Clinical and computed tomography features in patients with coronavirus disease 2019

DONGXU WANG[1], YUGUANG WANG[1], QING ZHANG[2], BAIMING JIN[3], QIUTING WEN[4], FENGXIA DU[5], JUN HE[6], TIANYU ZHANG[1], BO LI[1] and GUOXU DING[7]

[1]Department of CT Diagnosis, The Second Affiliated Hospital of Qiqihar Medical College, Qiqihar, Heilongjiang 161006; [2]Department of Infectious Diseases, The First Hospital of Jilin University, Changchun, Jilin 130021; Departments of [3]School of Public Health, [4]Pathology, [5]Microbiology and [6]Anatomy, Qiqihar Medical College; [7]Party Committee Office, The Second Affiliated Hospital of Qiqihar Medical College, Qiqihar, Heilongjiang 161006, P.R. China

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Abstract. Coronavirus disease 2019 (COVID-19) has recently broken out in China. To describe the clinical and computed tomography (CT) characteristics in patients with COVID-19-induced pneumonia, the current study retrospectively analyzed the data of 152 patients with pneumonia between December 30, 2019 and February 29, 2020. Pharyngeal swabs for nucleic acid detection of respiratory secretions were used for all patients. A total of 65 cases were diagnosed as COVID-19, and 87 cases were non-COVID-19. When comparing the clinical and CT characteristics of the two groups of patients, only sex and history of exposure presented a statistically significant difference. The normal/low white blood cell count, low lymphocyte ratio and high C-reactive protein (CRP) exhibited a statistically significant difference between the two groups. A total of 62 patients in the COVID-19 group exhibited ground-glass opacity (GGO), which was higher than that in the non-COVID-19 group. In the COVID-19 group, 33 cases presented angiographic thickening in GGO, and 27 cases displayed a paving stone sign, which were higher than those in the non-COVID-19 group. Compared with the non-COVID-19 group, the lesions in the COVID-19 group were principally characterized by bilateral lungs, multifocal and subpleural distribution. The results of the present study revealed that when the male patients with contact history in the epidemic area exhibited fever and cough symptoms, the laboratory tests indicated normal/low white blood cell counts, low lymphocyte ratios and elevated CRP levels. CT scans were recommended for subsequent examination. GGO or GGO and consolidation with bilateral lungs were indicated to be primarily distributed in the multifocal subpleural area and were accompanied by angiographic thickening in GGO and paving stone sign. In conclusion, regardless of whether the viral nucleic acid test is positive, COVID-19 should be considered for medical treatment observation in isolation.

Correspondence to: Dr Yuguang Wang, Department of CT Diagnosis, The Second Affiliated Hospital of Qiqihar Medical College, 37 West Zhonghua Road, Qiqihar, Heilongjiang 161006, P.R. China
E-mail: 84535929@qq.com

Dr Guoxu Ding, Party Committee Office, The Second Affiliated Hospital of Qiqihar Medical College, 37 West Zhonghua Road, Qiqihar, Heilongjiang 161006, P.R. China
E-mail: 249165024@qq.com

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Introduction

Undiagnosed pneumonia was first reported in Wuhan (Hubei province) in December 2019, followed by outbreaks in several parts of China in the following month, and also in South Korea, Japan, Thailand, America, Australia and other countries. A novel coronavirus has been isolated from the respiratory tract of patients, which has been named severe acute respiratory syndrome (SARS) coronavirus (CoV) 2 (SARS-CoV-2) by the International Virus Classification Committee (1). The disease, which is caused by SARS-CoV-2, was named coronavirus disease 2019 (COVID-19) by the World Health Organization (1,2).

Coronaviruses are single-stranded positive strand RNA viruses, which are divided into four genera: α, β, λ and δ (1,2). Coronaviruses have been indicated to infect numerous animals, including bats, pigs, cattle, mice and monkeys (3,4). A total of six types of coronavirus in infected individuals exist, which belong to the genera α (229E and NL63) and β (OC43, HKU1, Middle East respiratory syndrome-related CoV and SARS-CoV) (2). SARS-CoV-2 is a newly discovered β-coronavirus (4), and it has been speculated that it was transmitted to humans by bats.

At present, Wuhan is the most serious epidemic area in China. COVID-19 is a public health emergency with the fastest speed and the widest scope in Chinese history. Although COVID-19 has been listed in China as a class B infectious disease, a prevention and control scheme for class A infectious diseases has been adopted (4). The clinical and imaging features of COVID-19 have been rarely reported, to the best of our knowledge. In the current study, the clinical and imaging characteristics of COVID-19 were summarized via comparing and analyzing the clinical, laboratory and imaging data of patients with COVID-19 and non-COVID-19, which may aid in the improvement of the understanding and diagnosis of the disease, and in limiting the spread of COVID-19.

Materials and methods

Patients. The study protocol was approved by the Regional Ethics Committee for Clinical Research of the Second Affiliated Hospital of Qiqihar Medical College (Qiqihar, China). Written informed consent was obtained from all patients. For patients that were minors, informed consent was obtained from their parents or guardians.

