The following were considered negative CT findings: a normal chest, lack of significant features or findings suggestive of a pulmonary pathology unrelated to Covid–19 infection (such as bronchopneumonia, tree-in-bud opacities, neoplasia, cavitation, isolated pleural effusion).

Positive or equivocal CT scans were then visually classified for radiological severity according to the extent of pulmonary impairment, using the Score RAD-Covid (Figure 1):

- RAD-Covid Score 1 (mild): pulmonary involvement < 25%.
- RAD-Covid Score 2 (moderate): pulmonary involvement 25–50%.
- RAD-Covid Score 3 (severe): pulmonary involvement > 50%.

For negative CT scans, we used the descriptors:

- RAD-Covid Score 0 (normal chest): pulmonary findings lacking or insignificant.
- RAD-Covid Score N/A: features of another pulmonary pathology.

After the classification data underwent interobserver agreement analysis, divergent interpretations were resolved by consensus.

Statistical analysis

The analyses were conducted with R software, version 3.6.0. (The R Foundation for Statistical Computing). Exploratory data analysis was performed using summary measures (mean, standard deviation, frequency and percentage). Interrater agreement was assessed with the Kappa coefficient. The influence of the RAD-Covid Score and other clinical and laboratory variables on clinical severity and mortality was assessed using ordinal logistic regression. Stepwise variable selection was used in the multiple models. The significance level was set at 0.05.

Results

1 - Study population and Clinical Severity Groups

A total of 658 patients were included in the study, 364 females (55.3%) and 294 males (44.7%), whose age ranged from 21 to 100 years, with a mean of 64.9 years and standard deviation (SD) of 18.2 years. Their ages were categorized as follows: 152 patients (23.1%) aged <50 years, 138 patients (21.0%) aged 51 to 60 years; 63 patients (9.6%) aged 61 to 70 years; 139 patients (21.1%) aged 71 to 80 years, and 166 patients (25.2%) aged > 80 years.

The main comorbidities were arterial hypertension (365 patients, 55.6%), diabetes mellitus (202 patients, 30.7%) and cardiovascular disease (86 patients, 13.1%). There was a low occurrence (less than 10%) of other comorbidities such as

obesity, asthma/COPD, neoplasia and chronic kidney disease. Regarding clinical severity, 232 patients (35.3%) were assigned home treatment, 321 patients (48.8%) were hospitalized, and 105 patients (16.0%) were admitted to the ICU.

2 - Chest CT findings

The chest CTs were classified as positive in 559 patients (84.95%), equivocal in 66 patients (10.93%) and negative in 33 patients (5.02%). The main pulmonary alterations were pure GGO (47.0%) and GGO associated with consolidation (47.4%); crazy-paving (89.9%) and bronchial thickening (72.0%). Most opacities were round (63.5%). The reversed halo sign was observed in 28.8% of the patients. The vast majority had bilateral involvement (88.8%), with either predominantly central and peripheral distribution (59.9%) or only peripheral distribution (34.8%). Pleural effusion was observed in only 55 patients (8.4%) and enlarged lymph nodes were unusual (1.5%). The stratification of RAD-Covid Scores was 340 mild cases (51.7%); 177 moderate cases (26.9%) and 107 severe cases (16.3%).

3 - RAD-Covid Score: interobserver agreement and accuracy in predicting clinical severity

Table 1 shows the interobserver agreement for the RAD-Covid Score. The concordance correlation coefficient was 0.833, with high overall agreement (89.5%).

Table 2 shows the association between RAD-Covid Score and clinical severity (home treatment, hospitalization, and ICU admission). An ordinal logistic regression model was created with clinical severity as the response variable and RAD-Covid Score as the predictor variable. According to this model, the risk of increased clinical severity were 5.28 times (95% CI 3.56 to 7.96) higher for patients with RAD-Covid Score 2 (moderate) than for those with RAD-Covid Score 1 (mild). They were 35.82 times (95% CI 21.07 to 62.24) higher for RAD-Covid Score 3 (severe) than for RAD-Covid Score 1 (mild) (p-value <0.001).

Most patients in the home treatment group were classified as RAD-Covid Score 1, having mild pulmonary involvement (88.12%). Among the patients in the hospitalization group, 44.5% had RAD-Covid Score 1, 41.6% had RAD-Covid Score 2, and 13.9% had RAD-Covid Score 3. The occurrence of RAD-Covid Score 3 was high in the ICU group (58.10%) and low in the hospitalization (13.9%) and home treatment (0.99%) groups (see Table 2). For severity classification, the RAD-Covid Score had a sensitivity of 90%, a specificity of 61% and an accuracy of 71.1%.

4—The correlation between imaging findings and clinical severity

Table 3 shows the association between radiological patterns and clinical severity. Patients with a pure GGO pattern were 11.98 times more likely to have a more severe clinical score than those without opacities. Patients presenting with GGO lesions and consolidation had a 21.57 times higher risk of a more severe clinical score than patients with no opacities. Patients with round opacities was had a 55% lower risk of a more severe clinical score than patients with irregularly shaped opacities. Patients with mosaic perfusion had a 4.97 times higher risk of a more severe clinical score was than those without it. Patients with unilateral involvement and a single affected lobe had an 87% and 90% lower risk, respectively, of a more severe clinical score than patients with bilateral involvement and two or more affected lobes.

5—The correlation between clinical severity at admission and demographic and clinical data

There was no significant difference between men and women regarding clinical severity (Table 4). Patients over 50 years of age had a higher risk of increased clinical severity on admission than those under 50 years of age ($p < 0.001$), and those over 80 years of age had a 36.51-fold higher risk ($p < 0.001$).

The number of comorbidities varied between 0 and 8 per patient, with a mean (±SD) of 1.55±1.37. Patients with hypertension, obesity, diabetes mellitus, current neoplasia, cardiovascular disease and cerebrovascular disease had a higher risk of increased clinical severity upon hospital admission than patients without comorbidities ($p<0.05$).

