Clinical and Transmission Characteristics of COVID-19—A Retrospective Study of 25 Cases from a Single Thoracic Surgery Department

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Summary: The outbreak of corona virus disease 2019 (COVID-19) imposes a major challenge in managing patients undergoing surgical operation. In this study, we analyzed clinical and transmission features of 25 cases of COVID-19 from a single thoracic department, including 13 patients and 12 health care staff. There were 13 males and 12 females. The median age of the patients was 61 (range: 51 to 69) years. The median age of the health care staff was 35 (range: 22 to 51) years. By the end of follow-up date (Mar. 3, 2020), there were 16 non-severe cases (64%) and 9 severe cases (36%), 5 cases were dead (20%). Nineteen (76%) of the infected cases were confirmed by SARS-CoV-2 nucleic acid test, the rest were clinically diagnosed as suspected COVID-19 cases, and 19 (76%) of the infected cases had positive exposure history. We found that COPD was significantly associated with severity and death ($P=0.040$, and $P=0.038$, respectively), and chest operation was significantly associated with death for COVID-19 patients ($P=0.039$). A potential “super spreader” may be the source of the transmission before the implementation of quarantine and comprehensive protection. It was concluded that COVID-19 is associated with poor prognosis for patients undergoing thoracic operation, especially for those with COPD. Implementation of comprehensive protective measures is important to control nosocomial infection.

Key words: corona virus disease 2019; SARS-CoV-2; nosocomial infection

Since corona virus disease 2019 (COVID-19) emerged in Wuhan in December 2019, SARS-CoV-2 has infected more than 80 000 people with a large number of deaths across 60 countries worldwide. People of all ages are susceptible to SARS-CoV-2 infection. Confirmed transmission routes include airborne and close contact. Fecal-oral route and aerosol transmission could not be excluded^[1]. Hospital outbreaks of SARS-CoV-2 infection occurred in the early phase of epidemic when the disease was not recognized and before quarantine measures were implemented. Patients admitted in thoracic surgery department undergoing operation, are commonly presented with pulmonary infections before or after thoracic operations. In the early phase of epidemic, the differential diagnosis between COVID-19 and infections caused by other pathogens is not well recognized. Thus, it is even more difficult to identify SARS-CoV2 infected patients and to take appropriate protective measures to prevent nosocomial infection. In this study, we retrospectively analyzed the clinical characteristics and transmission history of 25 cases of

COVID-19 in our department. We explore the impact of SARS-CoV-2 infection on the prognosis of patients undergoing thoracic operation and transmission routes of coronavirus in thoracic surgery ward.

1 MATERIALS AND METHODS

1.1 Study Subjects

205 patients admitted to the Department of Thoracic Surgery of Tongji Hospital affiliated to Tongji Medical College of Huazhong University of Science and Technology, between January 1, 2020 and February 20, 2020 (no new patients were admitted after February 20, 2020) and 148 health care staff of thoracic surgery department were collected and retrospectively analyzed. Epidemiological investigation, laboratory results, CT imaging and SARS-CoV-2 nucleic acid test results were collected, and a total of 25 cases (including 13 hospitalized patients and 12 health care staff) were included in the COVID-19 study. This study was approved by the Medical Ethics Committee of Tongji Hospital affiliated to Tongji Medical College of Huazhong University of Science and Technology (TJ-IRB20200307).

1.2 Data Collection

Clinical medical records and telephone

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questionnaire were used to approach the clinical characteristics for all COVID-19 cases. Temperature and CT imaging changes of all cases were analyzed, and SARS-CoV-2 nucleic acid tests for suspected infected cases were further performed. All infected health care staff had filled in questionnaires with time of exposure to COVID-19 cases, personal protective measures, and clinical symptoms. All COVID-19 cases were followed up until Mar. 3, 2020, and the statistical clinical characteristics included: gender, age, basic diseases, smoking history, epidemic history, surgery history, surgical methods, postoperative fever, laboratory examination results during treatment, SARS-CoV-2 nucleic acid test results, CT imaging, and the status at the last follow-up date. According to the evidence of infection, exposure history and pathway of moving beds in the wards, the most likely time and route of infection were evaluated and speculated.