A retrospective study was conducted in 152 patients with pneumonia diagnosed in the Second Affiliated Hospital of Qiqihar Medical College and the First Hospital of Jilin University from December 30, 2019 to February 29, 2020. Inclusion criteria: Clinical symptoms such as cough, sputum, fever and chest tightness; physical examination with or without lung rales, or tubular breathing; and a CT diagnosis showing pneumonia. Pharyngeal swabs for nucleic acid detection of respiratory secretions were used for all patients. All patients have complete clinical records. Malignant tumor, secondary infection of bronchiectasis and pulmonary fibrosis pneumonia were excluded. The clinical characteristics of the patients are presented in Table I.

Nucleic acid detection. Throat swabs were collected from all of the patients. The swab head was broken and immersed in an Eppendorf (EP) tube containing 2 ml of isotonic salt solution. The cap of the tube was closed and sent to the hospital laboratory within 15 min to 2 h. Total RNA was extracted using nucleic acid extraction or purification kits (Zhongshan Daan gene company; cat. no. DA0623). The procedures were as follows: 200 μl liquid from the EP tube was taken and put into the nucleic acid extraction plate hole, which was pre-loaded with 20 μl protease K. According to the magnetic bead extraction method (5), total RNA was extracted using the Tianlong nucleic acid automatic extraction instrument (Shaanxi Xi'an Tianlong Technology Co., Ltd.; nucleic acid extractor NP968). A total of 5 μl of extracted RNA was added into the PCR reaction tubules which were pre-loaded with 19 μl fluorescent PCR probe (designed for the conservative ORF1a/b: Forward primer: CCCTGTGGGTTTTACACT TAA, reverse primer: ACGATTGTGCATCAGCTGA, fluorescent probe: 5'-FAM-CCGTCTGCGGTATGTGGAAAG GTTATGG-BHQ1-3' and N genes: Forward primer: GGG GAACTTCTCCTGCTAGAAT, reverse primer: CAGACA TTTTGCTCTCAAGCTG, fluorescent probe: 5'-FAM-TTG CTGCTGCTTGACAGATT-TAMRA-3') and 1 μl RT-PCR enzyme mixed amplification reagent (Sun Yat-sen University Daan Gene Co., Ltd.). An ABI 7500 real time PCR system (Applied Biosystems; Thermo Fisher Scientific, Inc.) was used to carry out the amplification procedure, the details were as follows: 50˚C for 15 min, 95˚C for 15 min, followed by 45 cycles of 94˚C for 15 sec and 55˚C for 45 sec.

Chest computed tomography (CT). The patients underwent a 64-slice CT scan. The patients were placed on the supine position on a CT scan bed, and ceased breathing temporarily for the chest scan to take place. The CT parameters were as follows: The tube voltage was 120 kV, the tube current was 100-150 mA, the thickness of the layer was 1 mm and the distance of the layer was 1 mm. Two experienced radiologists retrospectively evaluated the CT images of the patients, according to the following factors: Ground-glass opacity (GGO), resolution, angiographic thickening, paving stone sign, air bronchi sign, halo sign and CT distribution. GGO was defined as mildly increased opacification that did not obscure the underlying vasculature. Angiographic thickening refers to the thickened blood vessels visible in GGO. Paving stone sign refers to the widening of the leaflet interval visible in GGO.

Clinical examination and data collection. Within 24 h of admission, blood samples were collected at the Second Affiliated Hospital of Qiqihar Medical College and sent to the affiliated laboratory. The blood samples were tested for white blood cell count (normal range, 3.50-9.5x10^9/l), neutrophil ratio (normal range, 0.3-0.7), lymphocyte ratio (normal range, 0.2-0.5), monocyte ratio (normal range, 0.03-0.1), eosinophil ratio (normal range, 0.004-0.08), C-reactive protein (normal range, 0-5 mg/l) and procalcitonin (normal range, 0-0.5 μg/l). The patients' clinical manifestations and laboratory results were analyzed retrospectively.

Statistical analysis. Statistical analyses were performed using SPSS v18.0 software (SPSS, Inc.). The data are presented as the mean ± standard deviation for continuous variables. Data on categorical variables (laboratory inspection and CT findings) are presented as n-values and percentages. According to the nucleic acid detection results, the patients were divided into COVID-19 and non-COVID-19 groups. Data were compared using Student's unpaired t-tests for continuous variables and χ^2 or Fisher's exact test for categorical variables. The relevant receiver operating characteristic (ROC) curves were plotted, and the AUC was calculated. P<0.05 was considered to indicate statistically significant difference.

Results

Clinical manifestations. The current study included 152 patients, of which 65 cases with a positive reverse transcription-quantitative PCR (RT-qPCR) test were diagnosed as COVID-19, and 87 cases with a negative RT-qPCR test were non-COVID-19 (Table I). Except for gender (P=0.036) and contact history (P<0.001), there was no significant difference in the clinical characteristics of asymptomatic (P=0.739), cough (P=0.438), fever (P=0.897) and sore throat (P=0.243) between the two groups. The difference between age (P=0.357) and underlying disease (P=0.608) in patients with diabetes was not statistically significant. In the COVID-19 group, 70.77% (46/65) patients were male, and 98.46% (64/65) patients had lived, traveled or contacted infected people in the affected area, which were higher than those in the non-COVID-19 group (Table I).