Symptom onset time ranged from 0 to 32 days, with a mean of 5.7±4.57 days. We observed longer symptom duration among patients with more severe conditions upon admission (hospitalization and ICU groups) than among the home treatment group ($p < 0.001$).

6- Multivariate analysis of RAD-Covid Score, age and comorbidities in relation to clinical severity upon admission

The variables RAD-Covid Score, age range, and comorbidities (hypertension, obesity, diabetes mellitus, former smoker, current neoplasia, treated neoplasia, cardiovascular disease, cerebrovascular disease and chronic kidney disease) were included in a multiple ordinal logistic regression model with clinical severity as the response variable for a total of 620 patients. Figure 6 shows the stepwise variable selection. Independent predictive factors for increased clinical severity were higher RAD-Covid Score and advanced age. With age as a fixed effect, patients with RAD-Covid Score 2 were 3.18 times more likely to have increased clinical severity than patients with RAD-Covid Score 1, while patients with RAD-Covid Score 3 were 21.10 times more likely to have increased clinical severity than patients with RAD-Covid Score 1. With RAD-Covid Score as a fixed effect, we observed that the older the patient, the greater the risk of more severe clinical conditions. Patients 51–60 years of age were 8.79 times more likely to have increased clinical severity than patients under 50 years of age. Patients over 80 years of age were 17.06 times more likely to have increased clinical severity than patients under 50 years of age.

7 - Correlation of the RAD-Covid Score with fatal outcome

Table 5 shows the results of the logistic regression model, in which fatal outcome as the response variable and RAD-Covid Score as the predictor variable. The mortality risk in patients with RAD-Covid Score 2 was 2.63 times higher than that of patients with RAD-Covid Score 1, while the mortality risk in patients with RAD-Covid Score 3 was 7.67 times higher than that of patients with RAD-Covid Score 1.

Discussion

Few studies have investigated the correlation between pulmonary involvement in Covid–19 infection and clinical severity upon admission. In this study we have proposed a simple and convenient method for quantifying imaging results to assess the radiological severity of the disease and identify patients in need of hospitalization.

The RAD-Covid Score had an almost perfect concordance correlation coefficient (0.833) with high overall agreement (89.5%), showing its reproducibility as an evaluation system. It is based on criteria that can be easily and quickly observed in chest CT. Two other studies [26, 27] have used more complex scoring methods to classify the extent of pulmonary involvement, assessing the opacification of several pulmonary regions. Similar to our findings, these methods also obtained excellent interobserver agreement and found higher radiological scores for cases of greater clinical severity.

Our results showed that the proposed RAD-Covid Score was positively correlated with the clinical severity of the disease, i.e., the higher the RAD-Covid Score, the higher the risk of progressing to more severe clinical conditions. The RAD-Covid Score was an independent predictor of severity, along with advanced age and comorbidities, and was positively correlated with risk of fatal outcome.

Regarding demographic data, gender did not significantly influence clinical severity scores, nor was it relevant in another recent publication [26]. Age, on the other hand, was a significant predictor of clinical severity, as has been reported in recent publications [33]. Patients over 50 years of age had a higher risk of increased clinical severity upon admission than patients under 50 years of age ($p < 0.001$). There was also a significant progressive increase in clinical severity in higher age groups that was especially evident in patients over 80 years of age (odds ratio 36.51).

Regarding comorbidities, hypertension, obesity, diabetes mellitus, current neoplasm, cardiovascular disease and cerebrovascular disease were correlated with increased clinical severity upon hospital admission. An association of two or more comorbidities increased the risk of clinical severity: the risk of a higher score increased 64% with each additional comorbidity (Table 4). According to the literature, clinical comorbidities in Covid–19 patients are heterogeneous, with the most frequent being hypertension and diabetes mellitus [28, 29]. Recent publications have observed that patients with chronic diseases are more susceptible to respiratory failure and death from Covid–19 [30, 31]. Another study [32] found that any comorbidity in Covid–19 patients predisposes them to a worse prognosis, the risk of which increases with every additional comorbidity.

Our study has some limitations, the first of which is that assessing the extent of pulmonary involvement is a subjective process, and there will be disagreement over pulmonary involvement percentages in borderline scores. Although we found a high rate of agreement among observers, artificial intelligence software that can objectively estimate such percentages could lead to even more reliable results. Second, we evaluated chest CT scans upon hospital admission and set no limit on days since symptom onset, which may have impacted the stratification of RAD-Covid Scores. Due to the study's retrospective nature, our data collection was limited regarding certain comorbidities (COPD and current smoking), some of which were reported incorrectly in the medical records, which probably impacted our results.

We can conclude that, in confirmed cases of Covid–19 infection, the proposed RAD-Covid Score protocol predicted clinical severity upon hospital admission and fatal outcome with good accuracy, being an independent predictor of clinical severity in relation to age and comorbidities, two variables that also influence outcomes. Thus, we propose that CT scores be included in the radiological report as further support for clinical decision making.

Declarations

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Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Written informed consent was not required for this retrospective article.

