

Association between chest CT findings and prognosis in patients with SARS-CoV-2 pneumonia over a 4-week follow-up

Asociación entre los hallazgos en escanografía de tórax y el pronóstico de pacientes con neumonía por SARS-CoV-2 en un seguimiento de cuatro semanas

Liliana Arias Álvarez[1]
Lucas Ortiz Mesa[2]
David Mauricio Ruska Jara[2]
Juan José Ramírez Mosquera[3]

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Summary

Introduction: The SARS-CoV-2 pandemic has caused millions of deaths, and pneumonia caused by this virus has been the leading cause of acute respiratory infection. This article aims to evaluate the association between chest CT findings and the prognosis of patients hospitalized for this infection. ***Methods:*** We included 360 adult patients from a tertiary care center who were diagnosed with COVID-19 by RT-PCR and underwent chest CT scans at the beginning of their hospitalization. We used logistic regression to evaluate the association between imaging findings and survival. ***Results:*** The most common findings were the "ground glass" pattern (87%), followed by consolidation (27%), cobblestone pattern (18%), and organizing pneumonia (6%). Most patients survived (77.5%), while 16.9% died within four weeks. Abnormalities in diagnostic imaging tended to be risk factors for death; consolidation was found to be associated with a 10% increase in mortality risk. ***Discussion:*** Abnormalities or semiological findings on chest CT scans are associated with a worse prognosis within the first four weeks in patients with SARS-CoV-2 infection. The results highlight that early identification of certain findings in the images could improve the prediction of severity and guide clinical decisions. It is recommended to evaluate the chronological evolution of the findings to optimize the management of patients with SARS-CoV-2 infection.

Resumen

Introducción: La pandemia por SARS-CoV-2 ha provocado millones de muertes, y la neumonía por este virus ha sido la causa principal de infección respiratoria aguda. Este artículo tiene el objetivo de evaluar la asociación entre hallazgos en la tomografía de tórax y el pronóstico de pacientes hospitalizados por esta infección. ***Métodos:*** Se incluyeron 360 pacientes adultos de un centro de cuarto nivel, diagnosticados con COVID-19 mediante RT-PCR, quienes tuvieron tomografía de tórax al inicio de su hospitalización. Se evaluó mediante regresión logística la asociación entre los hallazgos imagenológicos y la supervivencia. ***Resultados:*** Los hallazgos más frecuentes fueron el patrón en "vidrio esmerilado" (87 %), seguido por consolidación (27 %), patrón empedrado (18 %) y neumonía en organización (6 %). La mayoría de los pacientes sobrevivieron (77,5 %), mientras que el 16,9 % falleció dentro de las cuatro semanas siguientes. Las alteraciones en las imágenes diagnósticas mostraron una tendencia a ser factores de riesgo de muerte; así mismo, se encontró que la consolidación se asoció con un aumento del riesgo de mortalidad en un 10 %. ***Discusión:*** Las alteraciones o hallazgos semiológicos en la escanografía de tórax se asocian con un peor pronóstico dentro de las primeras cuatro semanas en pacientes con infección por SARS-CoV-2. Los resultados resaltan que la identificación temprana de ciertos hallazgos en las imágenes podría mejorar la predicción de la gravedad y guiar decisiones clínicas. Se recomienda evaluar la evolución cronológica de los hallazgos para optimizar el manejo de los pacientes con infección por SARS-CoV-2.

Introduction

The SARS-CoV-2 pandemic has infected more than 197 million people, with a mortality rate exceeding 4 million deaths (1), which is related to the overcrowding of medical services, the lack of effective treatments, the mutation of the virus, and difficulties in the uniform administration of the vaccine, among other factors. For this reason, it remains one of the leading causes of acute respiratory infection, despite the possibility of reduced transmission due to immunity following mass vaccination

[1]Radiologist, Associate Professor, Department of Radiology and Diagnostic Imaging, Hospital Universitario San Ignacio, Pontificia Universidad Javeriana. Bogotá, Colombia.

