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COVID-19 findings in chest computed tomography

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SUMMARY

OBJECTIVE: The aim of this study was to describe chest computed tomography image findings in patients with COVID-19.

METHODS: The chest computed tomography scans of 453 hospitalized patients with confirmed COVID-19 were collected at two tertiary care Brazilian hospitals. Demographics and clinical data were extracted from the electronic record medical system.

RESULTS: The main chest computed tomography findings were ground-glass opacities (92.5%), consolidation (79.2%), crazy-paving pattern (23.9%), parenchymal bands (50%), septal thickening (43.5%), and inverted halo sign (3.5%). Of the 453 hospitalized patients, 136 (30%) died. In this group, ground-glass opacities (94.1%), consolidation (89.7%), septal thickening (58.1%), crazy-paving pattern (52.2%), and parenchymal bands (39.7%) were the most common imaging findings.

CONCLUSIONS: In a dynamic disease with a broad clinical spectrum such as COVID-19, radiologists can cooperate in a better patient management. On wisely indicated chest computed tomography scans, the fast identification of poor prognosis findings could advise patient management through hospital care facilities and clinical team decisions.

KEYWORDS: COVID-19. CT x ray. Lung. Thorax. SARS-CoV-2.

INTRODUCTION

Being declared by the World Health Organization (WHO) as a pandemic on March 11, 2019, the novel coronavirus disease (COVID-19)[1] became a major challenge for health care systems worldwide. It was first described on December 2019 as an "unknown etiology pneumonia" at Hubei, a province of China[2]. COVID-19 will hallmark human history as one of the most impressive public health calamities: a life-threatening disease steadily increasing the cause of more than 1 million death and 141 million confirmed cases worldwide[3], not to mention the social, economic, and political distress.

In this scenario, thoracic imaging can be assessed for diagnosis and clinical course monitoring. Although X-rays and ultrasonography have proved their utility, especially on intensive care unit (ICU) and campaign hospitals settings, high-definition computed tomography (HDCT) is the first choice when imaging is required due to its high sensitivity[4-6]. However, the low specificity of the computed tomography (CT)[7] explained why radiology societies' recommendations are against the method as an initial approach to diagnosis[8,9]. Even though reverse transcription polymerase chain reaction (RT-PCR) tests were adopted as the reference standard, dissociation between laboratory and tomographic findings must be expected and CT manifestations remain critical for patient management when first RT-PCR results are negative or unknown[10].

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To contribute with the current literature, the present study describes chest CT findings in patients with COVID-19 in the Brazilian State of Espírito Santo and correlates the results with in-hospital mortality.

METHODS

A retrospective study was conducted focusing on analyzing thoracic findings in hospitalized patients with SARS-CoV-2 confirmed with real-time reverse transcriptase polymerase chain reaction (rRT-PCR) of respiratory secretions or rapid detection tests to detect the SARS-CoV-2 antibody. It was a multicentric data analysis by two tertiary care Brazilian hospitals, one in Vitória-ES (Hospital Universitário Cassiano Antônio Moraes or HUCAM) and the other one in Serra-ES (Hospital Estadual Jayme Santos Neves or HEJSN).

All imaging examinations were performed according to the clinical indications. CT imaging was performed using Toshiba Alexion 16-slice (Toshiba Medical Systems, Nasu, Japan) at HEJSN and Toshiba 64-slice (Toshiba Medical Systems) at HUCAM. The protocols in both institutions were similar with 2-mm-section thickness, 40 cm field of view, 120 kV (peak), and 200–260 mA. This study was approved by the research ethics committee (CAAE 31424720.1.0000.5071).

Four radiologists (C.C., Y.O., B.B.Z., and W.B. with 1, 3, 3, and 5 years of experience in interpreting CT images, respectively) reviewed the first CT scans of these patients. The radiologists evaluated the initial CT for ground-glass opacities, consolidation, septal thickening, parenchymal bands, inverted halo sign, crazy-paving pattern, lobes affected, pleural effusion, thoracic lymphadenopathy (lymph node size of ≥1 cm in short-axis dimension), and other abnormalities (pneumothorax, pneumomediastinum, bronchiectasis, pulmonary cysts, cavitated nodule, pulmonary emphysema, and random nodules). They classify the degree of lung involvement qualitatively through visual analysis as none (0%), minimal (1–25%), mild (26–50%), moderate (51–75%), or severe (76–100%). Clinical information was collected from the electronic medical records. The analysis of the axial distribution of the lesions was performed, which was classified as lesions with central distribution or lesions with peripheral distribution.