Ethical approval Institutional Review Board approval was obtained from Dante Pazzanese of Cardiology Institute Ethical Committee CAAE: 32408920.2.0000.5462

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Tables

Table 1: RAD-Covid Score interobserver agreement (kappa = 0,833; agreement = 89,5%)

Observer 1	Observer 2				
	RAD-Covid 1 Score (mild)	RAD-Covid Score 2 (moderate)	RAD-Covid Score 3 (severe)	N/A	Normal Chest CT
RAD-Covid Score 1 (mild)	330 50,2%	16 2,4%	0 0,0%	0 0,0%	0 0,0%
RAD-Covid Score 2 (moderate)	20 3,0%	138 21,0%	5 0,8%	0 0,0%	0 0,0%
RAD-Covid Score 3 (severe)	1 0,2%	19 2,9%	95 14,4%	0 0,0%	0 0,0%
N/A	0 0,0%	0 0,0%	0 0,0%	19 2,9%	0 0,0%
Normal Chest CT	0 0,0%	0 0,0%	0 0,0%	8 1,2%	7 1,1%

Table 2: RAD-Covid score and clinical severity correlation

RAD-Covid Score	Clinical Severity		
	Home treatment (N=202)	Hospitalization (N=317)	ICU (N=105)
RAD-Covid Score 1 (<25%)	178 (88,12%)	141 (44,48%)	21 (20,00%)
RAD-Covid Score 2 (25-50%)	22 (10,89%)	132 (41,64%)	23 (21,90%)
RAD-Covid Score 3 (50%)	2 (0,99%)	44 (13,88%)	61 (58,10%)
Ordinal Logistic Regression: OR ($IC_{95\%}$)			
Moderate 5,38 (3,63-8,10)			
Severe 36,04 (21,31-62,27)			

Table 3: Association of imaging features with clinical severity

Imaging Features	Clinical Severity			Univariate Ordinal Logistic Regression					Missing
	Home treatment (N=226)	Hospitalization (N=313)	ICU (N=104)	p-value	adj.p-value	OR	LL	UL	
Pattern of lesions									
No opacities	30 (12,9%)	4 (1,25%)	0 (0,00%)						
Consolidation	0 (0,00%)	1 (0,31%)	2 (1,90%)	Category excluded from the regression model					
GGO and consolidation	84 (36,2%)	161 (50,2%)	67 (63,8%)	**<0,001**	**<0,001**	21,57	8,26	73,96	
GGO	118 (50,9%)	155 (48,3%)	36 (34,3%)	**<0,001**	**<0,001**	11,98	4,61	40,97	
Rounded morphology				**<0,001**	**<0,001**	0,45	0,33	0,61	
No	46 (22,8%)	131 (41,3%)	51 (48,6%)	**<0,001**	**<0,001**	21,57	8,26	73,96	
Yes	156 (77,2%)	186 (58,7%)	54 (51,4%)						
Crazy Paving				**<0,001**	**<0,001**	4,97	2,91	8,75	
No	42 (20,8%)	18 (5,68%)	3 (2,86%)						
Yes	160 (79,2%)	299 (94,3%)	102 (97,1%)						
Reverse Halo Sign				0,509	0,518				
No	152 (75,2%)	213 (67,2%)	79 (75,2%)						
Yes	50 (24,8%)	104 (32,8%)	26 (24,8%)						
Bronchial thickening				**<0,001**	**<0,001**	1,93	1,38	2,70	
No	76 (37,6%)	79 (24,9%)	20 (19,0%)						
Yes	126 (62,4%)	238 (75,1%)	85 (81,0%)						
Pleural Effusion				**<0,001**	**<0,001**	4,02	2,38	6,84	
No	227 (97,8%)	291 (90,7%)	85 (81,0%)						
Yes	5 (2,16%)	30 (9,35%)	20 (19,0%)						
Lymphdenomegalia									
No	230 (99,1%)	316 (98,4%)	102 (97,1%)						
Yes	2 (0,86%)	5 (1,56%)	3 (2,86%)						

Distribution of lesions								
No opacities	30 (12,9%)	4 (1,25%)	0 (0,00%)					
Central	1 (0,43%)	0 (0,00%)	0 (0,00%)	Category excluded from the regression model				
Central and Peripheric	81 (34,9%)	219 (68,2%)	94 (89,5%)	**<0,001**	**<0,001**	30,69	11,76	105,29
Peripheric	120 (51,7%)	98 (30,5%)	11 (10,5%)	**0,001**	**0,001**	6,70	2,55	23,06
Lung Lobes Involvement				**<0,001**	**<0,001**	0,10	0,05	0,19
2+	158 (78,2%)	308 (97,2%)	103 (98,1%)					
One lobe	44 (21,8%)	9 (2,84%)	2 (1,90%)					
Bilaterality				**<0,001**	**<0,001**	0,13	0,07	0,23
Bilateral	150 (74,3%)	302 (95,3%)	102 (97,1%)					
Unilateral	52 (25,7%)	15 (4,73%)	3 (2,86%)					
Right Upper Lobe				**<0,001**	**<0,001**	7,20	4,59	11,54
No	77 (38,1%)	24 (7,57%)	7 (6,67%)					
Yes	125 (61,9%)	293 (92,4%)	98 (93,3%)					
Right Medium Lobe				**<0,001**	**<0,001**	4,63	3,13	6,93
No	82 (40,6%)	41 (12,9%)	10 (9,52%)					
Yes	120 (59,4%)	276 (87,1%)	95 (90,5%)					
Right Lower Lobe				**<0,001**	**<0,001**	5,09	2,76	9,85
No	31 (15,3%)	14 (4,42%)	1 (0,95%)					
Yes	171 (84,7%)	303 (95,6%)	104 (99,0%)					
Left Upper Lobe				**<0,001**	**<0,001**	5,35	3,37	8,69
No	60 (29,7%)	25 (7,89%)	5 (4,76%)					
Yes	142 (70,3%)	292 (92,1%)	100 (95,2%)					
Left Lower Lobe				**<0,001**	**<0,001**	4,25	2,54	7,31
No	42 (20,8%)	20 (6,31%)	4 (3,81%)					
Yes	160 (79,2%)	297 (93,7%)	101 (96,2%)					

