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Retrospective Cohort Study

COVID-19 infection, a potential threat to surgical patients and staff? A retrospective cohort study

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ABSTRACT

Background: This study aimed to describe the epidemiologic and clinical characteristics of coronavirus disease 2019 (COVID-19) in surgical patients and medical staff.
Methods: A single-center case series of 1586 consecutive surgical patients was selected at our hospital from January 13 to March 12, 2020. The epidemiological and clinical characteristics of COVID-19 were analyzed and followed up to May 20, 2020. The transmission of COVID-19 between the surgical patients and medical staff was also recorded.
Results: Seventeen (1.07%) surgical patients were diagnosed with COVID-19, with a high incidence in the thoracic department (9.37%), and the median age was 58 years (IQR, 53–73). The median time from hospital admission to COVID-19 diagnosis was 9.0 days (7.0–12.0) and was 6.0 days (4.0–7.0) from the day of surgery to COVID-19 diagnosis. Eleven (64.70%) patients suffered from pulmonary infection before surgery. When COVID-19 was diagnosed, common symptoms were fever (82.35%) and cough (94.12%), and most (82.35%) neutrophil/lymphocyte ratios were high (>3.5). Chest computed tomography (CT) (82.35%) showed bilateral dense shadows. Surgical patients with COVID-19 stayed in the hospital for approximately 35.0 days (25.5–43.0), with a mortality rate of 11.76%. Sixteen medical staff were infected with COVID-19 in the early stage.
Conclusions: In this series of 1586 surgical patients, the COVID-19 infection rate was 1.07%, with an especially high incidence among patients with thoracic diseases. Middle-aged and elderly patients with preoperative pulmonary infection were more susceptible to COVID-19 infection after surgery. Medical staff were infected with COVID-19 and should take protective measures to protect themselves.

1. Introduction

The current outbreak of coronavirus disease 2019 (COVID-19) is the third epidemic caused by coronavirus in the 21st century. Currently, the number of cases is far beyond 80 000 in China and will likely increase by the time of publication [1]. COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and its main manifestations are fever, dry cough, fatigue, respiratory distress, which can be transmitted by droplet, contact and aerosol transmission [2–4]. The high infection rate of the virus and the ability of the host to shed the infection with unexpectedly widespread transmission in communities and hospitals has led to high severity and mortality ratios [5,6]. However, most studies have focused on the epidemiological and clinical characteristics of normal patients infected with COVID-19, and a few have reported medical staff were infected [3,6,7], which means that nosocomial infection may be a very serious problem in the early stage of the COVID-19 epidemic.

However, the epidemiological risk of perioperative infection with COVID-19 pneumonia and the clinical manifestations of COVID-19 in surgical patients are still unknown [8]. Moreover, studies on how to protect clinical medical staff from COVID-19 infection are urgently needed. Answers to these questions are essential for formulating the principles and guidelines of perioperative treatment for surgical patients and protection for medical staff during the epidemic of COVID-19

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pneumonia [8]. In this study, we report the epidemiological and clinical characteristics, treatment, and outcomes of surgical patients with confirmed COVID-19 pneumonia infection and the infection transmission from surgical patients to medical staff.

2. Patients and methods

2.1. Study design and participants

This retrospective clinical study was registered with No. ChiCTR2000031245 and approved by the Medical Ethical Committee of our hospital (No. WDRY-2020-K024), and written informed consent was obtained from each enrolled patient, and the work has been reported in line with the STROCSS criteria[9]. A retrospective review of COVID-19 infection in surgical patients admitted to our hospital and staff was performed, and the latest follow-up was May 20, 2020. The inclusion criteria were consecutive surgical patients receiving surgeries from January 13 to March 12, 2020, and surgeries performed out of the above periods were excluded.

The diagnosis of COVID-19 pneumonia was based on the New Coronavirus Pneumonia Prevention and Control Program (5th edition) published by the National Health Commission of China [10]. Patients with COVID-19 pneumonia were considered positive for SARS-CoV-2 with the use of the Chinese Center for Disease Control and Prevention (CDC) recommended kit (BioGerm, Shanghai, China), following WHO guidelines for qRT-PCR [5], or by chest computed tomographic (CT) scans [10].

In the early stage of this epidemic (before January 23rd, 2020), the nucleic acid tests were performed only on the suspected surgical patients with fever more than 37.3 °C and/or pulmonary infection (Chest CT/X-R ray showing) when entering the operating room, and medical staff only used the surgical mask to protect themselves. However, massive testing of nucleic acid test was performed for surgical patients, and medical staff used personal protective equipment (PPE) including protective suits surgical masks, N95 respirators and face shields after January 23rd in our hospital.