[2]Fourth-year resident in Radiology and Diagnostic Imaging, Pontificia Universidad Javeriana. Bogotá, Colombia.

[3]Twelfth-semester student at the Faculty of Medicine, Pontificia Universidad Javeriana. Bogotá, Colombia.

Department of Radiology and Diagnostic Imaging, Hospital Universitario San Ignacio, Pontificia Universidad Javeriana

(2). This situation has highlighted the need to identify this entity in a timely and efficient manner based on clinical, paraclinical, and imaging criteria in order to reduce the risk of healthcare system collapse. Therefore, the role of diagnostic imaging is to provide a tool in everyday practice that allows for the evaluation and classification of the severity of SARS-CoV-2 pneumonia, which, together with clinical assessment and other paraclinical tests, helps to anticipate the need for hospital admission and the choice of appropriate treatment that will impact patient outcomes (3).

Computed tomography (CT) scanning of the chest provides highly relevant information when assessing lung involvement by SARS-CoV-2, not only in patients with moderate to severe disease, but also in those with impaired cardiopulmonary function (4). It allows the severity of the infection to be classified according to the presence, extent, and type of pulmonary semiological findings (5-7). In response, work has been done on the implementation of artificial intelligence to accurately differentiate the findings specific to SARS-CoV-2 infection from other pulmonary entities, segmenting the regions of the lung where the greatest aggregation of findings is found ("opacities," "ground glass," "organizing pneumonia," "cobblestone pattern") (8), as well as allowing the prognosis in the hospital setting and the prediction of clinical outcome to be elucidated with a certain margin of error (9, 10). These results could potentially be extrapolated to other clinical entities of particular importance to public health, making it necessary to determine the prognosis of patients with SARS-CoV-2 infection in order to establish a predictive model and thus be able to determine timely and efficient management (11).

It has been reported that macroscopic changes in the lung, when present, are observed between days 6 and 10, demonstrating that this imaging progression in many cases occurs in a specific sequence, but that it is not subject to the development of other patterns of findings in a specific order; ground glass opacity is the predominant pattern followed by consolidations (12). Therefore, this study explores the association between the spectrum of initial manifestations on chest CT scans in patients with SARS-CoV-2 pneumonia and their prognosis. To this end, we reviewed the possible relationship between the semiological findings in chest CT scans (opacities, ground glass, organizing pneumonia, cobblestone pattern of opacities) (7) and the clinical outcome within the first four weeks of diagnosis for the population to be studied, discriminating the impact of each of the imaging findings.

Methods

Type of study

This is a cross-sectional study based on the medical records of patients hospitalized at the Hospital Universitario San Ignacio.

Population

Adult patients treated at a tertiary care hospital in Bogotá, Colombia, during the last 12 months of the pandemic who were diagnosed with SARS-CoV-2 infection by RT-PCR and underwent chest CT scanning during the first days of their hospital stay. Patients with a history of known structural or functional lung disease prior to the infectious process, known coronary artery disease with a left ventricular ejection fraction of less than 50%, swallowing disorders that cause airway aspiration, and patients with sequelae after hospitalization that are attributed to interventions performed during that event and not specifically to SARS-CoV-2 infection. In individuals with more than one episode of infection, the findings from the first episode were considered. A sample size of 366 individuals was calculated with an alpha of 5% and a power of 10% (Figures 1 to 4).