1.3 Clinical Classification of COVID-19

According to the “Diagnosis and treatment guideline of COVID-19 (version 7.0)” from the National Health Commission of the People’s Republic of China^[1], there were four stages for COVID-19 as follows: (1) Mild stage: the clinical symptoms were mild, and no signs of pneumonia were found on imaging; (2) Common stage: fever, respiratory tract and other symptoms, imaging findings of pneumonia; (3) Severe stage, 1 of the following criteria existed: (a) shortness of breath, respiratory rate ≥ 30 times/min; (b) in resting state, oxygen saturation is less than 93%; (c) $\text{PaO}_2/\text{FiO}_2 \leq 300$ mmHg. CT imaging showed significant lesion progression $>50\%$ within 24 to 48 h; (4) Critical stage, one of the following occurred: (a) Respiratory failure requiring mechanical ventilation; (b) Shock; (c) Complicated with other organ failure requiring ICU care.

1.4 Statistical Analysis

Data analysis was performed using SAS 9.2 software. Quantitative data were expressed as mean $\pm$ SD, and independent Student’s *t* test was used for inter-group comparison. The qualitative data were expressed as the number of cases (percentage), and the comparison between groups was conducted by Fisher’s exact test. The difference between the comparison groups was considered statistically significant if $P < 0.05$.

2 RESULTS

2.1 Clinical Characteristics

Total 25 cases of COVID-19 were enrolled in the study. Among them, 19 cases (76%) were confirmed COVID-19 by positive SARS-CoV-2 nucleic acid test, and 6 cases (24%) were considered as suspected COVID-19 as diagnosed by clinical manifestations, exposure history and CT examination. Thirteen (52%)

were hospitalized patients and 12 (48%) were health care staff. The clinical characteristics of patients and staff were shown in table 1. Several clinical features, including gender, age, smoking history and COPD, showed significant difference between patients and health care staff. The laboratory tests from patients and health care staff were shown in table 1. There were significant differences in white blood cell (WBC) count $> 9.5 \times 10^9/\text{L}$, LDH level, D-D dimer level, transaminase level and electrolyte disorder condition between those two groups ($P=0.001$, $P=0.005$, $P=0.015$, $P=0.005$ and $P=0.005$, respectively).

2.2 Chest CT Examination

All the cases received chest CT exams to evaluate the severity. Imaging findings of COVID-19 patients are shown in fig. 1. Mild case presented single or multiple ground glass opacity (GGO) mainly in the dorsal or periphery part of the lung. Most common cases showed local or bilateral patchy shadowing, with or without interstitial abnormalities. In severe cases, CT imaging showed rapidly increased size and density of lesions, and diffused damage covered both lungs, with air bronchogram and interstitial abnormalities. “White lung” could be seen in severe or critical cases, which predicted very poor prognosis.

2.3 Prognosis Analysis for COVID-19 Cases

All confirmed SARS-CoV-2 infected cases were under quarantine and received treatment. By the end of the follow-up date (Mar. 3, 2020), there were 9 cases (36%) of severe type, and 5 deaths (20%). All the dead cases were from hospitalized postoperative patient group. There was significant difference in vital status between postoperative patients and health care staff ($P=0.039$), and age and COPD were significantly associated with disease severity ($P=0.041$ and $P=0.040$, respectively) and death ($P=0.015$ and $P=0.038$, respectively) for COVID-19 patients.

2.4 Potential “Super Spreaders”

Among all COVID-19 cases, 19 (76%) cases had traceable positive exposure history, including 8 patients with a spatiotemporal correlation of close contact (adjacent bed) and 11 health care staff. The average days of exposure to the onset of fever (temperature $> 37.3^\circ\text{C}$) was 5.9 ± 4.7 days for patient group and 3.9 ± 1.9 days for health care staff group, and no significant difference was found between them ($P=0.220$). Nineteen of those infected cases had positive results for SARS-CoV-2 nucleic acid test. Four out of 19 cases had no traceable exposure history. According to the exposure history, nosocomial infection transmission routes are shown in fig. 2A. We found a potential preoperative SARS-CoV-2 carriers (“Patient 01”). Patient 01 had a localized ground glass change on CT scan on January 3, 2020 (fig. 1C), but he had no fever until the first day after operation. Two days later, his CT scan showed severe infection in both lungs and rapidly progressive legion