2.2. Data collection

Epidemiological and clinical records, laboratory findings, chest CT scans, treatments and outcome data were obtained with customized data collection forms from electronic medical records. Information recorded included demographic data, medical history, exposure history, underlying comorbidities, symptoms, signs, laboratory findings, chest CT scans, and treatment measures (i.e., antiviral therapy, corticosteroid therapy and respiratory support). The date of COVID-19 pneumonia onset was defined as chest CT scans and throat swab samples that were positive for 2019 novel coronavirus (2019-nCoV) nucleic acid. Medical staff, diagnosed with COVID-19, had a history of expose to the COVID-19 surgical patients, signs and symptoms with the evidence of chest CT or positive COVID-19 nucleic acid.

2.3. Statistical analysis

All statistical analyses were performed using SPSS (version 22.0, IBM, Armonk, NY, USA). Categorical variables were described as percentages, and continuous variables were described using median and interquartile range (IQR) values. The Mann-Whitney test was used for analyzing continuous variables in Table 3. Fisher's exact test was used for the proportions of categorical variables in Table 3. For unadjusted comparisons, a 2-sided α of less than 0.05 was considered statistically significant.

3. Results

3.1. Presenting characteristics of epidemiology

The study population included 1586 hospitalized surgical patients (598 males, 988 females, median 47 years and IQR [22–67] years), in which 264 surgical patients were detected with 2019-nCoV nucleic acid, and forty-nine (3.09%) patients were suspected before surgery from January 13 to March 12, 2020 (Fig. 1). Seventeen (1.07%) patients were confirmed to have COVID-19 pneumonia (6 males, 11 females) with 15 laboratory-confirmed 2019-nCoV infections and 2 clinical diagnoses (Fig. 1, Table 1), including 14 (1.43%) elective surgical patients and 3 (0.50%) emergency surgical patients. The onset times of these 17 patients' surgeries were mainly distributed from January 13 to 23 (14 [82.35%]), but there was no significant difference ($P = 0.962$) between the incidence rates before January 23 (14 [1.07%]) and after January 23 (3 [1.10%]) (Table 1). COVID-19 surgical patients were mainly in middle (45–65 years) (9 [1.55%]) and elderly age (>65 years) (5 [2.31%]), and the median age was 58 years (IQR, 53–73). Most patients (11 [64.71%]) with preoperative pulmonary infection were more susceptible to COVID-19 infection after surgery. None of the 17 surgical patients included in this study had a clear history of exposure to the Wuhan Huanan Seafood Wholesale Market. Most of the surgical patients with COVID-19 received general anesthesia (7 [23.53%]), with 1 patient receiving regional block and 1 patient receiving epidural anesthesia. The COVID-19 surgical patients were mainly distributed in the thoracic (9.37%), gastrointestinal (2.80%), and neurosurgery (1.85%) departments (Table 1).

The median time from hospital admission to onset of COVID-19 diagnosis was 9.0 days (7.0–12.0), and the median time from the day of surgery to onset of COVID-19 diagnosis was 6.0 days (4.0–7.0) (Table 2). Hypertension (7 [41.18%]), malignancy (5 [29.41%]), and cardiovascular disease (7 [23.53%]) were the most common comorbidities, especially in elective patients. Most of the patients underwent surgeries with surgical difficulty categories of level 2 (6 [35.29%]) and level 3 (2 [52.94%]) and with American Society of Anesthesiologists (ASA) level 2 (12 [82.35%]) and ASA level 3 (4 [23.53%]) (Table 2). Four patients admitted to the ICU underwent surgery. The median surgical time was 210 min (75–300) (Table 2).

3.2. Vital signs and laboratory parameters

Before surgery, 6 patients presented with cough (31.29%), and 1

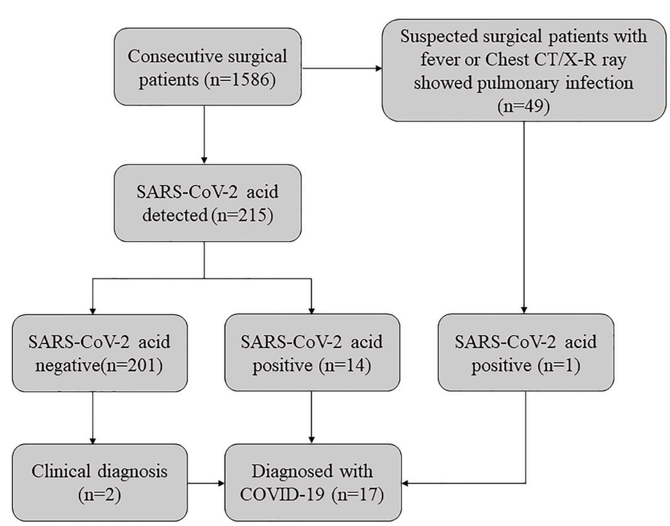

Fig. 1. Flow diagram of screening for the diagnosis of surgical patients with COVID-19.