Results of laboratory examination. The normal/low white blood cell count (P<0.001), low lymphocyte ratio (P=0.002)

Table I. Comparison of clinical information between patients with COVID-19 and non-COVID-19.

Clinical information	Patients with COVID-19 (n=65)	Patients with non-COVID-19 (n=87)	t/χ^2 value	P-value
Sex				
Male	46 (70.77)	47 (54.02)	4.393[a]	0.036
Female	19 (29.23)	40 (45.98)		
Age, years	43.646±14.387	46.046±16.840	0.924[b]	0.357
Symptoms				
None	3 (4.62)	2 (2.30)	0.111[a]	0.739
Cough	28 (43.08)	43 (49.43)	0.602[a]	0.438
Fever	61 (93.85)	80 (91.95)	0.017[a]	0.897
Sore throat	1 (1.54)	6 (6.90)	1.365[a]	0.243
Contact history	64 (98.46)	9 (10.34)	115.729[a]	<0.001
Underlying disease	3 (4.62)	7 (8.05)	0.624[a]	0.608

Data are expressed as n (%). [a]χ^2 values, [b]t values. COVID-19, coronavirus disease 2019.

and high CRP (P=0.036) exhibited a statistically significant difference between the two groups. 87.69% (57/65) patients in the COVID-19 group presented normal/low white blood cell count, 67.69% (44/65) patients exhibited low lymphocyte ratio, and 53.85% (35/65) patients displayed high CRP. In the non-COVID-19 group, 35.63% (31/87) patients had normal/low white blood cell counts, 42.53% (37/87) patients had low lymphocyte ratio and 36.78% (32/87) patients had high CRP. In the COVID-19 group, 33.85% (22/65) patients had high neutrophilic ratios, 41.54% (27/65) patients had high monocyte ratios, 58.46% (38/65) patients had low eosinophilic ratios and 50.77% (33/65) patients had high procalcitonin levels. In the non-COVID-19 group, 42.53% (37/87) patients had high neutrophilic ratios, 47.13% (41/87) patients had high monocyte ratios, 50.57% (44/87) patients had low eosinophilic ratios and 54.02% (47/87) patients had high procalcitonin levels. There was no statistically significant difference between the two groups of patients in the high neutrophil ratios (P=0.277), high monocyte ratios (P=0.493), low eosinophil ratio (P=0.334) and high procalcitonin (P=0.691) (Table II).

Results of chest CT. The comparisons of the CT findings between patients with COVID-19 and non-COVID-19 are presented in Table III. In the COVID-19 group, 95.38% (62/65) patients showed GGO (Fig. 1) or GGO and consolidation, and 4.62% (3/65) patients showed consolidation. In the non-COVID-19 group, GGO or consolidation was found in 19.54% (17/87) patients and 80.46% (70/87) patients. GGO was the most common imaging feature in the COVID-19 group compared with non-COVID-19 group (P<0.001). In the COVID-19 group, 50.77% (33/65) patients had angiographic thickening in GGO (Fig. 2), 41.54% (27/65) patients had paving stone sign (Fig. 3), 35.38% (23/65) patients had air bronchi sign, 21.54% (14/65) patients had fibrotic session formation, 16.92% (11/65) patients had halo sign and 3.08% (2/65) patients had plural fusion. In the non-COVID-19 group, 12.64% (11/87) patients had angiographic thickening in GGO, 10.34% (9/87) patients had paving stone sign, 48.28% (42/87) patients had air bronchi sign, 32.18% (28/87) patients had fibrotic session formation, 26.44% (23/87) patients had halo sign and 8.05% (7/87) patients had plural fusion. The frequency of angiographic thickening in GGO (<0.001) and paving stone sign (<0.001) in the COVID-19 group was significantly higher than that in the non-COVID-19 group. There was no significant difference in the frequency of air bronchi sign (P=0.112), fibrotic reduction formation (P=0.146), halo sign (P=0.164) and plural fusion (P=0.349) between the two groups. In the COVID-19 group, 83.08% (54/65) patients presented with bilateral lung distribution, 80.00% (52/65) patients had multifocal distribution and 84.62% (55/65) patients had subpleural distribution. In the non-COVID-19 group, 56.32% (49/87) patients had bilateral lung distribution, 64.37% (56/87) patients had multifocal distribution, and 62.07% (54/87) patients had subpleural distribution (Fig. 4). Compared with the non-COVID-19 group, the lesions in the COVID-19 group were primarily characterized by bilateral lungs (P<0.001), multifocal (P=0.036) and subpleural distribution (P=0.002).