a- GGO: ground glass opacities

Table 4: Association of clinical variables with Clinical Severity

Variable	Clinical Severity			Univariate Ordinal Logistic Regression					Missing
	Home treatment (N=226)	Hospitalization (N=313)	UCI (N=104)	p-value	Adj. p-value	OR	LL	UL	
Male	99 (42,7%)	141 (43,9%)	54 (51,4%)	0,206	0,236				
Female	133 (57,3%)	180 (56,1%)	51 (48,6%)						
Time onset symptoms	4,52 (353)	6,25 (5,04)	6,61 (4,60)	**<0,001**	**<0,001**	1,08	1,04	1,11	2
Age Group									
<50	131 (56,5%)	20 (6,23%)	1 (0,95%)						
51-60	20 (8,62%)	32 (9,97%)	11 (10,5%)	**<0,001**	**<0,001**	15,85	8,11	67,15	
61-70	33 (14,2%)	85 (26,5%)	21 (20,0%)	**<0,001**	**<0,001**	19,41	11,12	31,89	
71-80	29 (12,5%)	100 (31,2%)	37 (35,2%)	**<0,001**	**<0,001**	29,60	17,04	35,16	
>80	19 (8,19%)	84 (26,2%)	35 (33,3%)	**<0,001**	**<0,001**	36,51	20,58	53,42	
HAS ausente	157 (68,3%)	101 (31,5%)	33 (31,4%)	**<0,001**	**<0,001**	3,67	2,69	5,03	2
HAS presente	73 (31,7%)	220 (68,5%)	72 (68,6%)						
Absent Obesity	216 (93,5%)	285 (88,8%)	91 (86,7%)	**0,028**	**0,037**	1,72	1,06	2,78	1
Obesity	15 (6,49%)	36 (11,2%)	14 (13,3%)						
Absent Diabetes	201 (86,6%)	190 (59,2%)	65 (61,9%)	**<0,001**	**<0,001**	2,69	1,96	3,71	
Diabetes	31 (13,4%)	131 (40,8%)	40 (38,1%)						
Absent asthma	216 (93,1%)	312 (97,2%)	102 (97,1%)						
Asthma	16 (6,90%)	9 (2,80%)	3 (2,86%)						
No COPD	214 (94,7%)	295 (94,2%)	93 (89,4%)	0,120	0,147				
COPD	12 (5,31%)	18 (5,75%)	11 (10,6%)						
No smoker	220 (94,8%)	303 (94,4%)	94 (89,5%)						
Current Smoking	12 (5,17%)	18 (5,61%)	11 (10,5%)						
Never smoked	229	316 (98,4%)	105	**0,006**	**0,009**	1,98	1,22	3,22	

	(98,7%)		(100%)						
Former smoker	3 (1,29%)	5 (1,56%)	0 (0,00%)						
No Malignancy	218 (94,0%)	286 (89,1%)	89 (84,8%)	**0,001**	**0,002**	2,89	1,50	5,57	1
Malignancy	14 (6,03%)	35 (10,9%)	16 (15,2%)						
Absent CVD	213 (91,8%)	276 (86,0%)	83 (79,0%)	**0,001**	**0,002**	2,06	1,34	3,18	
CVD	19 (8,19%)	45 (14,0%)	22 (21,0%)						
Absent Cerebrovasc Dis	225 (97,0%)	290 (90,3%)	95 (90,5%)	**0,007**	**0,010**	2,11	1,23	3,63	
Cerebrovasc Dis	7 (3,02%)	31 (9,66%)	10 (9,52%)						
Absent CKD	222 (95,7%)	298 (92,8%)	98 (93,3%)	0,243	0,272				
CKD	10 (4,31%)	23 (7,17%)	7 (6,67%)						
Number of comorbidities#	0,91 (1,27)	1,85 (1,29)	2,03 (1,29)	**<0,001**	**<0,001**	1,64	1,46	1,84	

a - CVD: cardiovascular disease; Cerebrovasc Dis: cerebrovascular disease; CKD – Chronic Kidney Disease

Table 5: Association between the RAD-COVID Score and death

Score RAD	**Death**	
	No (N=436)	**Yes (N=188)**
RAD-COVID Score 1 (<25%)	281 (64,45%)	59 (31,38%)
RAD-COVID Score 2 (25-50%)	114 (26,15%)	63 (33,51%)
RAD-COVID Score 3 (50%)	41 (9,40%)	66 (35,11%)
Ordinal Logistic Regression: OR (95%CI)		
Moderate: 2,63 (1,74-4,00)		
Severe: 7,67 (4,77-12,49)		

Figures

Step 1: Are there imaging criteria suggestive of COVID-19?

YES	**Typical Covid-19 pulmonary findings (POSITIVE CT)**	GGO with or without consolidations, with predominantly peripheral and bilateral distribution; rounded morphology, thickening of intralobular septa ("crazy-paving" pattern), reverse halo sign or other signs of organizing pneumonia.
MAYBE	**Indeterminate findings for Covid-19 (EQUIVOCAL CT)**	Non-specific findings and absence of typical pattern, such as GGO with diffuse or central distribution, non-rounded or unilateral; or overlap of some of the typical findings with other underlying pathologies (such as fibrosis, emphysema) that limit the diagnosis.
NO	**Pulmonary findings not compatible with COVID-19 (NEGATIVE CT)**	Normal chest CT or findings that suggest another diagnostic possibility (e.g., bronchopneumonia, budding tree, neoplasm, etc.)

Step 2: What is the degree of pulmonary impairment? Severity assessment of pulmonary findings.

POSITIVE OR EQUIVOCAL CHEST CT FOR SUSPECTED Covid-19 INFECTION	
RAD-COVID Score 1	Mild (< 25% pulmonary involvement)
RAD-Covid Score 2	Moderate (25-50% pulmonary involvement)
RAD-Covid Score 3	Severe (> 50% pulmonary involvement)
NEGATIVE CHEST CT FOR SUSPECTED Covid-19 INFECTION	
RAD-Covid Score 0	Absence of pulmonary findings (normal chest CT)
RAD-Covid Score N/A	Findings suggestive of a pulmonary pathology unrelated to Covid-19 infection (such as bronchopneumonia, inflammatory bronchopathy, neoplasm, isolated pleural effusion).