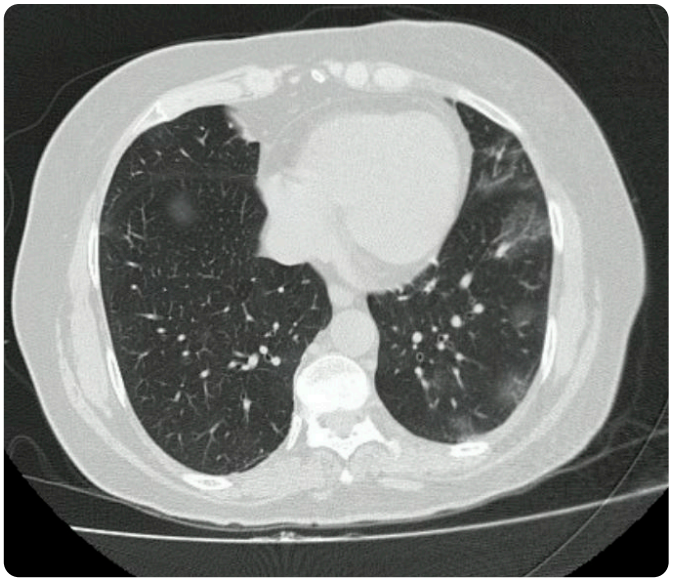


Figure 1. Chest CT scan in a patient with a confirmed diagnosis of SARS-CoV-2 by PCR, showing a ground-glass pattern in the lung parenchyma.

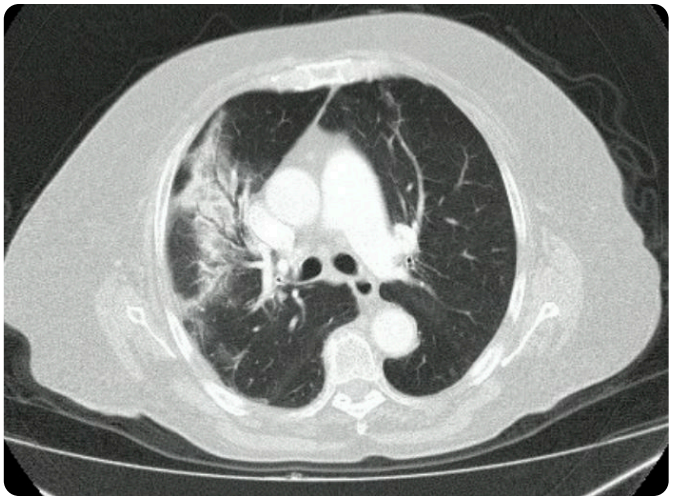


Figure 2. Chest scan of a patient with a confirmed diagnosis of SARS-CoV-2 by PCR, showing a consolidation pattern in the lung parenchyma.

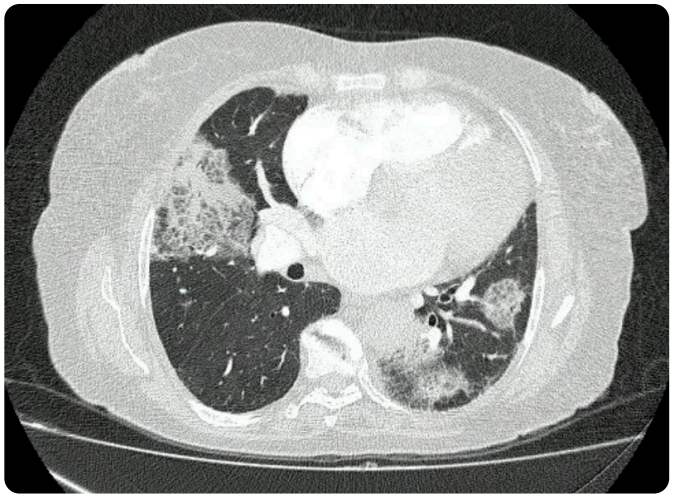


Figure 3. Chest scan of a patient with a confirmed diagnosis of SARS-CoV-2 by PCR, showing a "cobblestone pattern" in the lung parenchyma.