ROC curves of the CT characteristics. The ROCs of certain characteristics for the diagnosis of COVID-19 were plotted and the AUC was determined. GGO or GGO and consolidation presented an AUC of 0.879 and P<0.001 (Fig. 5A). Angiographic thickening in GGO for the diagnosis of COVID-19 exhibited an AUC of 0.691 and P<0.001 (Fig. 5B). Paving stone sign for COVID-19 diagnosis was plotted, with an AUC of 0.656 and P=0.001 (Fig. 5C). Bilateral lungs presented an AUC of 0.634 and P=0.005 (Fig. 5D). Finally, the ROC of subpleural distribution was plotted, with an AUC of 0.613 and P=0.018 (Fig. 5E).

Discussion

Currently, COVID-19 is expanding in China, which poses a threat to human health. The genetic similarity between SARS-CoV-2 and SARS-CoV reaches ~83% (5). The quick and accurate diagnosis of COVID-19 represents a key method of saving lives and controlling the epidemic. It has been indicated that the diagnosis of COVID-19 via nucleic acid

Table II. Comparison of laboratory inspection between patients with COVID-19 and non-COVID-19.

Laboratory inspection	Patients with COVID-19 (n=65)	Patients with non-COVID-19 (n=87)	χ^2-value	P-value
Normal/low white blood cell count	57 (87.69)	31 (35.63)	41.364	<0.001
High neutrophil ratio	22 (33.85)	37 (42.53)	1.181	0.277
Low lymphocyte ratio	44 (67.69)	37 (42.53)	9.464	0.002
High monocyte ratio	27 (41.54)	41 (47.13)	0.470	0.493
Low eosinophil ratio	38 (58.46)	44 (50.57)	0.931	0.334
High C-reactive protein	35 (53.85)	32 (36.78)	4.395	0.036
High procalcitonin	33 (50.77)	47 (54.02)	0.158	0.691

Data are expressed as n (%). COVID-19, coronavirus disease 2019.

Table III. Comparison of CT findings between patients with COVID-19 and non-COVID-19.

CT findings	Patients with COVID-19 (n=65)	Patients with non-COVID-19 (n=87)	χ^2-value	P-value
GGO or GGO and consolidation	62 (95.38)	17 (19.54)	85.738	<0.001
Consolidation	3 (4.62)	70 (80.46)		
Angiographic thickening in GGO	33 (50.77)	11 (12.64)	26.293	<0.001
Paving stone sign	27 (41.54)	9 (10.34)	20.028	<0.001
Air bronchi sign	23 (35.38)	42 (48.28)	2.526	0.112
Fibrotic lesion formation	14 (21.54)	28 (32.18)	2.108	0.146
Halo sign	11 (16.92)	23 (26.44)	1.939	0.164
Pleural effusion	2 (3.08)	7 (8.05)	0.878	0.349
CT distribution				
Unilateral	11 (16.92)	38 (43.68)	12.191	<0.001
Bilateral	54 (83.08)	49 (56.32)		
Multifocal	52 (80.00)	56 (64.37)	4.420	0.036
Subpleural	55 (84.62)	54 (62.07)	9.323	0.002

Data are expressed as n (%). COVID-19, coronavirus disease 2019; GGO, ground-glass opacity.

detection exhibited strong specificity but poor sensitivity (6). It has been hypothesized that clinical symptoms, laboratory tests and CT images may serve an important role in preclinical screening.

Epidemiological investigations have indicated that the incubation period of COVID-19 was 1-14 days (7). A total of 98.46% of the patients in the current study presented with a history of exposure to the virus, which was the principal element to the diagnosis of COVID-19. Droplet transmission is the main means of disease transmission (8), however, SARS-CoV-2 may also spread in the form of aerosols, resulting in a strong propagation speed (9), which may cause an outbreak of COVID-19. In the present study, no difference in the underlying disease between the two groups existed, which indicated that immunity was not associated with COVID-19. In the COVID-19 group, 70.77% of patients were male. Yan and Xia (10) revealed that 38/51 (74.51%) patients with COVID-19 were male, SARS-CoV-2 has been indicated to infect more males than females. SARS-CoV-2 has been indicated to infect type II alveolar epithelial cells, which may express angiotensin-converting enzyme 2 (ACE2) (6,7). A recent study revealed that male type II alveolar epithelial cells exhibited a 2.5x higher percentage of endocrine ACE2 expression compared with the same cells in females (11). It was hypothesized that this may account for the increased cases of virus infection in males compared with females. SARS-CoV-2 exhibits a viral envelope on its surface, with a round or oval shape and a diameter of 60-140 nm (4). As the virus infects type II alveolar epithelial cells and induces respiratory problems, the most frequently observed clinical symptoms were fever and cough, which was consistent with the patients' CT manifestations.