Figure 1

PULMONARY ASSESSMENT TUTORIAL FOR IMAGING OF SUSPECTED Covid-19 INFECTIONS

Step 1: Are there imaging criteria suggestive of COVID-19?

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PULMONARY ASSESSMENT TUTORIAL FOR IMAGING OF SUSPECTED Covid-19 INFECTIONS

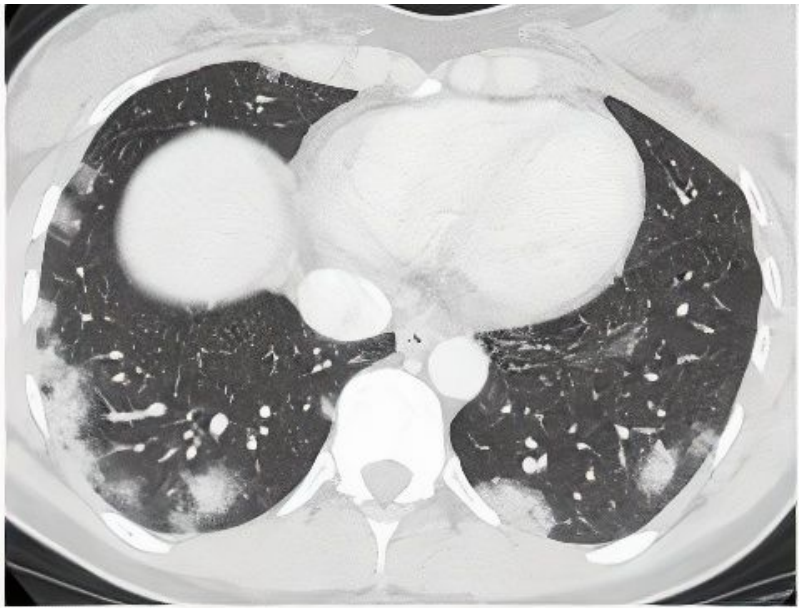

Figure 2

RAD Covid Score 1: Female patient, 25 years of age, with 5 days of symptoms and Covid-19 infection confirmed by rt-PCR. Mild pulmonary involvement (<25%). In this case, we see ground-glass opacities with bilateral and peripheral consolidation and rounded morphology.

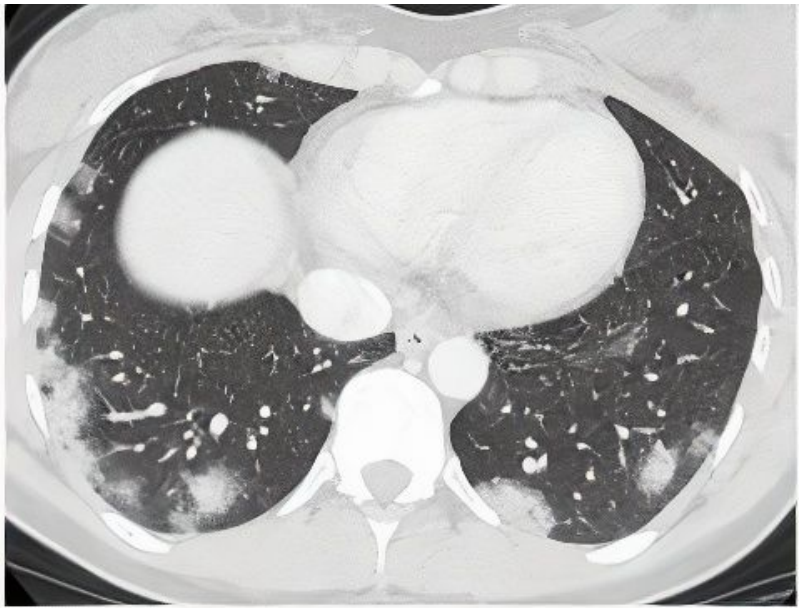

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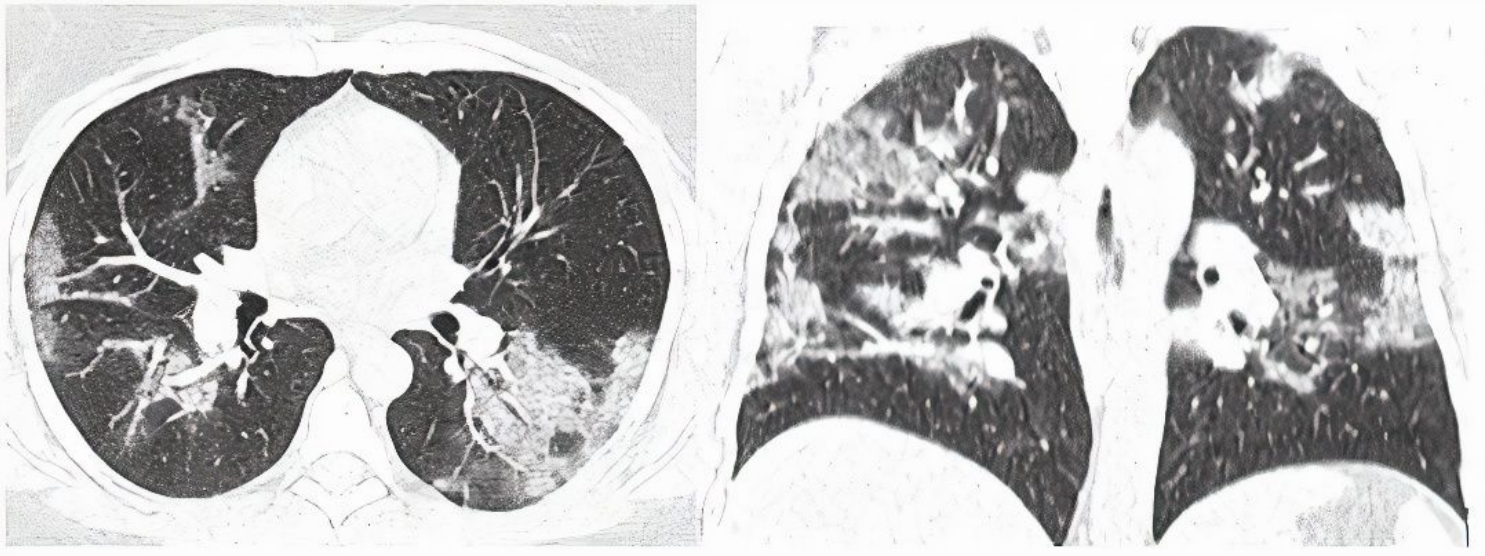
Figure 3