Table 1 Clinical characteristics of COVID-19 cases listed by hospitalized patients and health care staff

Characteristics	Hospitalized patients (n=13)	Health care staff (n=12)	P
Gender			
Male	10 (76.9%)	2 (16.7%)	0.005
Female	3 (23.1%)	10 (83.3%)	
Age (years)	60.2±5.6	35.8±9.2	<0.001*
History			
Smoking	7 (53.8%)	0 (0.0%)	0.005
Hypertension	2 (15.4%)	0 (0.0%)	0.480
Diabetes	1 (7.7%)	0 (0.0%)	1.000
COPD	5 (38.5%)	0 (0.0%)	0.039
Coronary heart disease	4 (30.8%)	0 (0.0%)	0.096
Symptoms			
Body temperature >37.3°C	13 (100.0%)	11 (91.7%)	0.480
Cough	10 (76.9%)	7 (58.3%)	0.411
Fatigue or muscular soreness	8 (61.5%)	9 (75.0%)	0.673
Short of breath	12 (92.3%)	8 (66.7%)	0.121
Diarrhea	2 (15.4%)	3 (25.0%)	0.645
COVID-19 severity			
Non-severe	6 (46.2%)	10 (83.3%)	0.097
Severe	7 (46.2%)	2 (16.7%)	
Exposure history			
Positive exposure	8 (61.5%)	11 (91.7%)	0.160
No positive exposure	5 (38.5%)	1 (8.3%)	
Days between exposure and fever	5.9±4.7	3.9±1.9	
Experimental examination			
SARS-CoV-2 positive	12 (92.3%)	7 (58.3%)	0.073
Lymphocyte count <1.1×10 ⁹ /L	12 (92.3%)	10 (83.3%)	0.593
WBC count >9.5×10 ⁹ /L	11 (84.6%)	2 (16.7%)	0.001
WBC count <4×10 ⁹ /L	3 (23.1%)	3 (25.0%)	1.000
Increase of LDH	11 (84.6%)	3 (25.0%)	0.005
Increase of CRP	8 (61.5%)	8 (66.7%)	1.000
Increase of ESR	4 (30.8%)	4 (33.3%)	1.000
Increase of Ferritin	5 (38.5%)	4 (33.3%)	1.000
Increase of PCT	0 (0.0%)	0 (0.0%)	-
Increase of BNP	3 (23.1%)	0 (0.0%)	0.220
Increase of cTnI	2 (15.4%)	0 (0.0%)	0.480
Increase of D-D dimer	9 (69.2%)	2 (16.7%)	0.015
Increase of Transaminase	10 (76.9%)	2 (16.7%)	0.005
Renal function damage	2 (15.4%)	1 (8.3%)	1.000
Electrolyte disturbance	11 (84.6%)	3 (25.0%)	0.005
Surgery type			
Lung	11 (84.6%)	0 (0.0%)	0.039
Esophagus	2 (15.4%)	0 (0.0%)	
Vital status			
Dead	5 (38.5%)	0 (0.0%)	0.039
Alive	8 (61.5%)	12 (100.0%)	

P values were calculated by two-sided Fisher's exact test. *P values were calculated using Student's *t* test.

(fig. 1C). Patient 01 died five days after the operation. During the hospitalization of "Patient 01", 8 health care staff had positive exposure with him, and fever occurred within 3 to 8 days after exposure. Six of them were confirmed SARS-CoV-2 infection. Additionally, 5 post-operational patients had positive exposure with "Patient 01", fever occurred within 2 to 10 days after exposure, and all of them had positive results for SARS-CoV-2 nucleic acid test. As a result, total 11 cases with a positive exposure with "Patient 01" were diagnosed as SARS-CoV-2 infection (fig. 2B).