In the current study, the total number of peripheral blood leukocytes in patients with COVID-19 was indicated to be at a normal/low level, the lymphocyte ratio was decreased, and CRP was increased in certain patients, which was consistent with the results of previous studies (12). This has also been observed in cases of SARS-CoV infection (6). A recent study reported that SARS-CoV-2 primarily infects lymphocytes (5). A decreased number of lymphocytes may result in decreased immunity in patients with COVID-19. Certain patients exhibit multiple organ failure (13). In the current study, steroids were used to prevent

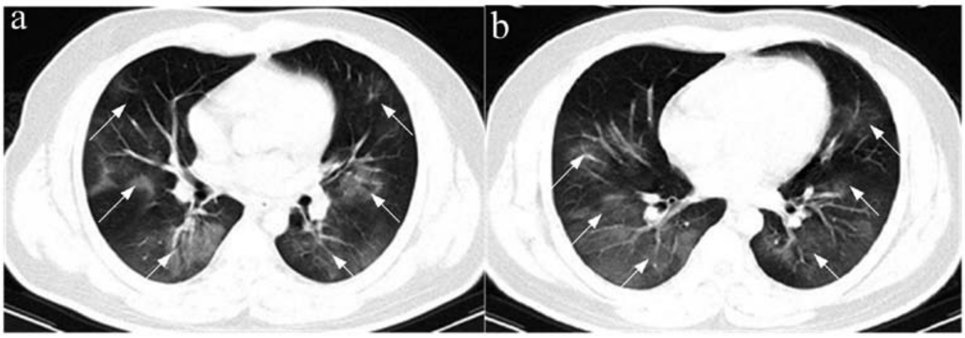

Figure 1. GGO. Representative images from a male, 32-year-old patient with coronavirus disease 2019, who presented with a fever and cough. CT plain scans were performed in the horizontal position. (a) Representative of all the patients CT features, which exhibited GGO distribution in bilateral upper lungs (arrow). (b) Representative of all the patients CT features, which exhibited GGO distribution in bilateral inferior lungs (arrow). GGO, ground-glass opacity.

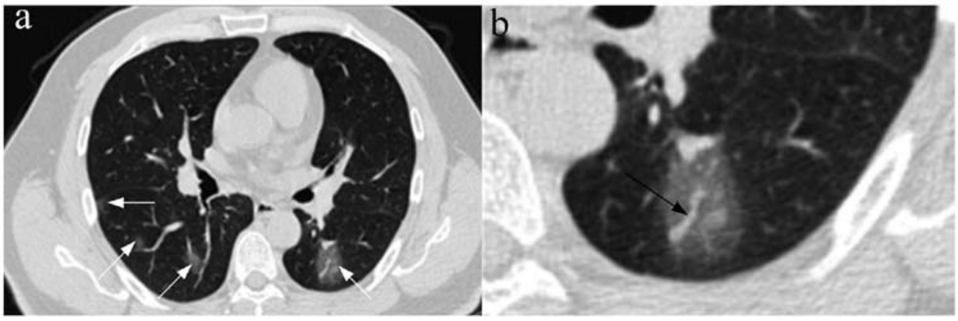

Figure 2. Angiographic thickening in GGO. Representative images from a male, 49-year-old patient with coronavirus disease 2019 who presented with a fever and cough. (a) CT plain scans were performed in the horizontal position. Representative of all the patients CT features demonstrated GGO distribution in the bilateral lungs (white arrow). (b) Magnification of image (a). Representative of all the patients CT features. Angiographic thickening was observed in GGO, indicated by the black arrow. GGO, ground-glass opacity.

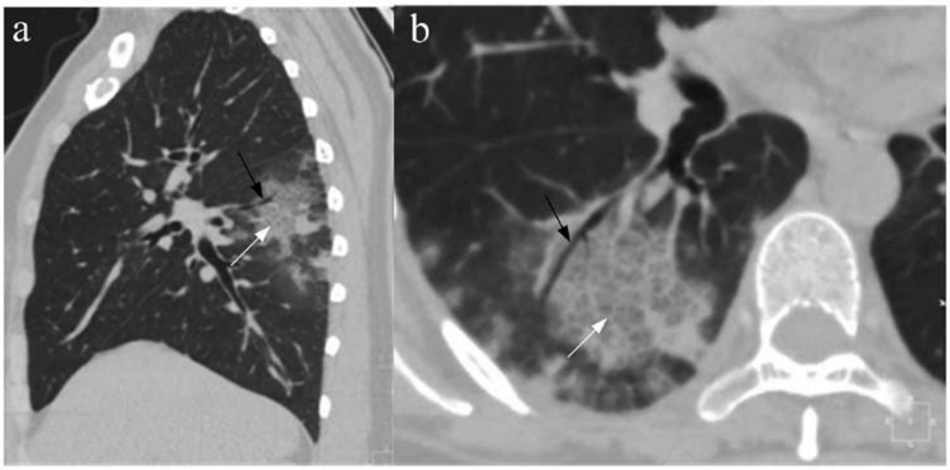

Figure 3. Paving stone sign and air bronchi sign. Representative images from a female, 39-year-old patient with coronavirus disease 2019. (a) CT plain scans were performed in the sagittal position. Representative of all the patients CT features exhibited multiple ground-glass opacity in bilateral lungs, paving stone sign (white arrow) and air bronchi sign (black arrow). (b) Magnification of image (a) in the horizontal position. Representative of all the patients CT features exhibited paving stone sign (white arrow) and air bronchi sign (black arrow).

possible infection during treatment. SARS-CoV-2 nucleic acid can be detected in nasopharyngeal swabs, sputum, low respiratory secretions and blood, among other samples; however, certain patients require repeated tests before diagnosis, which may delay the diagnosis of COVID-19 (14).