RAD-Covid Score 2. Male patient, 55 years of age, with 4 days of symptoms and Covid-19 infection confirmed by rt-PCR. Moderate pulmonary involvement (25-50%). In this case, we see ground-glass opacities with additional confluent consolidations and “crazy-paving”.



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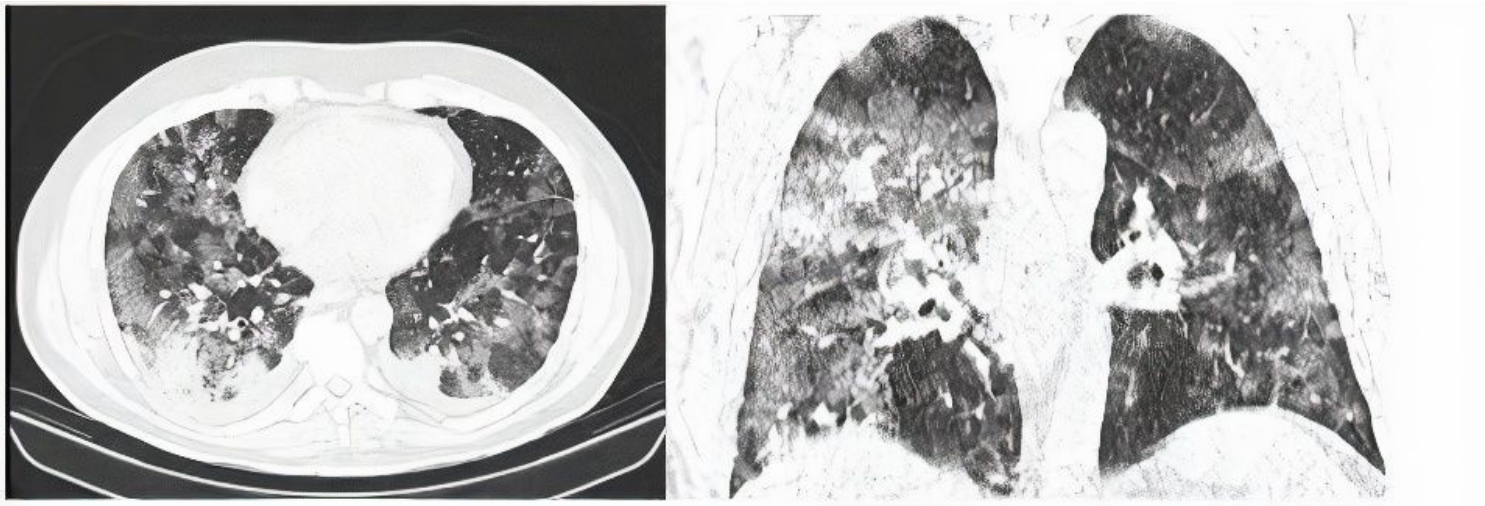
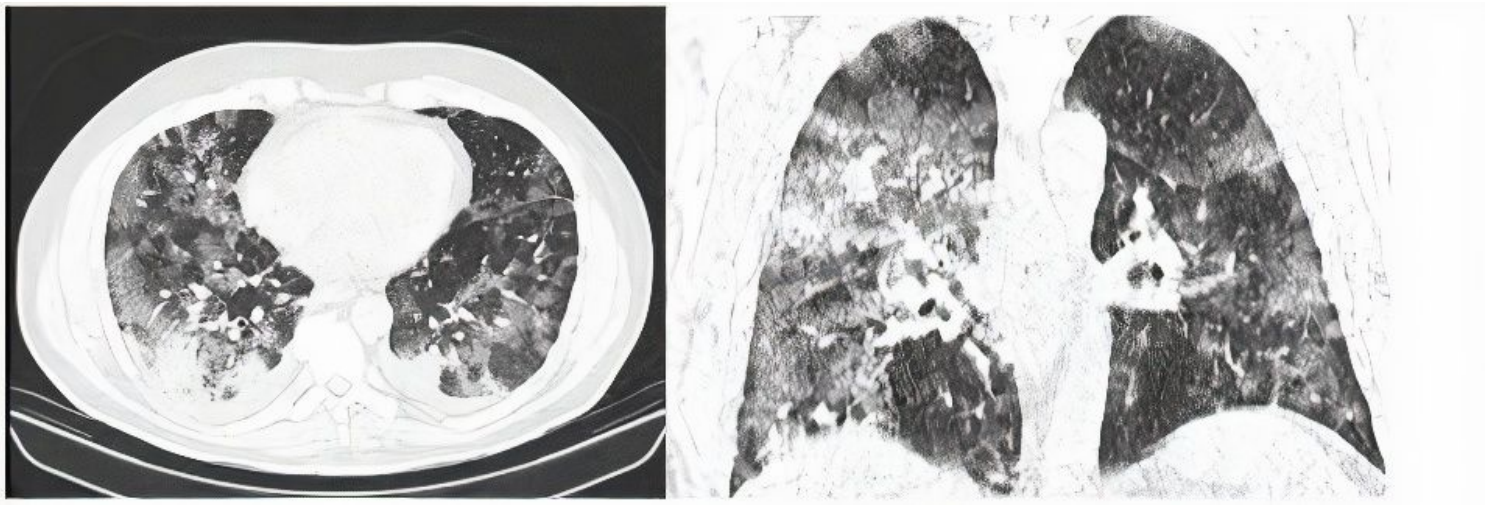


Figure 4

RAD-Covid Score 3. Male patient, 67 years of age, with 5 days of symptoms and Covid-19 infection confirmed by rt-PCR. Extensive pulmonary involvement (> 50%). In this case, we see ground-glass opacities, consolidations, and septal thickening/ “crazy-paving” occupying more than 50% of the total lung volume, with bilateral, peripheral, and central distribution.