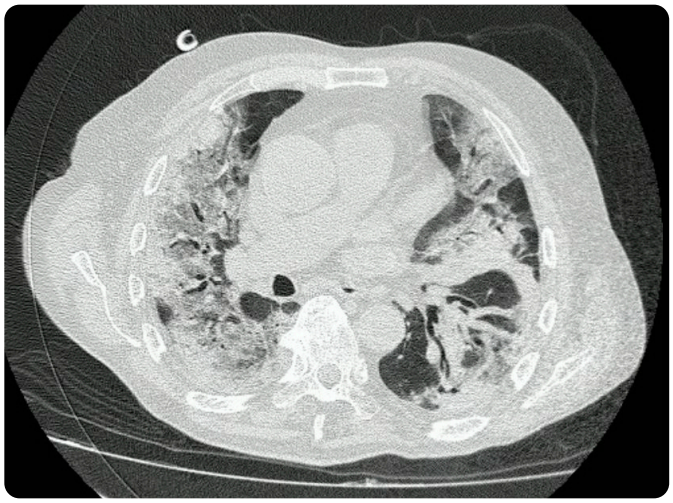


Figure 4. Chest scan in a patient with a confirmed diagnosis of SARS-CoV-2 by PCR, with a pattern of "organizing pneumonia" in the lung parenchyma.

Study description and statistical analysis

The images stored in the Picture Archiving and Communication System (PACS) of the Radiology Department of a tertiary hospital in Bogotá, Colombia, were analyzed, as were the medical records of these same patients. The image and patient data were entered into the REDCap® platform.

After obtaining the information, statistical analysis was performed. Initially, the population was described according to sex and outcome, as well as the difference between the groups using Student's t-test or chi-square test, depending on the nature of the variables. Then, to evaluate the association between the tomographic findings and patient outcome, a multiple logistic regression model was performed considering a dichotomous outcome (alive or dead), which included the findings analyzed, described in the Fleischner Society's semiological glossary of chest images: ground glass opacity, consolidation, or organizing pneumonia (13), along with control variables that took into account sex and age. The possible interaction of the findings with the control variables was also evaluated.

Results

A total of 360 patient records with complete information were included. The patients had a mean age of 64.56 years (SD: 14.13), and 52.5% were men (n=189). During hospitalization, the most common finding was ground-glass opacity (87%), followed by consolidation (27%), cobblestone pattern (18%), and finally organizing pneumonia (6%).

Regarding patient outcomes, 79.7% were discharged alive (n=287), while 4.2% of patients were referred to another institution (n=15) and 16% (n=58) died. However, when focusing on the four weeks following admission to the institution, 77.5% were discharged (n=279) and 16.9% (n=61) died, while the rest remained hospitalized or were referred.

When comparing the presentation of findings by sex, the only statistically significant difference was the ground-glass pattern, which was more prevalent in men (90% vs. 83%) (Table 1). When comparing presentation according to outcome, survivors were younger and had fewer cobblestone patterns (Table 2).

When evaluating the association between the findings, only the consolidation pattern was statistically significant, decreasing the risk of survival by 10% (OR: 0.9), while the other findings also represent a trend toward decreasing the risk of survival but are not statistically significant. Additionally, no interaction was found between age or sex and the different imaging findings included (Tables 3 and 4).

Table 1. Clinical presentation by gender

Indicator	Female (%)	Male (%)	p-value
n	171	189	
Age (mean [SD])	65.27 (14.47)	63.91 (13.82)	0.363
Frosted glass	83	90	0.037
Consolidation	29	25	0.488
Cobblestone	22	15	0.124
Organization	5	6	0.491
Discharge status*			0.532
Deceased	28 (16.4)	30 (15.9)	
Remission	5 (2.9)	10 (5.3)	
Alive	138 (80.7)	149 (78.8)	
4-week period*			0.358
Discharged	135 (78.9)	144 (76.2)	
Remission	5 (2.9)	9 (4.8)	
Deceased	30 (17.5)	31 (16.4)	
Hospitalized	1 (0.6)	5 (2.6)	

*Chi-square analysis; SD: standard deviation.

Table 2. Clinical presentation according to outcome

	Deceased (%)	Alive (%)	p-value
n	73	287	
Male	40 (54.8)	149 (51.9)	0.758
Age (mean [SD])	71.38 (11.77)	62.82 (14.17)	<0.001
Frosted glass	88	87	0.837
Consolidation	33	25	0.202
Cobblestone	26	16	0.057
Organization	7	5	0.590
Discharge status			<0.001
Deceased	1 (1.4)	278 (96.9)	
Remission	14 (19.2)	0	
Alive	58 (79.5)	3 (1.0)	
4-week period*	0	6 (2.1)	

*Chi-square analysis; SD: standard deviation.