COVID-19 has a variety of manifestations in CT scans. Cheng *et al* (15) revealed that 81.81% (9/11) patients with COVID-19 exhibited a double lung infection. Chung *et al* (16) reported that 80.95% (17/21) patients exhibited a GGO that was distributed in the subpleural region. At present, a small number of studies has performed comparative analysis on imaging features, especially ROC curve plots, to the best of our knowledge (17). Comparative studies may more accurately summarize the image characteristics of COVID-19. Patrick *et al* (18) reported

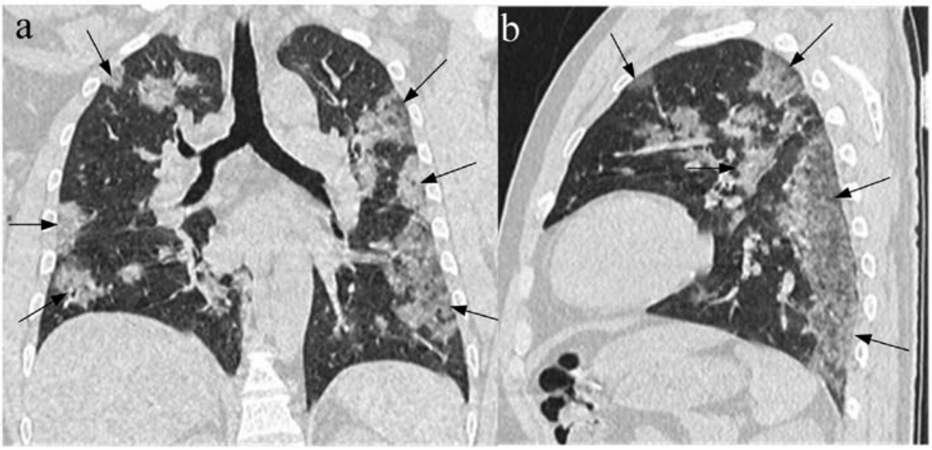

Figure 4. CT distribution. Representative images from a male, 45-year-old patient with coronavirus disease 2019, who presented with fever and a cough. (a) CT plain scan in the coronal position. Representative of all the patients CT features exhibited multifocal, subpleural distribution (black arrow) of ground-glass opacity in bilateral lungs. (b) CT plain scan in the sagittal position. Representative of all the patients CT features exhibited a multifocal, subpleural distribution (black arrow) of ground-glass opacity.