RESULTS

In this study, 453 CTs of hospitalized patients from March to July 2020 were analyzed. The main CT findings were ground-glass opacities in 419 (92.5%) patients, consolidation in 359 (79.2%), crazy-paving pattern in 122 (23.9%), parenchymal bands in 226 (50%), septal thickening in 197 (43.5%), and inverted halo sign in 16 (3.5%) patients. Pleural effusion was found in 83 (18.3%) patients and lymph node enlargement in 26 (5.7%), as given in Table 1.

We observed severe pulmonary involvement in 59 (13%) patients, moderate involvement in 145 (32%), mild involvement in 135 (29.8%), minimal involvement in 95 (21%), and 19 (4.2%) with none pulmonary involvement. The qualitative visual assessment of each one of the pulmonary lobes revealed a

Table 1. Demographics and CT characteristics.

	Total (n)	In-hospital mortality
Number of patients	453	136
Age (year) Mean=60.14±17.4, n (%)		
≤20	5 (1.1)	0 (0)
21–39	63 (13.9)	5 (3.7)
40–59	141 (31.1)	34 (25)
60–79	191 (42.2)	70 (51.5)
80–99	53 (11.7)	27 (19.9)
Sex, n (%)		
Female	193 (42.6)	57 (41.9)
Male	260 (57.4)	79 (58.1)
Pulmonary involvement, n (%)		
0%	19 (4.2)	5 (3.7)
1–25%	95 (21)	13 (9.6)
26–50%	135 (29.8)	25 (18.4)
51–75%	145 (32)	53 (39)
76–100%	59 (13)	40 (29.4)
CT findings, n (%)		
Ground-glass opacity	419 (92.5)	128 (94.1)
Consolidation	359 (79.2)	122 (89.7)
Parenchymal bands	226 (50)	54 (39.7)
Septal thickening	197 (43.5)	79 (58.1)
Crazy-paving pattern	122 (23.9)	71 (52.2)
Pleural effusion	83 (18.3)	29 (21.3)
Lymph node enlargement	26 (5.7)	12 (8.8)
Pulmonary emphysema	17 (3.8)	6 (4.4)
Inverted halo	16 (3.5)	3 (2.2)
Bronchiectasis	14 (3.1)	3 (2.2)
Pneumothorax	10 (2.2)	2 (1.5)
Tree-in-bud	8 (1.8)	1 (0.7)
Pulmonary cysts	7 (1.5)	2 (1.5)

predominance of greater involvement in the lower lobes. Most patients had a bilateral multilobar pattern of involvement, with only nine patients with unilobar commitment.

Out of 453, 136 (30%) patients died during hospitalization. Of these, the distribution of the findings occurred as follows: ground-glass opacities in 128 (94.1%) patients, consolidation in 122 (89.7%), crazy-paving pattern in 71 (52.2%), septal thickening in 79 (58.1%), parenchymal bands in 54 (39.7%), and inverted halo sign in three (2.2%). Pleural effusion was found in 29 (21.3%) patients, being the sole observation in one of them (0.7%). Lymph node enlargement was identified in 12 (8.8%) individuals who died and 5 (3.7%) had normal initial CT. Pneumomediastinum was found in six patients, five of whom died (Figures 1 and 2).

Of the patients who died, 13 (9.6%) had minimal pulmonary involvement, 25 (18.4%) had mild involvement, 53 (39%) had moderate involvement, and 40 (29.4%) had severe involvement.

DISCUSSION

The pulmonary pathogenesis caused by SARS-CoV-2 has been associated with the coronavirus entrance in cells through angiotensin-converting enzyme two receptor, abundant on the