Table 1
The epidemiological distribution of surgical patients during the COVID-19 epidemic.

	Total	Suspected	Infected with COVID-19
Number (%)	1586	49 (3.09)	17 (1.07)
Number before January 23rd	1313	15 (1.14)	14 (1.07)
Number after January 23rd	273	34 (12.45)	3 (1.10)
Age, median (IQR), y	47 (22–67)	54 (35–63)	58 (53–73)
>65 years (%)	216	11 (5.09)	5 (2.31)
45–65 years (%)	579	24 (4.14)	9 (1.55)
<45 years (%)	791	14 (1.77)	3 (.38)
Sex			
Male (%)	598	24 (4.01)	6 (1.00)
Female (%)	988	25 (2.53)	11 (1.13)
Exposure to Huanan Seafood Wholesale Market	..	..	0
Preoperative pulmonary infection (%)	232	32 (13.79)	11 (4.74)
Non-preoperative pulmonary infection (%)	1354	17 (1.26)	6 (.44)
2019-nCoV acid detection	264	49 (18.56)	17 (2.53)
Elective surgery	980	10 (1.02)	14 (1.43)
Emergency surgery	606	39 (6.44)	3 (.50)
Anesthesia			
General anesthesia	966	33 (3.42)	15 (1.55)
Regional block	379	4 (1.06)	1 (.26)
Epidural anesthesia	108	12 (11.11)	1 (.93)
Surgical Dept.			
Cardiac surgery (%)	22	2 (9.09)	0
Gastrointestinal (%)	107	9 (8.41)	3 (2.80)
Breast (%)	132	0	2 (1.52)
Hepatobiliary (%)	38	4 (10.53)	0
Neurosurgery (%)	108	11 (10.18)	2 (1.85)
Obstetrics (%)	132	12 (9.09)	1 (.76)
Gynecology (%)	224	1 (.45)	0
Thoracic (%)	32	2 (6.25)	3 (9.37)
Orthopedics (%)	187	1 (.53)	3 (1.60)
Urinary (%)	157	2 (1.27)	2 (1.27)
ENT (%)	160	4 (2.50)	1 (.63)
Ophthalmology (%)	216	1 (.46)	0

Suspected means surgical patients suffered with fever more than 37.3 °C or Chest CT/X-R ray showed pulmonary infection when entering the operating room. Age data are median (IQR), (%), or n/N (%), where N is the total number. Abbreviations: COVID-19, coronavirus disease 2019; IQR, interquartile range. Dep., department.

Table 2
The characteristics of surgical patients infected with COVID-19.