Table 3. Association of imaging findings with 4-week survival*

	Coefficient	Standard error	t-value	p-value
Male	-0.036	0.042	-0.855	0.392
Age	-0.007	0.001	-4.978	< 0.001
Ground glass opacity	-0.021	0.061	-0.334	0.738
Consolidation	-0.105	0.047	-2.227	0.026
Paving	-0.088	0.053	-1.632	0.103
Organization	-0.029	0.090	-0.322	0.747

*No interaction between variables when considering sex or age.

Table 4. Indirect risk of imaging findings for survival

	OR	2.5%	97.5%
Male	0.9650	0.8892	1.0473
Age	0.9927	0.9898	0.9955
Ground glass opacity	0.9795	0.8671	1.1065
Consolidation	0.9002	0.8204	0.9878
Cribriform pattern	0.9159	0.8239	1.0182
Organization	0.9713	0.8129	1.1606

Discussion

This study evaluated the association between imaging findings and four-week prognosis in patients with SARS-CoV-2 infection. To our knowledge, little research has been conducted on this relationship without limiting itself to a chronological order in the presentation of findings. This allows for the identification of factors that represent a higher risk of death, enabling more timely and accurate decision-making.

Although age has been described as a risk factor for death in this infectious disease (14), the population in this study has a relatively low average age, which is similar between the groups compared, as well as a comparable gender ratio. It was also found that the majority of these patients survived, despite the fact that up to 87% presented a ground-glass pattern; the percentage of deaths in this study was lower compared to other articles describing up to 21.1%, but those studies include more critically ill subjects requiring intensive care unit (ICU) admission (15).

In this context, it is essential to identify the relationship and risk that each of the clinical and paraclinical findings accessed may imply, such as the imaging findings in the case of this article. To this end, it was found that all findings showed a tendency to increase the risk of death, with a statistically significant value for the consolidation pattern, which increased the risk of death in these patients by 10%. Along these lines, Yuan et al. (16), with their scan scoring model, were able to predict mortality with a sensitivity of 85.6% and a specificity of 84.5%, while Colombi et al. (17) determined that a measurement of less than 73% lung parenchyma aeration was a predictor for ICU admission. In both studies, these outcomes were attributed to the sum of different variables, including chest scan findings, but without discriminating the value of each manifestation independently.

On the other hand, the chronology of findings is also described, and it has even been documented that macroscopic changes in the lung, when present, are observed between days 6 and 10, suggesting that this imaging progression in many cases occurs in a specific sequence, but that it is not subject to the development of another in a specific order, with ground-glass opacity being the predominant pattern followed by consolidations (12), as evidenced in the sample studied here. In this regard, Zhao et al. (4) conducted a similar study in a series of 101 patients, finding that the most frequent manifestations were ground-glass opacity with or without consolidation (65-87%), peripheral distribution (88%), basal distribution (55%), and bilateral distribution (84%).

This study has some limitations. For example, there was no way to identify those patients who died from causes other than SARS-CoV-2 infection; however, infection may be a predisposing factor or a modifying variable of the effect of comorbidities, also favoring the outcome of death. On the other hand, the change in the presentation of the semiological findings of chest scans was not evaluated, since, although it was not the objective to evaluate the chronology, future studies may review the evolution of these presentations.

In conclusion, the pattern of consolidation on chest scans is associated with a worse prognosis at four weeks for patients with SARS-CoV-2 infection within the set of semiological manifestations evaluated. Therefore, the development of prediction models and the identification of the risk inherent in each finding will be essential to establish the severity and appropriate treatment of pathologies.

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Correspondence

David Mauricio Ruska Jara
Carrera 68A # 23-47
Bogotá, Colombia
dmruskaj@javeriana.edu.co