Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Retrospective Cohort Study

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

Jiabao Hou, Xing Wan, Qianni Shen, Jie Zhu, Yan Leng, Bo Zhao, Zhongyuan Xia, Yuhong He, Yang Wu

Department of Anesthesiology, Renmin Hospital of Wuhan University, Wuhan, 430060, China
Nutrition and Foods Program, School of Family & Consumer Sciences, Texas State University, San Marcos, TX, 78666, USA
Infection and Control Office, Renmin Hospital of Wuhan University, Wuhan, 430060, China

ARTICLE INFO

Keywords:
Coronavirus disease 2019 (COVID-19)
Surgery
Epidemiologic characteristics
Clinical characteristics
Pneumonia

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 [6]. 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.
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-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, 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 exposure 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 $\alpha$ 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 [5.5%]) 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.](image-url)
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 with 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 range, 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). 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).

### 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 | 54 | 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 (3.88) |
| 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 (0.44) |
| 2019-nCoV detection (Table 2) | 264 | 49 (18.56) | 17 (2.53) |
| Elective surgery | 980 | 10 (1.02) | 14 (1.43) |
| Emergency surgery | 606 | 39 (6.44) | 3 (0.50) |

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

| n/Total | Elective | Emergency |
|---------|----------|-----------|
| Day after hospital admission | N = 17 | 8.7 | N = 14 | 9.0 | N = 3 | 4.0 |
| omnet, Median (IQR) | (6.5–12.8) | 7 (0.0–12.8) | (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 (41.08) | 7 (50.00) | 0 |
| Chronic kidney disease | 1 (5.88) | 1 (7.14) | 0 |
| Surgical difficulty 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 1 | 2 (17.05) | 10 (71.43) | 2 (66.67) |
| Level 2 | 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 (50–120) |
| Laboratory detection | | | |
| Neutrophil/Lymphocyte ratio >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 (21.43) | 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 (17–29.0) | 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) |

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.

Dep., department.
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

| 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 | | .310 | NA |
| Laboratory detection, Median (IQR) | | | | | |
| Neutrophil count, ×10⁹/L | 3.45 (2.24–4.22) | 5.85 (4.84–8.89) | 4.84 (3.25–6.96) | .129 | .086 |
| Lymphocyte count, ×10⁹/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, ×10⁹/L | 0.51 (0.24–0.66) | 0.57 (0.46–0.75) | 0.51 (0.35–0.68) | .789 | .367 |
| Platelet count, ×10¹⁰/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) | .484 | .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 |
| Immunglobulin | 0 | 1 (5.88) | 3 (17.65) | .227 | .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.
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 PaO₂ (110 mmHg) and PaCO₂ (42 mmHg) were in the normal ranges when she was diagnosed with COVID-19 pneumonia. However, PaO₂ (26 mmHg) and oxygenation index (58 mmHg) but not PaCO₂ (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 spread occurred in Operation room 20.

Table 4

| Staff Type                  | Total | Infected with COVID19 | Symptoms of suspected staff | Number (N = 20) | %  |
|----------------------------|-------|-----------------------|----------------------------|-----------------|----|
| Medical Staff              | 169   | 16                    | Fever                      | 2               | 10.0|
| Surgeon                    | 51    | 6                     | Cough                      | 11              | 55.0|
| Anesthesiologist           | 34    | 1                     | Sore throat                 | 13              | 65.0|
| Ward nurse                 | 38    | 9                     | Dizziness                  | 2               | 10.0|
| Operating room nurse       | 46    | 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 exposure to the COVID-19 surgical patients. The suspected staff means having a history of exposure 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.

Funding

This study was supported by grants from the National Natural Science Foundation of China (81471844), National Natural Science Foundation of Hebei (2020CB224) and the Fundamental Research Funds for the Central Universities (2042019kf0061).

CRediT authorship contribution statement

Jiabao Hou: Conceptualization, Methodology, Writing - original draft. Xing Wan: Software, Visualization. Qianli 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.