n%	Total	Elective	Emergency
	N = 17	N = 14	N = 3
Day after hospital admission onset, Median (IQR)	8.7 (6.5–12.8)	9.0 (7.0–12.8)	4.0 (1.0–5.0)
Day after Surgery, Median (IQR)	5.2 (3.0–7.3)	6.0 (4.0–9.5)	1.0 (1.0–2.0)
Comorbidities			
Hypertension	7 (41.18)	5 (35.71)	2 (66.67)
Diabetes	2 (11.76)	2 (14.29)	0
COPD	1 (5.88)	1 (7.14)	0
Malignancy	5 (29.41)	5 (35.71)	0
Cardiovascular disease	7 (41.18)	7 (50.00)	0
Chronic Kidney disease	1 (5.88)	1 (7.14)	0
Surgical difficultly category			
Level 1	1 (5.88)	1 (7.14)	0
Level 2	6 (35.29)	4 (28.57)	2 (66.67)
Level 3	9 (52.94)	8 (57.14)	1 (33.33)
Level 4	1 (5.88)	1 (7.14)	0
ASA level			
Level 2	12 (70.59)	10 (71.43)	2 (66.67)
Level 3	4 (23.53)	4 (28.57)	0
Level 4	1 (5.88)	0	1 (33.33)
Surgical time, (min) Median (IQR)	210 (75–300)	228 (97–306)	75 (62–130)
Laboratory detection			
Neutrophil/Lymphocyte>3.5	14 (82.35)	12 (85.71)	2 (66.67)
C-reactive protein, >10 mg/L	13 (76.47)	12 (85.71)	1 (33.33)
Procalcitonin, >0.1 ng/mL	11 (64.71)	11 (78.57)	NA.
Positive COVID-19 nucleic acid	15 (88.23)	13 (92.86)	2 (66.67)
Complications			
ARDS	4 (23.53)	3 (31.43)	1 (33.33)
Shock	3 (17.65)	2 (14.29)	1 (33.33)
Secondary infection	5 (29.41)	5 (35.71)	0
Acute cardiac injury	2 (11.76)	2 (14.29)	0
Arrhythmia	3 (17.65)	2 (14.29)	1 (33.33)
SAPS II score	23 (17–29.0)	22 (17.5–29)	29 (14–58)
CT evidence of virus pneumonia			
Bilateral distribution of patchy shadows or ground glass opacity	14 (82.35)	12 (85.71)	2 (66.67)
Prognosis till to May 20th			
Discharge	15 (88.24)	13 (92.86)	2 (66.67)
Death	2 (11.76)	1 (7.14)	1 (33.33)
Hospital day, Median (IQR)	34.6 (25.5–43.0)	39 (25.0–51.3)	22 (4.0–28.0)

Abbreviations: IQR, interquartile range; F/M, female/male; ASA, American Society of Anesthesiologists; ARDS, acute respiratory distress syndrome; COVID-19: 2019 novel coronavirus disease; COPD, chronic obstructive pulmonary disease; SAPS, simplified acute physiology score; NA., not applicable. n (%), or n/N (%), where N is the number of COVID-19 surgical patients.

patient presented with fever (5.88%). After surgery, 10 patients presented with cough (58.82%), and 6 patients presented with fever (35.29%). After being diagnosed with COVID-19 pneumonia, 14 patients presented with fever (84.35%), and 16 patients presented with cough (94.12%) (Table 2). The symptoms of dyspnea, chest tightness, malaise, dizziness and diarrhea did not change during this period (Table 2, eTable 2 in the Supplement).

Data from laboratory tests showed that neutrophil counts were increased and lymphocyte counts were decreased after surgery and COVID-19 pneumonia diagnosis (Table 3). The neutrophil/lymphocyte ratio (NLR) was increased after surgery (10.54 [5.62–14.83]) and COVID-19 pneumonia diagnosis (4.86 [3.85–7.97]) (Table 3), and 14 (85.7%) patients' NLRs were higher than 3.5 when COVID-19 pneumonia was diagnosed (Table 2). Additionally, 13 (76.47%) patients had elevated concentrations of C-reactive protein (>10 mg/L), and 11 (64.71%) patients had elevated concentrations of procalcitonin (>0.1 ng/mL) when COVID-19 was diagnosed (Table 2). COVID-19 had no effect on the eGFR, ALT/AST ratio, or monocyte and platelet counts in surgical patients (Table 3). Blood cellular immune function showed that the median counts of $CD3^+$, $CD4^+$, $CD16^+$ and $CD56^+$ cells were decreased compared with the normal ranges, but the CD4+/CD8+ ratio was in the normal range when COVID-19 pneumonia was diagnosed (eTable 2 in the Supplement).

Before surgery, 11 patients (64.71%) were diagnosed with pulmonary infection by chest CT scan, and only 4 patients (23.53%) showed typical multiple patchy ground-glass shadows in the lungs (Table 3). After surgery, the number of patients with typical multiple patchy ground-glass shadows in the lungs increased to 10 (58.82%) (Table 3). However, 14 (82.35%) of them showed bilateral dense shadows or ground-glass opacity when positive COVID-19 nucleic acid was detected (Tables 2 and 3 and Fig. 1). Two (11.76%) of them showed typical multiple patchy ground-glass shadows in the lungs and were diagnosed by clinical symptoms and signs (Tables 2 and 3). Typical dynamic changes in the chest CT files of Patient #5 are shown in Fig. 2A and were compared with medical staff infected by Patient #4 (Fig. 2B).