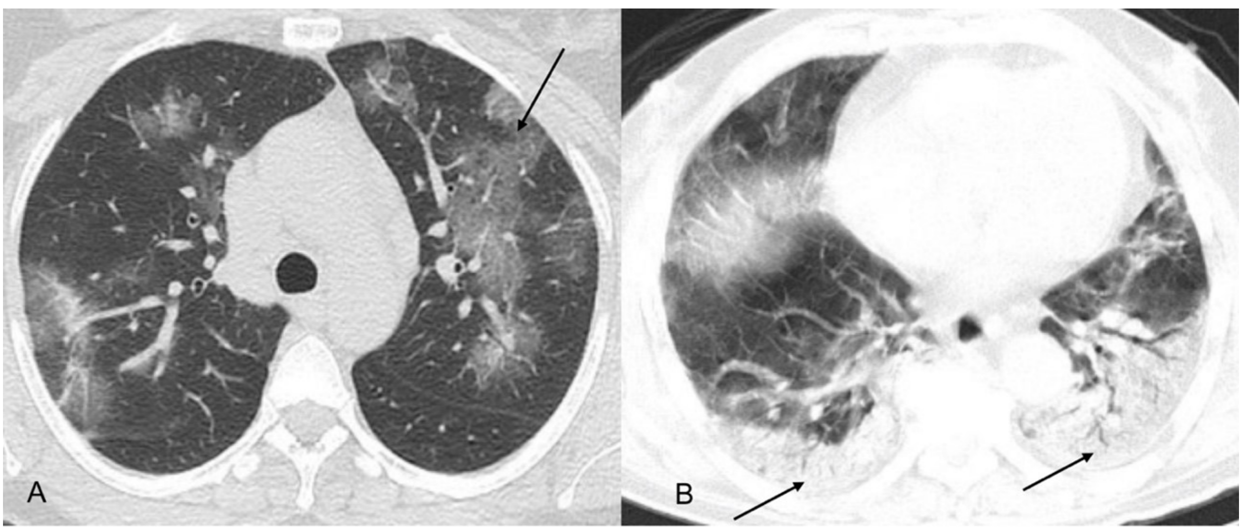

Figure 1. (A) Opacities with ground-glass attenuation (arrow). (B) Diffuse consolidation (arrows).

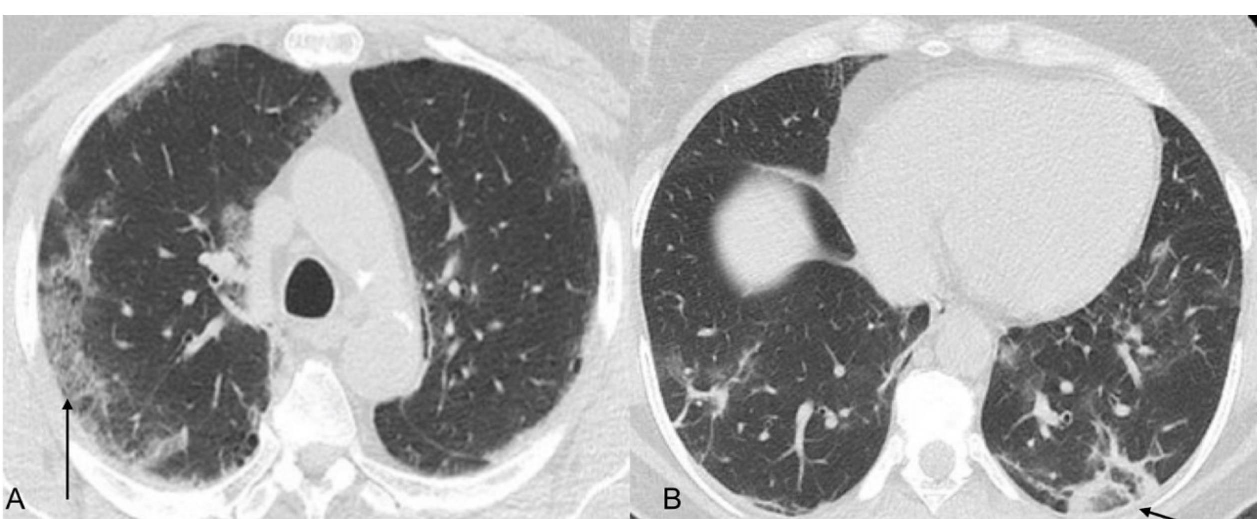

Figure 2. (A) Reticular opacities and ground-glass attenuation (arrow). (B) Ground-glass attenuation opacities surrounded by a consolidation ring – the reversed halo sign (arrow).

acinar side of pneumocytes within alveolar spaces. Once tissues are perpetrated, immune and nonimmune cells promote cytokines storm, resulting in damage to the host[11]. Fever and respiratory symptoms are the most common manifestations, as expected for an infectious pulmonary disease. Clinical findings can be diverse, ranging from asymptomatic patients to critical disease, and from sole lung impairment to multisystemic presentations[11,12].