3 DISCUSSION

According to the report of Chinese Center for Disease Control and Prevention (CDC)^[2], by February 11, 2020, there were 44 672 patients diagnosed as COVID-19, the severe type accounted for 19.1% and the mortality rate was 2.3%. In our department, severe type accounted for 53.8% (7/13), and the mortality rate was 30.8% (4/13), which was significantly higher than the reported results. Meanwhile, 15.4% (2/13) of the infected health care staff were in severe stage, slightly

Table 2 Clinical characteristics of COVID-19 cases listed by disease severity and vital status

Characteristics	Disease severity		<i>P</i>	Vital status		<i>P</i>
	Non-severe (<i>n</i> =16)	Severe (<i>n</i> =9)		Alive (<i>n</i> =20)	Dead (<i>n</i> =5)	
Gender						
Male	6	6	0.226	8	4	0.160
Female	10	3		12	1	
Age (years, median: 51)						
≤51	11	2	0.041	13	0	0.015
>51	5	7		7	5	
History						
Smoking	2	5	0.058	4	3	0.113
Hypertension	1	1	1.000	1	1	0.367
Diabetes	0	1	0.360	0	1	0.200
COPD	1	4	0.040	2	3	0.038
Coronary heart disease	3	1	1.000	3	1	1.000
Symptoms						
Body temperature >37.3°C	15	9	1.000	19	5	1.000
Cough	11	6	1.000	13	4	1.000
Fatigue or muscular soreness	13	4	0.087	14	3	1.000
Short of breath	12	8	0.308	16	4	0.456
Diarrhea	4	1	0.621	4	1	1.000
Chest operation	6	7	0.097	8	5	0.039
Experimental examination						
Lymphocyte count <1.1×10 ⁹ /L	14	8	1.000	18	4	0.504
WBC count >9.5×10 ⁹ /L	9	4	0.688	9	4	0.322
WBC count <4×10 ⁹ /L	5	1	0.364	5	1	1.000
Increase of LDH	8	6	0.677	11	3	1.000
Increase of CRP	9	7	0.401	13	3	1.000
Increase of ESR	3	5	0.087	6	2	1.000
Increase of Ferritin	5	4	0.671	7	2	1.000
Increase of BNP	1	2	0.530	2	1	0.504
Increase of cTnI	0	2	0.120	1	1	0.367
Increase of D-D dimer	6	5	0.434	9	2	1.000
Increase of transaminase	8	5	1.000	10	2	1.000
Renal function damage	1	2	0.530	2	1	0.504
Electrolyte disturbance	7	7	0.208	10	4	0.341

P values were calculated by two-sided Fisher's exact test.

lower than the reported result. The age, smoking history and comorbidities could all contribute to the different outcome of COVID-19 between patients and health care staff. In our study, we found that chest operation was significantly associated with death in COVID-19 patients, and COPD is significantly associated with severe COVID-19 and death. Operation would lead to lung function impairment and decreased immunity. These results indicate that SARS-CoV-2 infection is severe after thoracic operations, and could lead to a poor outcome. Liu *et al* found that CRP, LDH, and lymphocyte count may be predictors of the severity of lung injury^[3]. However, there is no significant correlation between the laboratory results and the severity of COVID-19. Jiang *et al* reported that PCT was increased in COVID-19 patients undergoing thoracic surgery^[4]. In our study, an increase of PCT was not observed in COVID-19 patients. The discrepancy may be explained by small sample size.

COVID-19 is mainly manifested as fever,

accompanied by cough, fatigue, muscular soreness, chest depression, shortness of breath, diarrhea and other symptoms^[1]. Postoperative patients may also have fever, cough and chest condition, which should be differentiate from COVID-19. Postoperative infection is mainly due to insufficient drainage and mostly caused by bacteria, commonly occurring 3 to 7 days after operation, accompanied with cough with sputum, elevated WBC count. While most COVID-19 patients had normal or reduced WBC count, and lower lymphocyte count. Early chest CT of COVID-19 shows localized ground glass shadows and interstitial changes, which are mainly in the dorsal or periphery part of the lung^[5]. Furthermore, multiple infiltrating shadows and lung consolidation can be seen in both lungs. Pleural effusion is rare in severe cases^[6,7]. Some early COVID-19 may present as single or multiple GGO-like changes, which needs to be identified from lung cancer^[8]. Some mild COVID-19 may progress to severe stage within a few days, and repeated chest CT