3.3. Main interventions and outcomes

In 17 surgical patients diagnosed with COVID-19, 16 patients (94.12%) received oxygen support, of whom 14 (82.35%) patients needed a high-flow nasal cannula, and 2 (11.76%) received noninvasive ventilation. Twelve patients received antiviral therapy (70.59%), 16 patients received antibacterial therapy (94.12%), 5 patients received glucocorticoid therapy (29.41%), and 3 patients received

Table 3
The progression information of COVID-19 surgical patients.

n = 17	Before surgery	Surgery onset to COVID-19 diagnosis	After COVID-19 diagnosis	*P* value 1	*P* value 2
Signs and symptoms					
Fever, (%)	1 (5.88)	6 (35.29)	14 (82.35)	<0.001	.006
Cough, (%)	6 (35.29)	10 (58.82)	16 (94.12)	<0.001	.015
Dyspnea, (%)	0	0	3 (17.65)	.070	.070
Chest tightness, (%)	1 (5.88)	1 (5.88)	4 (23.53)	.146	.146
Malaise, (%)	0	7 (41.18)	4 (23.53)	.033	.271
Dizziness, (%)	1 (5.88)	4 (23.53)	3 (17.65)	.287	.672
Diarrhea, (%)	1 (5.88)	0	0	.310	NA
Laboratory detection, Median (IQR)					
Neutrophil count, $\times 10^9$/L	3.45 (2.24–4.22)	5.85 (4.84–8.89)	4.84 (3.25–6.96)	.129	.086
Lymphocyte count, $\times 10^9$/L	1.32 (0.90–1.75)	0.73 (0.40–0.91)	0.85 (0.60–1.14)	.124	.246
Neutrophil/Lymphocyte ratio	2.75 (1.48–6.96)	10.54 (5.62–14.83)	4.86 (3.85–7.97)	.053	.012
Monocyte count, $\times 10^9$/L	0.51 (0.24–0.66)	0.57 (0.46–0.75)	0.51 (0.35–0.68)	.789	.367
Platelet count, $\times 10^9$/L	158 (119–214)	138 (126–179)	151 (122–239)	.964	.936
GLB, g/L	23.5 (21.2–26.7)	24.6 (21.5–27.8)	21.4 (19.0–26.9)	.675	.418
eGFR, mL/min	103 (87–115)	101 (76–110)	104 (92–109)	.435	.655
ALT/AST ratio	0.76 (0.61–1.17)	0.83 (0.69–1.13)	0.84 (0.65–1.17)	.684	.782
CT evidence					
Pulmonary infection, (%)	11 (64.71)	13 (76.47)	16 (94.12)	.452	.034
Bilateral shadows	4 (23.53)	10 (58.82)	14 (82.35)	<0.001	.132
Treatments					
Oxygen support	5 (29.41)	14 (82.35)	16 (94.12)	<0.001	.287
High-flow nasal cannula	0	0	14 (82.35)	<0.001	<0.001
Noninvasive ventilation	0	2 (11.76)	2 (11.76)	0.484	0.999
Antibiotic therapy	13 (76.47)	14 (82.35)	16 (94.12)	.146	.287
Antiviral therapy	0	0	12 (70.59)	<0.001	<0.001
Glucocorticoid therapy	5 (29.41)	7 (41.18)	5 (29.41)	.999	.473
Immunoglobulin	0	1 (5.88)	3 (17.65)	0.227	0.601

P value 1 means Before Surgery vs. After COVID-19 diagnosis; *P* Value 2 means Surgery onset to COVID-19 diagnosis vs. After COVID-19 diagnosis; Fisher's exact test was used to evaluate the signs and symptoms, CT evidence and treatments. The nonparametric Mann-whitney test was performed for Laboratory detection. Abbreviations: GLB, globulin; eGFR, effective glomerular filtration rate. ALT/AST, alanine aminotransferase/aspartate aminotransferase.