Although mild and moderate presentations are preponderant, COVID-19 is a dynamic disease with a quick clinical deterioration among severe symptomatic individuals, a group with considerable risk of prolonged critical illness and death[13]. Mortality among hospitalized patients in ICUs varies from 30% to 70% in the literature[14]. Similarly, we found 30% mortality in our patients, with the most important findings related to mortality: age over 60 years, female, and moderate or severe pulmonary involvement. To avoid unwanted outcomes, physicians must identify the main factors of poor prognosis, making quicker decisions and setting appropriate treatment goals[13]. An extent of different scenarios must be considered while interpreting deaths, from the environmental factors to the therapeutic limitations. In addition to this complexity, the results of the present study have important practical implications, providing indicators related to the increased risk of death from COVID-19 and meaningful on guiding physicians' decisions about intensive care practices in ICU settings[14].

Qualitative visual assessment of pulmonary involvement is a metric worth attention. In this study, most of the hospitalized patients had a pulmonary involvement more than 25% and the majority of the patients who died had pulmonary involvement more than 50%, inferring a worse prognosis related to the size of the affected area. Toussie et al.[15] reported that patients with ground-glass opacities represented in at least two pulmonary zones are more likely to need hospitalization and those in three zones were more likely to intubate, reinforcing the prerogative that the largest area affected is related to worse prognosis.

The main CT findings are similar to those that have been described in the literature, including predominantly bilateral multifocal ground-glass opacities, sometimes associated with a superimposed thin septal thickening ("crazy-paving" pattern), usually involving several pulmonary lobes and with distribution predominantly peripheral in the parenchyma[16,17].

Pulmonary cavitation and pneumothorax are less common findings in COVID-19 and, when described, should raise suspicion for other potential causes[11]. The low incidence of pleural effusion and the absence of other findings, such as lymph node enlargement, nodules, and excavated lesions, are in line with recent international experience[18]. Unilateral lesions are also uncommon, described only in 2% of patients with COVID-19 in the literature, and may be useful in differentiating COVID-19 pneumonia from other conditions[11].

It is important to recognize that imaging findings of the new coronavirus share some similarities with other diseases that cause viral pneumonia, particularly those within the same viral family (SARS and MERS). As new cases are identified, other exclusive pulmonary manifestations may emerge as potential points for discernment in this patient population. Future research studies will be essential to determine how patients with parenchymal lung disease evolve after the treatment[19]. Vidal et al.[20] reported that bacterial, fungal, and viral coinfections and superinfections in patients hospitalized with COVID-19 are low; however, when present, they can cause serious diseases. Therefore, any unusual finding may lead to further investigation.

A limitation of our study is the lack of data on patients' comorbidities; however, Revsing et al.[11] reported an increased risk of developing severe disease and increased mortality in patients with underlying cardiovascular disease, diabetes mellitus, hypertension, chronic lung disease, cancer (particularly hematological malignancies, lung cancer, and metastatic disease), obesity, and chronic kidney disease. The Centers for Disease Control and Prevention also includes immunocompromised status and liver disease as potential risk factors for serious illnesses, although specific data on the risks associated with these conditions are limited[11,21].

Chest radiography is generally the initial imaging method and the American College of Radiology advises against the use of CT as a first-line tool in the diagnosis of COVID-19, recommending it to be used in moderation and reserved for symptomatic patients hospitalized with specific clinical indications, as an assessment of complications[11]. However, Tao et al.[22] reported that 97% of patients confirmed with COVID-19 with RT-PCR assays had positive results on chest CT, confirming a high sensitivity in detecting the disease.

CONCLUSIONS

This work represents an investigation of the chest CT findings in hospitalized patients with COVID-19. The radiologist plays a crucial role in the fast identification and early diagnosis of new cases, in addition to identifying factors of worse prognosis, which can be a great benefit not only for the patient but also for the broader health surveillance and response systems public[23]. Therefore, the CT evaluation, when well indicated, offers important information, identifying typical findings or suggesting other diagnoses and findings about a worse prognosis, unfavorable evolution, or mortality, such as consolidation or crazy-paving pattern, pneumomediastinum, and moderate/severe pulmonary involvement.

AUTHORS' CONTRIBUTIONS

CC: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **FFF:** Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **LL:** Conceptualization, Data curation, Formal analysis, Writing – review & editing. **RMB:** Conceptualization, Data curation, Formal analysis, Writing – review & editing. **BBZ:** Conceptualization, Data curation, Formal analysis, Writing – review & editing. **YOJ:** Conceptualization, Data curation, Formal analysis, Writing – review & editing. **WHB:** Conceptualization, Data curation, Formal analysis, Writing – review & editing.

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