Acknowledgments

We acknowledge all health-care workers involved in the diagnosis and treatment of patients in Wuhan; we thank the surgical, imaging and clinical laboratory staff in our hospital for coordinating data collection for patients with COVID-19 infection.

Appendix A. Supplementary data

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

References

[1] National Health Commission of China, Report of novel coronavirus-infected pneumonia in China. http://www.nhc.gov.cn/xcs/yqfkdt/202002/261727a4be4c9d56821334f467.shtml, 2020. (Accessed 18 April 2020).
[2] P. Zhou, X.L. Yang, X.G. Wang, et al., A pneumonia outbreak associated with a new coronavirus of probable bat origin, Nature 579 (7798) (2020) 270–273, https://doi.org/10.1038/s41586-020-1217-1.
[3] D. Wang, B. Hu, C. Hu, et al., Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in wuhan, China, J. Am. Med. Assoc. 323 (11) (2020) 1061–1069, https://doi.org/10.1001/jama.2020.1585.
[4] Q. Li, X. Guan, P. Wu, et al., Early transmission dynamics in wuhan, China, of novel coronavirus-infected pneumonia, N. Engl. J. Med. (2020), https://doi.org/10.1056/NEJMc2001316.
[5] C. Del Rio, P.N. Malani, Novel coronavirus-important information for clinicians, J. Am. Med. Assoc. 323 (11) (2019) 1039–1040, https://doi.org/10.1001/jama.2020.1490, 2020.
[6] J. Wu, J. Liu, X. Zhao, et al., Clinical characteristics of imported cases of COVID-19 in jiangsu province: a multicenter descriptive study, Clin. Infect. Dis. (2020) cia199, https://doi.org/10.1093/cid/cia199.
[7] J. Chu, N. Yang, Y. Wei, et al., Clinical characteristics of 54 medical staff with COVID-19: a retrospective study in a single center in Wuhan, China, J. Med. Virol. (2020), https://doi.org/10.1002/jmv.25793.
[8] B. Bikdeli, M.V. Madhavan, D. Jimenez, et al., COVID-19 and thrombotic or thromboembolic disease: implications for prevention, antithrombotic therapy, and follow-up: JACC state-of-the-art review, J. Am. Coll. Cardiol. 75 (23) (2020) 2950–2973, https://doi.org/10.1016/j.jacc.2020.04.031.
[9] R. Agba, A. Abdall-Razak, E. Crossley, et al., STROCSS 2019 Guideline: strengthening the reporting of cohort studies in surgery, Int. J. Surg. 72 (2020) 156–165, https://doi.org/10.1016/j.ijsu.2019.11.002.
[10] National Health Commission of China, New coronavirus pneumonia prevention and control Program (5th edition). http://www.nhc.gov.cn/yzygj/s7653p/202002/3596894ac9b4204a79b8b981df4440.html, 2020. (Accessed 19 February 2020).
[11] W. Liang, W. Guan, R. Chen, et al., Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China, Lancet 21 (3) (2020) 335–337, https://doi.org/10.1016/S0140-6736(20)30066-0.
[12] D. Yang, M.C. Grant, A. Stone, et al., A meta-analysis of intraoperative ventilation strategies to prevent pulmonary complications: is low tidal volume Alone sufficient to protect healthy lungs? Ann. Surg. 263 (5) (2016) 881–887, https://doi.org/10.1097/SLA.0000000000001441.
[13] H. Chen, J. Guo, C. Wang, et al., Clinical characteristics and intraoperative vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records, Lancet 395 (10226) (2020) 809–815, https://doi.org/10.1016/S0140-6736(20)30359-5.
[14] C. Huang, Y. Wang, X. Li, et al., Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China, Lancet 395 (10223) (2020) 497–506, https://doi.org/10.1016/S0140-6736(20)30183-5.