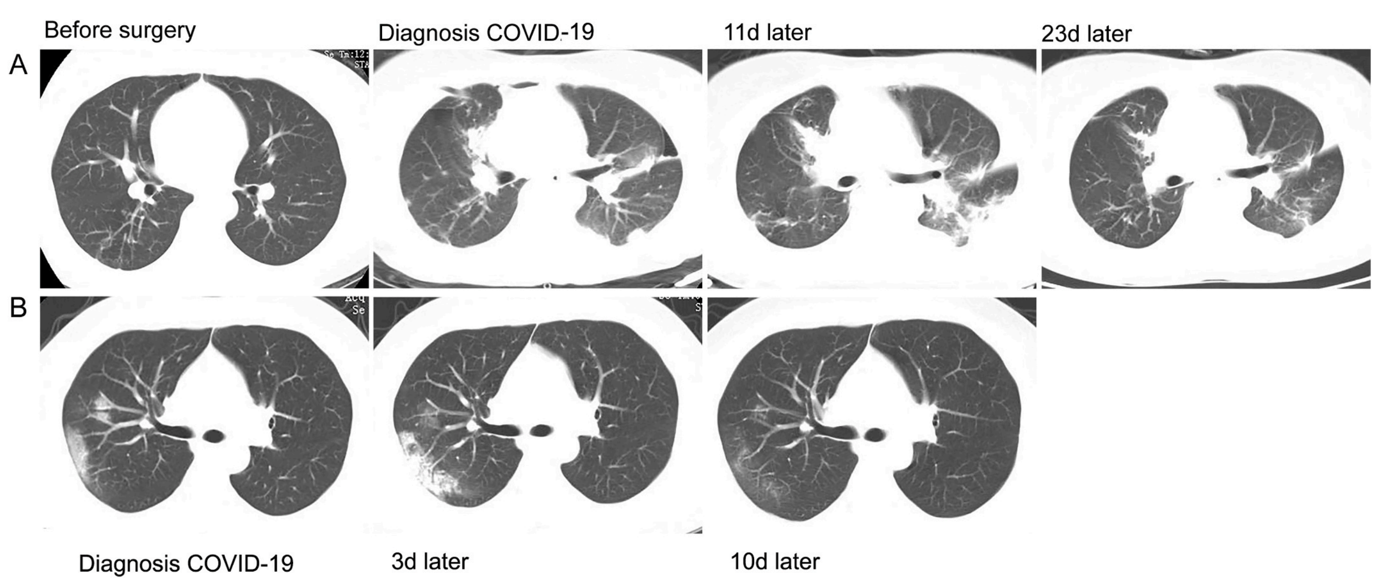

Fig. 2. The dynamic progression of chest CT for Patient #5 and medical staff infected by special Patient #4 (transverse plane). (A) The dynamic progression of Patient #5 from before surgery to the diagnosis of COVID-19 and, finally, to receiving anti-virus therapy 11 days and 23 days later. Patient 5 underwent right upper anterior segment pulmonary wedge resection and left upper and lower pulmonary wedge resection and stayed with Patient #4 in the same ward after surgery. (B) The dynamic progression of the staff from the time of COVID-19 diagnosis to receiving anti-virus therapy 3 days and 11 days later. The staff was the attending doctor of Patient #4. Median indicates the transverse section of the lungs.

immunoglobulin therapy (17.65%) (Table 1). As of May 20, 2020, all COVID-19 surgical patients had developed pneumonia after surgery, and common complications included ARDS (4 [23.53%]), shock (3 [17.65%]), secondary infection (5 [29.41%]), arrhythmia (3 [17.65%]), and acute cardiac injury (2 [11.76%]) (Table 2). The median of simplified acute physiology score (SAPS) II score was 23 (17–29.0), and there was no significant difference between surgical patients received elective surgeries [22 (17.5–29)] and emergency surgeries [29 (14–58)].

A total of 15 surgical patients (88.24%) were discharged, with a long hospital stay (34.6 days, IQR, 25.5–43.0), and 2 patients (11.76%) died (1 patient received emergency surgery [33.33%], and 1 patient received elective surgery [7.14%]) (Table 2). Chest CT also showed that patients with pulmonary operations had significantly increased numbers of treatment cycles and lengths of hospital stay compared with patients without operations (medical staff) (Fig. 2).

3.4. Case report of patient #4

Patient #4 received thoracoscopic right lower partial lobectomy on January 17 and had a fever (38.9 °C) on the 3rd day after surgery. Chest CT showed bilateral multiple dense shadows and ground-glass opacities when COVID-19 infection was diagnosed with positive COVID-19 nucleic acid (eFig. 1). Unfortunately, she died 8 days later due to acute respiratory distress. Blood gas analysis showed that PaO_2 (110 mmHg) and $PaCO_2$ (42 mmHg) were in the normal ranges when she was diagnosed with COVID-19 pneumonia. However, PaO_2 (26 mmHg) and oxygenation index (58 mmHg) but not $PaCO_2$ (42 mmHg) levels were significantly decreased 2 h before she died (eTable 3 in the Supplement).