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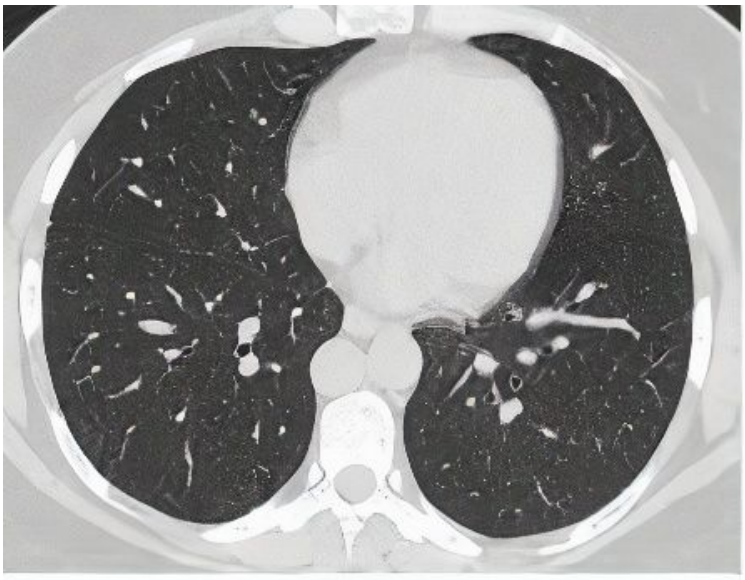
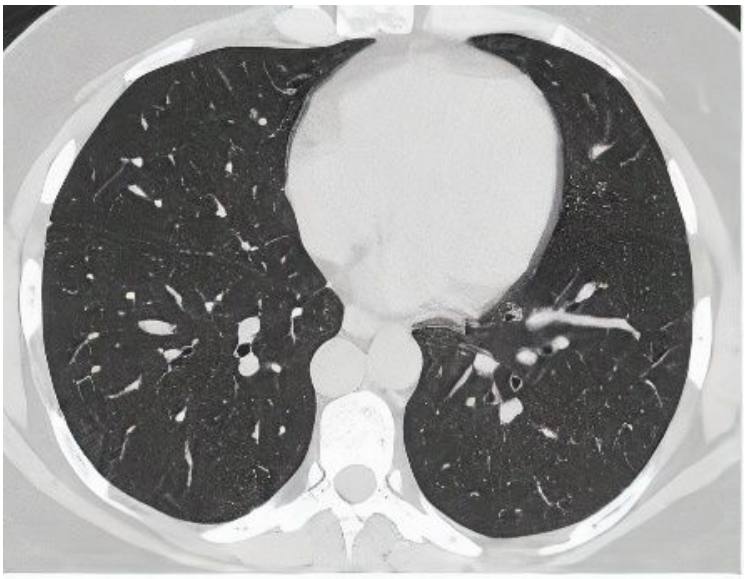


Figure 5

RAD-Covid Score 0. Male patient, 42 years of age, with 2 days of symptoms and Covid-19 infection confirmed by rt-PCR. The axial chest CT image shows no relevant pulmonary changes (normal chest CT). The chest CT can be negative in the first days of symptoms (the literature reports up to 50% normal CT in patients with less than 2 days of symptoms) (20).