Fig. 1 Chest imaging findings of COVID-19 patients

A: 38-years-old man, a small patch of mixed GGO was first observed in his right upper lobe, then the lesion was markedly progressed in the extent and density (January 30, 2020), and 12 days later, the lesion was completely absorbed after treatment (February 11, 2020); B: 30-years-old man, the initial chest CT showed single GGO in his right lower lobe (January 23, 2020), and the first follow-up CT demonstrated multiple GGOs and extensive consolidations in the bilateral lower lobes. Meanwhile, the patient had normal body temperature without dyspnea (February 2, 2020). After supportive treatments, most of lesions were markedly absorbed, but the RT-PCR test of SARS-CoV-2 was still positive (February 14, 2020); C: 63-year-old man, a patch of pure GGO and subpleural interstitial changes were observed before the operation (January 3, 2020). Multiple patches were found 2 days after the operation (January 19, 2020) and the disease was rapidly progressed, appearing as multiple GGOs with crazy-paving sign and consolidations (January 21, 2020); D: 56-year-old woman, chest CT was normal before the surgery (January 15, 2020). Multiple patches of consolidations and GGOs were found in bilateral lungs (February 7, 2020), indicating a disease progression. Chest X-ray showed “white lung” (February 24, 2020) before death.

is necessary.

SARS-CoV-2 is highly infectious and is susceptible to all populations. Respiratory droplets and contact transmission are the main transmission routes, and aerosol transmission is also possible^[1]. Infected patient is the main source of transmission, even in asymptomatic stage. Thoracic surgery requires patients to do respiratory function exercise after operation, including

Fig. 2 Transmission and exposure routes among COVID-19 patients

A: Transmission tree of COVID-19 outbreak. Numbers inside the nodes of the tree are the serial number of each case; B: Time table of the 11 COVID-19 patients who had exposure history with “Patient 01”.

productive cough. Cough training will produce a large amount of droplets and aerosols to the surrounding space, which can increase efficacy of exposure. To *et al*^[9] found that sputum was an important source of transmission. Therefore, COVID-19 patients are highly contagious in department of thoracic surgery. Tuite *et al*^[10] found that the average basic infection number R_0 of SARS-CoV-2 was 2.3 on January 24, 2020, and the effective infection number R_e was reduced to 1.5 after effective protective measures were taken on February 3, 2020. Therefore, effective protective measures can reduce R_0 . However, with daily standard protection equipment, health care staff are highly susceptible to COVID-19^[11]. We suggest thoracic surgeons should delay the selective operation and confine operation, and strictly grasp the indications of emergency operation during the outbreak. Asymptomatic patients should be concerned, and routine blood test, chest CT and SARS-CoV-2 nucleic acid examination should be performed before emergency surgery.

“Super spreader” indicates patient potentially transmits infection to more than 10 people. To our knowledge, no “super spreader” has been reported in China yet. Retrospective analysis of 25 cases of COVID-19 in our department revealed 11 SARS-CoV-2 infected cases with traceable exposure history with “Patient 01”. “Patient 01” was a 63-year-old smoking male with lung cancer who had COPD. The preoperative evaluation of lung function is sufficient for lobectomy. Before the operation was performed, his CT image showed a patch opacity in the right lung and interstitial abnormalities in both lungs, the early signs

of COVID-19. He was misdiagnosed before operation. Eleven confirmed COVID-19 cases occurred after the operation date of “Patient 01”, most likely due to aerosol and droplets generated from his cough. Due to insufficient preparation, inappropriate protective measures were implemented at the beginning of outbreak and caused a large number of infection among hospitalized patients and health care staff. Unfortunately, “Patient 01” had rapid progression and died from respiratory failure 5 days after operation. He was considered as a “super spreader” in the outbreak of SARS-CoV-2 infection in our department.

In summary, SARS-CoV-2 is highly contagious. Hospitalized patients and health care staff in the epidemic are at high risk of infection. Patients infected with COVID-19 in perioperative period have high risk of death. Therefore, implementing comprehensive protective measures such as quarantine and disinfection are essential to control nosocomial infection.

Conflict of Interest Statement

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the manuscript we submitted.

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