3.5. Infection transmission

Patient #4 and Patient #5 stayed in the same ward after surgery, and the attending clinician of patient #4 experienced fever and suffered from COVID-19 pneumonia 9 days later. Person-to-person transmission, from surgical patients to medical staff, mainly happened in ward area (15 [93.75%]), few in operating room (1 [6.25%]) and none in intensive care unit. Sixteen staff members (9.47%) had a definitive diagnosis and needed hospitalized therapy: 6 surgeons (11.76%), 1 anesthesiologist (2.94%), and 9 ward nurses (23.68%) (Table 4). Twenty staff members (11.83%) in operating room had a history of exposure to COVID-19 surgical patients, who were with different signs and symptoms, such as fever (2 [10%]), cough (11 [55%]), sore throat (13 [65%]), dizziness (2 [10%]), headache (7 [35%]) and diarrhea (2 [10%]), but without evidence of chest CT scan or positive COVID-19 nucleic acid testing (Table 4).

4. Discussion

We studied 1586 surgical data points from January 13 to March 12, 2020, and found that 264 surgical patients were detected with 2019-nCoV nucleic acid, among whom 17 surgical patients (1.07%) were diagnosed with COVID-19 pneumonia confirmed by chest CT and/or positive nucleic acid. The COVID-19 surgical patients were not distributed uniformly, with a particularly high incidence in the thoracic department. Middle-aged and elderly patients who underwent surgery were more susceptible to COVID-19 infection during the perioperative period. Hypertension, malignancy, cardiovascular disease, and pulmonary infection were the most common comorbidities before surgery. Surgical trauma and general anesthesia can aggravate previous pulmonary infection [7], which might increase the susceptibility to infection. Other studies have indicated that old patients with lung carcinoma facilitate in infecting with COVID-19 pneumonia, which is related to low immunity and resistance [11].

Signs and symptoms were not typical before surgery [12], and most surgical patients received elective surgeries before COVID-19 was diagnosed. Although body temperature was measured when entering the operating room, these patients were not screened out, which meant that fever was not highly related to COVID-19 pneumonia diagnosis before surgery. A single neutrophil or lymphocyte count could not predict COVID-19 infection [13,14], but the NLR was sensitive for surgical patients infected with COVID-19 pneumonia, especially those with an NLR >3.5, which is considered significant in the diagnosis of COVID-19 pneumonia. Another study also showed that the NLR could predict the progression of pneumonia [15]. In this study, patients with a high NLR (>3.5) had a higher rate of mortality and long hospital stays after COVID-19 infection. CRP and procalcitonin were not highly related to viral infection but showed whether bacterial infection complications existed for surgical patients infected with COVID-19 pneumonia.

Surgical patients with COVID-19 showed significantly increased complications compared with patients infected with COVID-19 without surgery, especially in terms of ARDS (23.53%), shock (17.65%), secondary infection (5 [29.41%]), arrhythmia (3 [17.65%]), and acute cardiac injury (2 [11.76%]), and complication incidence rates were also higher compared with surgical patients without COVID-19 infection [16]. Although the SAPS II scores in surgical patients with COVID-19 were not higher than that in normal surgical patients [17], two surgical patients (11.76%) died of COVID-19-associated complications, which was much higher than the reported overall case-fatality rate of 4.3% in COVID-19 patients without surgery [3] and was also higher than the case-fatality rate of 7.9% in noncardiac surgical patients [16].

Currently, no specialized medication is available for the treatment of COVID-19 infection [18]. The main treatment is antiviral and symptomatic support [19]. Thus, a patient's immune function is a major determinant of disease severity [20]. Interestingly, the numbers, not the distribution, of $CD3^{+}$ and $CD4^{+}$ cells in COVID-19 surgical patients were lower than those in mild COVID-19 patients without surgery and were similar to those in severe COVID-19 patients [21], which meant that COVID-19 seriously inhibited the immune function of T lymphocytes after surgery. These findings would help to guide glucocorticoid or immunoglobulin therapies. A similar study also showed that cellular immunity was found to be a good prognostic indicator for predicting admission to the ICU in patients with SARS compared with age and leucocyte count [22]. Thus, the high mortality in surgical patients infected with COVID-19 may be associated with abnormal cellular immune function.

Studies have indicated that COVID-19 acts on the ACE II receptor [2], which is mainly distributed on type II alveolar epithelial cells regulating lung compliance [23], but few are distributed on type I alveolar epithelial cells [24]. COVID-19 pneumonia can lead to dyspnea and chest tightness, even respiratory failure, so patients need high-flow oxygen support, even ventilator therapy. The dynamic profile of arterial blood gas in Patient #4 receiving pulmonary surgery showed that COVID-19 pneumonia led to death, mainly by decreasing oxygen exchange but not carbon dioxide excretion, which suggested that pulmonary surgery may exacerbate the worse prognosis of COVID-19 pneumonia.