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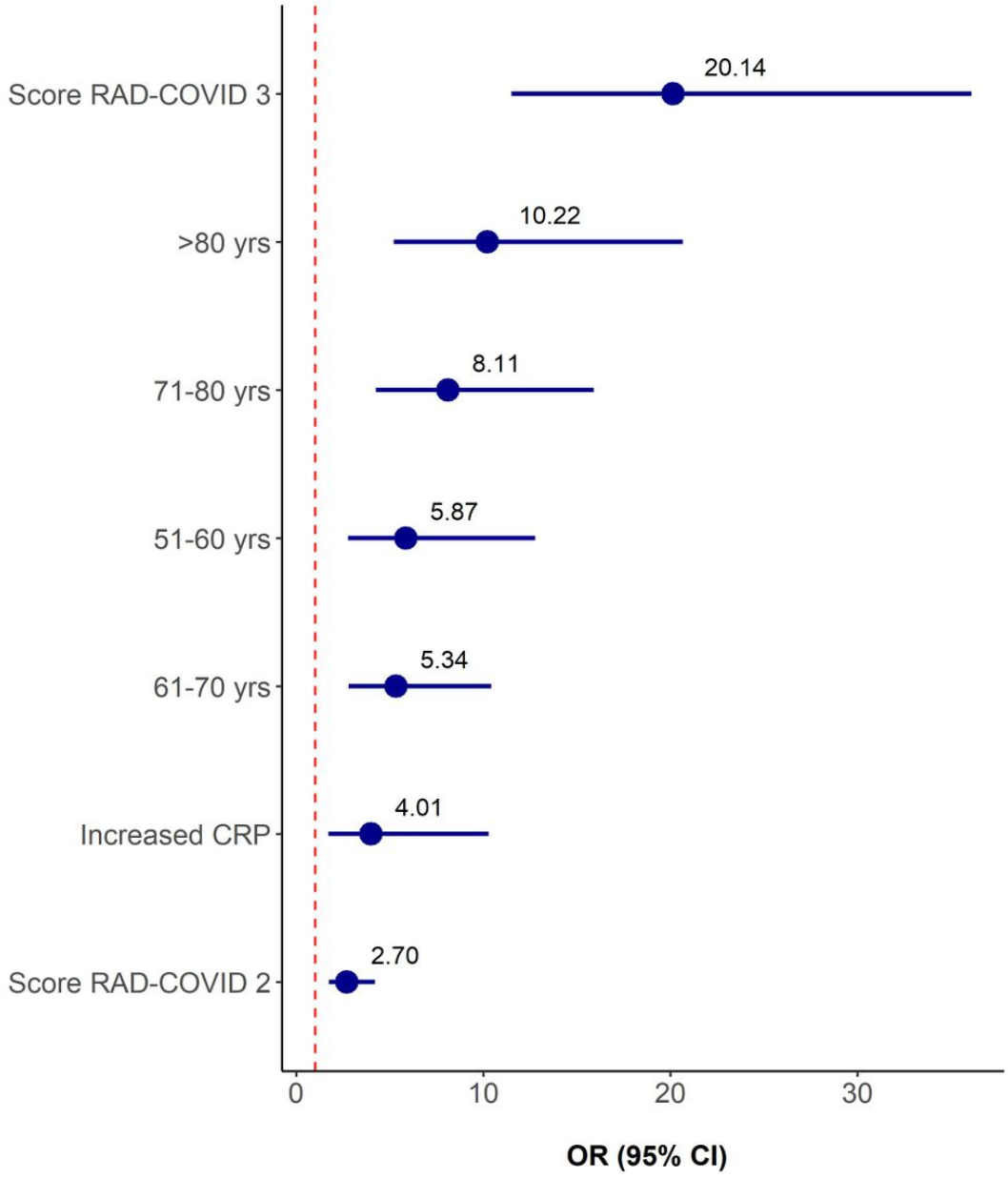
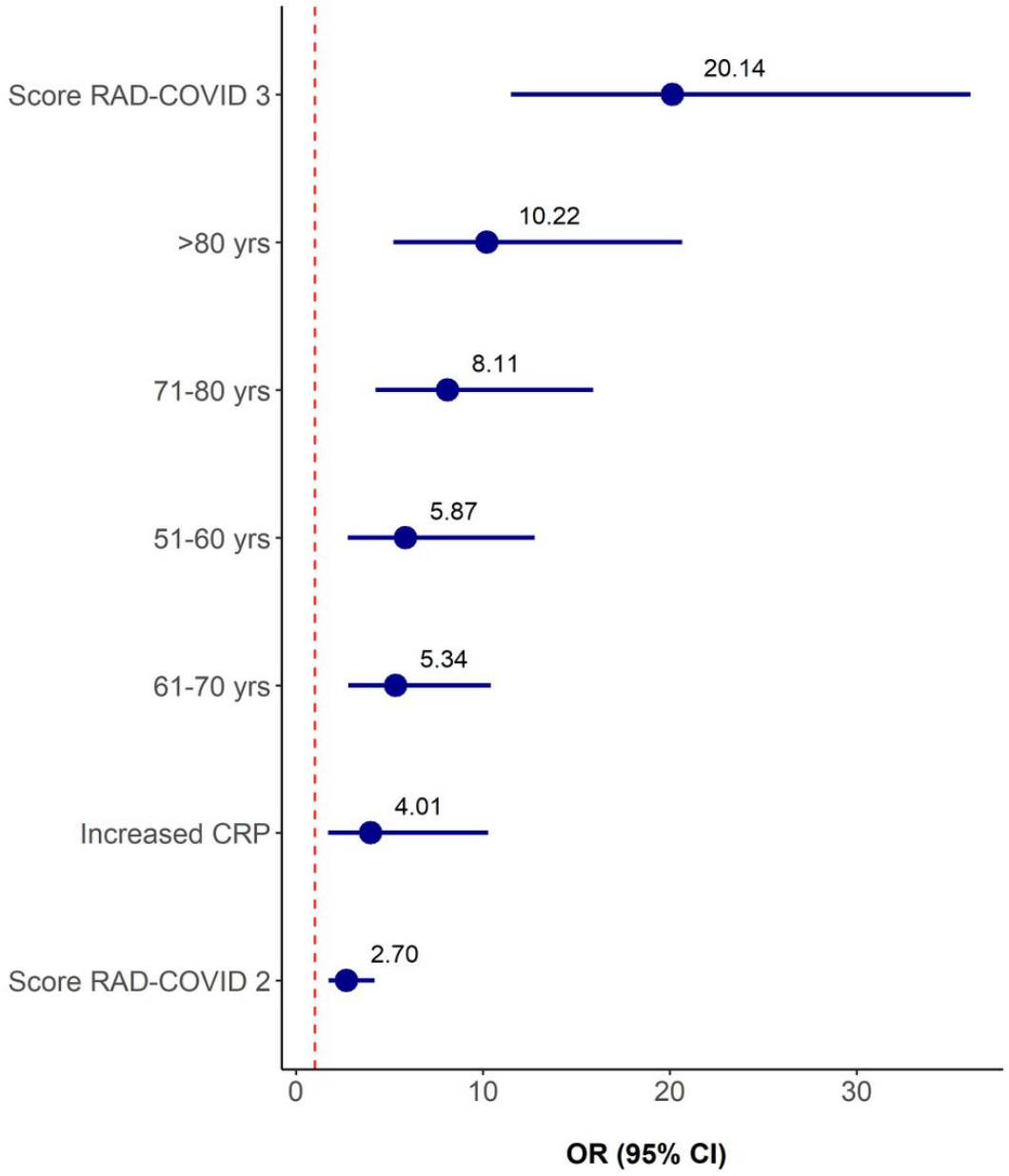


Figure 6

Odds ratios and 95% CI of the Ordinal Regression Model for Clinical Severity



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