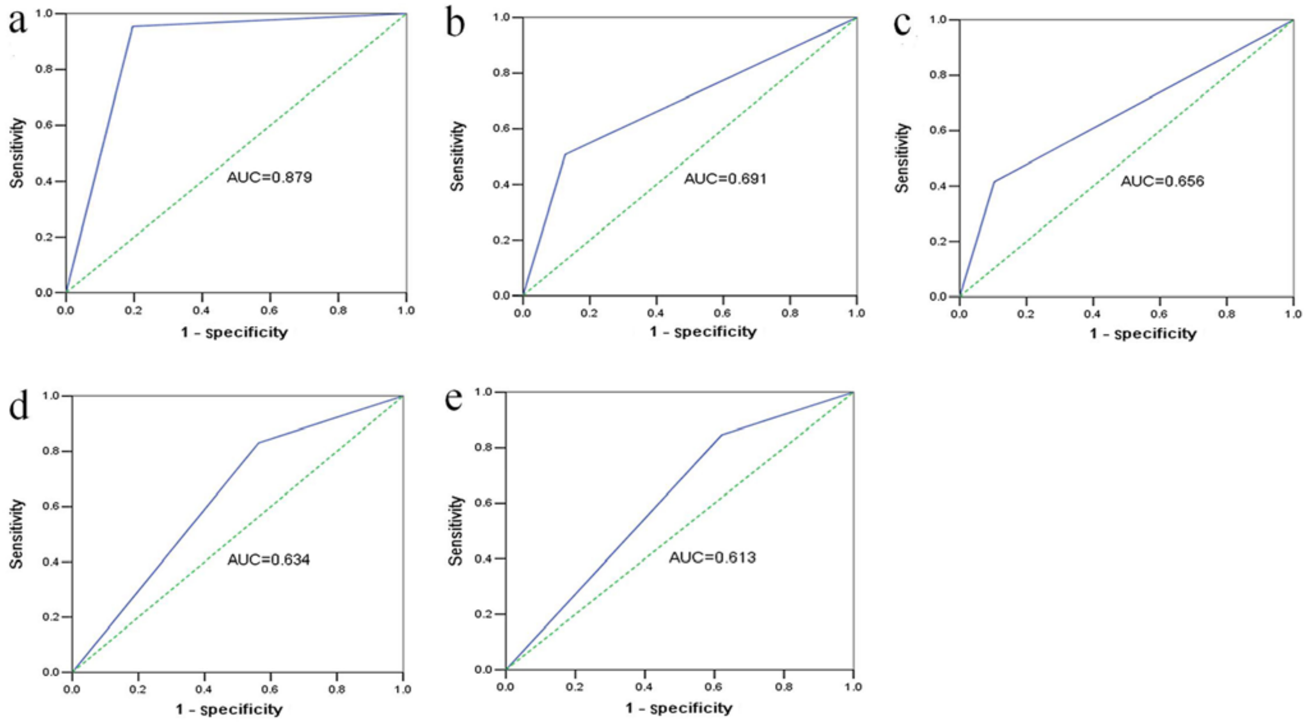

Figure 5. Receiver operating characteristic curves and calculated AUC of computed tomography features for patients that were diagnosed with coronavirus disease 2019. AUC, area under the curve. (a) GGO or GGO and consolidation presented an AUC of 0.879. (b) Angiographic thickening in GGO exhibited an AUC of 0.691. (c) Paving stone sign exhibited an AUC of 0.656. (d) Bilateral lungs presented an AUC of 0.634. (e) Subpleural distribution exhibited with an AUC of 0.613. AUC, area under the curve; GGO, ground-glass opacity.

that 81.31% of patients with SARS-CoV pneumonia exhibited multiple inflammatory foci in the subpleural region of the lungs. Following the evaluation of recent and previous studies, it can be suggested that the distribution of COVID-19-induced inflammation is consistent with that in other viral pneumonias (14). The imaging findings of different viral pneumonias are similar (19). In patients with herpesvirus pneumonia, 31% of CT images revealed a paving stone sign (17). In the current study, angiographic thickening and paving stone sign were the principal CT features of COVID-19. However, the pathological basis of COVID-19 has not been reported, to the best of our knowledge. A recent study demonstrated that viral pneumonia, which was induced by SARS-CoV-2 infection of type II alveolar epithelial cells, induced hemorrhagic alveolar inflammation and necrosis, which resulted in diffuse alveolar injury (6). Alveolar injury may result in alveolar edema, bleeding and collapse of the alveolar cavity, which were indicated in the CT images as GGO. The pathological basis of angiographic thickening in GGO is unclear. In a previous study, it was also suggested that paving stone markers are common features of viral pneumonia (20). It has been hypothesized that SARS-CoV-2 infection may cause inflammation of the intralobular interstitial lymph network, resulting in thickening of the intralobular interstitial space as a fine grid-like shadow, which resembles a 'paving stone sign' (21). In the present study, the occurrence probability of air bronchi signs was similar in both groups, which was consistent with the findings of previous studies (22). At present, air bronchi signs cannot be used to identify bacterial pneumonia or viral pneumonia (17). A recent study reported that halo sign appeared in viral infection (23). In the present study, halo sign was also observed in patients with COVID-19; however, this was not observed in all patients. Moreover, in the current study, the CT images of some lesions with COVID-19 showed a clear strip shadow on the edge of the lesion, forming a fibrotic lesion. Whether the fibrotic lesion remains following patient recovery, requires additional investigation. Based on the ROC curve analysis of GGO or GGO and consolidation, angiographic thickening in GGO, paving stone sign, bilateral and subpleural distribution of the patients that were diagnosed with COVID-19, it was suggested that these CT features may be useful for the diagnosis of COVID-19. Among them, GGO or GGO and consolidation exhibited the highest clinical diagnostic value.

In conclusion, CT was indicated to represent not only a diagnostic tool for COVID-19, but also an evaluation tool for the treatment process. Although not all patients with COVID-19 exhibited typical CT features, the majority of CT scans presented similar features. CT is a quicker method than viral nucleic acid detection, which may generate false negative results and often requires repetition. The results of the present study indicated that the patients with COVID-19 exhibited specific clinical symptoms, laboratory examination results and CT characteristics. The male patients with contact history in the epidemic area were indicated to exhibit fever and cough symptoms. The results of the current study suggested that when the laboratory tests of the aforementioned patients present normal/low white blood cell counts, low lymphocyte ratios and increased CRP, a CT scan should be recommended. Moreover, when the CT scan indicates a multifocal GGO with subpleural and bilateral distribution in the lungs, which is accompanied by angiographic thickening in GGO and paving stone sign, whether the virus nucleic acid test is positive or negative, COVID-19 should be considered and medical isolation and observation should be performed.

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Availability of data and materials

The datasets used and analyzed during the present study are available from the corresponding author on reasonable request.

Authors' contributions

DW participated in the project design and research, performed the statistical analysis, and was responsible for drafting and revision of the manuscript. YW and GD participated in the project design and coordination, assisted in writing the manuscript and helped with the statistical analysis. JH was responsible for sample collection. QW and FD performed the virological analysis and helped with the drafting of the manuscript. BJ, QZ, TZ and BL performed the CT analysis and sample collection and participated in performing the statistical analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study protocol was approved by the Regional Ethics Committee for Clinical Research of the Second Affiliated Hospital of Qiqihar Medical College (approval no. QMC-2020013). All patients provided written informed consent.

Patient consent for publication

Written informed consent was obtained from all patients or their legal guardians for the use of their CT images and personal data in the current study.

Competing interests

The authors declare that they have no competing interests.