More importantly, patient #4 and patient #5 stayed in the same ward after surgery, and the attending doctor of patient #4 suffered from COVID-19 pneumonia 9 days later, suggesting that person-to-person transmission occurs in the surgical ward and that infection

Table 4
Infection transmission from surgical patients to medical staff.

Till to May 20th	Total	Infected with COVID19	%	Symptoms of suspected staff	Number (N = 20)	%
Medical Staff	**169**	**16**	9.47	Fever	2	10.0
Surgeon	51	6	11.76	Cough	11	55.0
Anesthesiologist	34	1	2.94	Sore throat	13	65.0
Ward nurse	38	9	23.68	Dizziness	2	10.0
Operating room nurse	46	0	0	Headache	7	35.0
Suspected staff in Operation room	**20**			Diarrhea	2	10.0

Infected with COVID-19 means medical staff infected with COVID-19, who had a history of expose to the COVID-19 surgical patients. The suspected staffs mean having a history of exposing to the COVID-19 surgical patients, signs and symptoms, but without the evidence of chest CT or positive COVID-19 nucleic acid. n (%), or n/N (%), where N is the total number.

transmission may start even earlier. The time from hospitalization to diagnosis of COVID-19 was 9.0 days (6.5–12.5), and another study showed that the median time from symptom onset to first hospital admission was 7 days (4.0–8.0) [10], so COVID-19 transmission infection mostly occurred in hospitals. Infection of hospitalized medical staff with COVID-19 pneumonia mainly occurred in the surgical ward, and one anesthesiologist was infected in the operating room, which might be related to the delay in diagnosis, endotracheal intubation and invasive procedures without taking effective protection measures.

COVID-19 mainly includes three modes of transmission: droplet transmission, contact transmission, and aerosol transmission caused by long-term exposure to high-concentration aerosols in a relatively closed environment [25,26]. Therefore, during the perioperative period, first, medical staff were required to undergo training regarding the infection control management procedures for COVID-19. All patients' blood, body fluids, secretions, and excreta should be treated as infective agents, and medical staff should take patient-to-staff two-sided protective measures and take measures such as droplet isolation, contact isolation and air isolation [27]. Second, medical staff and patients followed the established biosafety procedures when entering and leaving the operating room. Third, patients wore a surgical mask before endotracheal intubation, and medical staff must use PPE including protective suits surgical masks, N95 respirators and face shields when contacting surgical patients with confirmed or suspected COVID-19, especially during the endotracheal intubation period [25]. Fourth, the working area of medical staff was isolated from the ward, and critical workers caring for patients with coronavirus should use PPE [28].

There are several limitations in our study. First, as the total enrollment was affected by the Spring Festival and Wuhan lockdown, hospitals in Wuhan only accepted emergency patients, and elective surgeries could not be performed normally from January 23 to March 12. The infection of COVID-19 in general population was increased in the early stage of COVID-19 outbreak, but the incidence rate in surgical patients was not increased after January 23 (see in Table 1), which was mainly because of the efficient control, few patients transferred from primary hospitals and decreased number of surgeries. Second, surgical patients did not receive preoperative SARS-CoV-2 confirmation tests before January 23, so the data lacked the reservoir of infection and accurate infection onset of each patient due to the understanding of the epidemic situation and the shortage of 2019-nCoV confirmation kits at that time.

In summary, in this series of 1586 surgical patients, the COVID-19 infection rate was 1.07%, with an especially high incidence among patients with thoracic diseases, and the median age was 58 years (IQR, 53–73). Middle-aged and elderly surgical patients with preoperative pulmonary infection were more susceptible to COVID-19 infection after surgery. Medical staff may be infected with COVID-19 during the perioperative period and must wear protective equipment to protect themselves.

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CRediT authorship contribution statement

Jiabao Hou: Conceptualization, Methodology, Writing - original draft. **Xing Wan:** Software, Visualization. **Qianni Shen:** Data curation, Investigation. **Jie Zhu:** Writing - review & editing. **Yan Leng:** Supervision, Writing - original draft. **Bo Zhao:** Writing - review & editing. **Zhongyuan Xia:** Conceptualization, Writing - review & editing. **Yuhong He:** Software, Validation. **Yang Wu:** Conceptualization, Data curation, Writing - original draft.

Declaration of competing interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2020.08.037.

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