[15] J. Curbelo, S. Luquerio Bueno, J.M. Galvan-Roman, et al., Inflammation biomarkers in blood as mortality predictors in community-acquired pneumonia admitted patients: importance of comparison with neutrophil count percentage or neutrophil-lymphocyte ratio, PloS One 12 (3) (2017), e0173947, https://doi.org/10.1037/jmv.2020.1069, https://doi.org/10.1016/j.jacc.2020.04.031.
[16] P. Kamar, M.K. Renuka, M.S. Kalaiselvan, et al., Outcome of noncardiac surgical patients admitted to a multidisciplinary intensive care unit, Indian J. Crit. Care Med. 21 (1) (2017) 17–22, https://doi.org/10.4103/0972-5299.198621.
[17] W.G. Melsen, M.M. Rovers, R.H. Groenwold, et al., Attributable mortality of ventilator-associated pneumonia: a meta-analysis of individual patient data from randomised prevention studies, Lancet Infect. Dis. 13 (8) (2013) 665–671, https://doi.org/10.1016/S1473-3099(13)70081-1.
[18] T. Wang, Z. Du, F. Zhu, et al., Comorbidity and multi-organ injuries in the treatment of COVID-19, Lancet 395 (10228) (2020) e52, https://doi.org/10.1016/S0140-6736(20)30558-4.
[19] P. Zhai, Y. Ding, X. Wu, et al., The epidemiology, diagnosis and treatment of COVID-19, Int. J. Antimicrob. Agents 55 (5) (2020) 105955, https://doi.org/10.1016/j.ijantimicag.2020.105955.
[20] P. Mehta, D.F. McAuley, M. Brown, et al., COVID-19: consider cytokine storm syndromes and immunosuppression, Lancet 395 (10229) (2020) 1033–1034, https://doi.org/10.1016/S0140-6736(20)30628-6.
[21] C. Qin, L. Zhou, Z. Hu, et al., Dysregulation of immune response in patients with COVID-19 in Wuhan, China, Clin. Infect. Dis. (2020) ciaa248, https://doi.org/10.1093/cid/ciaa248.
[22] M.H. Chan, V.W. Wong, C.K. Wong, et al., Serum LD1 isoenzyme and blood lymphocyte subsets as prognostic indicators for severe acute respiratory syndrome, J. Intern. Med. 255 (4) (2004) 512-518, https://doi.org/10.1111/j.1365-296.2004.01523.x.
[23] M. Zhang, Y. Gao, W. Zhao, et al., ACE-2/ANG1-7 ameliorates ER stress-induced apoptosis in seawater aspiration-induced acute lung injury, Am. J. Physiol. Lung Cell Mol. Physiol. 315 (6) (2018) L1015–L1027, https://doi.org/10.1152/ajplung.00163.2018.
[24] R.S. Wiener, Y.X. Cao, A. Hinds, et al., Angiotensin converting enzyme 2 is primarily epithelial and is developmentally regulated in the mouse lung, J. Cell. Biochem. 101 (5) (2007) 1278–1291, https://doi.org/10.1002/jcb.21248.
[25] R. Chen, Y. Zhang, L. Huang, et al., Safety and efficacy of different anesthetic regimens for parturients with COVID-19 undergoing Cesarean delivery: a case series of 17 patients, Can. J. Anaesth. 67 (6) (2020) 655-663, https://doi.org/10.1007/s12630-020-01630-7.
[26] H.F. Zhang, L. Bo, Y. Lin, et al., Response of Chinese anesthesiologists to the COVID-19 outbreak, Anesthesiology 132 (6) (2020) 1333–1338, https://doi.org/10.1097/ALN.0000000000003300.
[27] S.P. Adhikari, S. Meng, Y.J. Wu, et al., Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak period: a scoping review, Infect Dis Poverty 9 (1) (2020) 29, https://doi.org/10.1186/s40249-020-00646-x.
[28] M. Allam, S. Cai, S. Ganesh, et al., COVID-19 diagnostics, tools, and prevention, Diagnostics 10 (6) (2020), https://doi.org/10.3390/diagnostics10060409.