References

1. Carlos WG, Dela Cruz CS, Cao B, Pasnick S and Jamil S: Novel Wuhan (2019-nCoV) coronavirus. Am J Respir Crit Care Med 201: P7-P8, 2020.
2. World Health Organization: Middle East Respiratory Syndrome Coronavirus (MERS-CoV). November, 2019. http://www.who.int/emergencies/mers-cov/en/. Accessed January 19, 2020.
3. World Health Organization: Novel Coronavirus-China. http://www.who.int/csr/don/12-january-2020-novel-coronavirus-china/en/. Accessed January 19, 2020.
4. Chai X, Hu L, Zhang Y, Han W, Lu Z, Ke A, Zhou J, Shi G, Fang N, Fan J, *et al*: Specific ACE2 expression in cholangiocytes May cause liver damage after 2019-nCoV infection. BioRxiv: Feb 4, 2020. doi: org/10.1101/2020.02.03.931766.
5. Yu F, Du L, Ojcius DM, Pan C and Jiang S: Measures for diagnosing and treating infections by a novel coronavirus responsible for a pneumonia outbreak originating in Wuhan, China. Microbes Infect 22: 74-79, 2020.
6. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X, *et al*: Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 395: 497-506, 2020.
7. People's Daily Online. Wuhan is expected to send 15 million passengers during Spring Festival in 2020 (In Chinese). December 28, 2019. http://hb.people.com.cn/n2/2019/1228/c194063-33671662.html. Accessed January 2, 2020.
8. The 2019-nCoV Outbreak Joint Field Epidemiology Investigation Team and Li Q: An outbreak of NCIP (2019-nCoV) infection in China-Wuhan, Hubei Province, 2019-2020. China CDC Weekly 2: 79-80, 2020.
9. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, Ren R, Leung KS, Lau EH, Wong JY, *et al*: Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 382: 1199-1207, 2020
10. Yan L and Xia L: Coronavirus disease 2019 (COVID-19): Role of chest CT in diagnosis and management. AJR Am J Roentgenol 214: 1280-1286, 2020.
11. Lei J, Li J, Li X and Qi X: CT imaging of the 2019 novel coronavirus (2019-nCoV) pneumonia. Radiology 295: 18, 2020.
12. Read JM, Bridgen JR, Cummings DA, Ho A and Jewell CP: Novel coronavirus 2019-nCoV: Early estimation of epidemiological parameters and epidemic predictions. medRxiv: Jan 28, 2020 (Epub ahead of print). doi: 10.1101/2020.01.23.20018549.

13. Liu T, Hu J, Kang M, Lin L, Zhong H, Xiao J, He G, Song T, Huang Q, Rong Z, *et al*: Transmission dynamics of 2019 novel coronavirus (2019-nCoV). bioRxiv: Jan 26, 2020 doi: https://doi.org/10.1101/2020.01.25.919787.
14. Kanne JP: Chest CT findings in 2019 novel coronavirus (2019-nCoV) infections from Wuhan, China: Key Points for the Radiologist. Radiology 295: 16-17, 2020.
15. Cheng Z, Lu Y, Cao Q, Qin L, Pan Z, Yan F and Yang W: Clinical features and Chest CT manifestations of coronavirus disease 2019 (COVID-19) in a single-center study in Shanghai, China. AJR Am J Roentgenol 215: 121-126, 2020.
16. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, Cui J, Xu W, Yang Y, Fayad ZA, *et al*: CT imaging features of 2019 novel coronavirus (2019-nCoV). Radiology 295: 202-207, 2020.
17. Shi H, Han X, Jiang N, Cao Y, Alwalid O, Gu J, Fan Y and Zheng C: Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study. Lancet Infect Dis 20: 425-434, 2020.
18. Patrick DM, Petric M, Skowronski DM, Guasparini R, Booth TF, Krajden M, McGeer P, Bastien N, Gustafson L, Dubord J, *et al*: An outbreak of human coronavirus OC43 infection and serological cross-reactivity with SARS coronavirus. Can J Infect Dis Med Microbiol 17: 330-336, 2006.
19. Zhao S, Ran J, Musa SS, Yang G, Wang W, Lou Y, Gao D, Yang L, He D and Wang MH: Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: A data-driven analysis in the early phase of the outbreak. Int J Infect Dis 92: 214-217, 2020.
20. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, Wang B, Xiang H, Cheng Z, Xiong Y, *et al*: Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 323: 1061-1069, 2020.
21. Pan Y, Guan H, Zhou S, Wang Y, Li Q, Zhu T, Hu Q and Xia L: Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): A study of 63 patients in Wuhan, China. Eur Radiol 30: 3306-3309, 2020.
22. Xu H, Zhong L, Deng J, Peng J, Dan H, Zeng X, Li T and Chen Q: High expression of ACE2 receptor of 2019-nCoV on the epithelial cells of oral mucosa. Int J Oral Sci 12: 8, 2020.
23. Wang D, Wu C, Gao J, Zhao S, Ma X, Wei B, Feng L, Wang Y and Xue X: Comparative study of primary pulmonary cryptococcosis with multiple nodules or masses by CT and pathology. Exp Ther Med 16: 4437-4444, 2018.