Special Diagnosis and Treatment for Patients with COVID-19

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6.1 Emergency Surgery

6.1.1 Principle of Handling COVID-19 Complicated with Emergency Surgery

Yong Zhang

For the patients diagnosed with COVID-19 complicated with emergency surgery, medical staff, on the one hand, need to formulate individualized treatment protocols in a timely manner in strict accordance with the diagnosis and treatment principles of emergency surgery; on the other hand, they need to carry out COVID-19 screening and treatment.

All emergency surgical patients in need of observation or hospitalization are subject to routine tests, including CT scan of lungs, SARS-CoV-2 nucleic acid
testing with nasopharyngeal swabs, IgM and IgG antibody detection and general laboratory tests. In addition to COVID-19 screening, relevant surgical workup is also required, such as B-mode ultrasound, radiography, and CT imaging evaluations. CT has a higher diagnostic value for surgical emergencies and can be completed simultaneously with the CT scan of lungs. The patients with higher possibility of surgery are recommended to receive relevant examinations at one time as early as possible, such as blood routine, blood biochemistry, coagulation function, pretransfusion examination, etc., to avoid increased risk of cross-infection due to multiple blood drawings. Vascular surgical acute abdomen mainly includes type B aortic dissection, abdominal aortic aneurysm, superior mesenteric artery dissection or thrombosis, and portal vein thrombosis. For the patients with acute abdomen due to vascular causes, aortic CTA and B-mode ultrasound of abdominal vessels must be performed in addition to other required routine surgical examinations.

Lung injury due to mechanical ventilation under anesthesia, surgical stress, postoperative pain, and difficulty in expectoration due to slow cough reflex may aggravate pulmonary inflammation or lead to the COVID-19 progression, especially for the patients with severe and critical COVID-19. However, in order to save lives in an emergency, the indications for emergency surgery must be fully controlled with adequate preparation and strict protection to avoid missing the best time for treatment. In addition to saving lives, reducing injury and protecting functions, surgeries must be designed with streamlined processes and shortened duration to avoid increasing the infection or exposure rate of medical staff. Preoperative discussions must be presided over by the doctors with associate senior titles or above, with the doctors on emergency duty from the surgery department, anesthesiology department, infectious disease department, operating room, etc. involved. Preoperative discussions may be done by telephone or video in the hospital to clarify the necessity of emergency surgery, anesthesia method, surgical approach and processes, possible problems and solutions [1].

Device preparation: The instruments, consumables, and drugs for surgeries should be prepared and placed in the operating room as much as possible depending on the type of surgery; the medical staff for surgeries should be designated and unrelated persons are not allowed for access; surgeries should be performed with disposable surgical kits, instruments, excipients, and consumables. For the patients with hemorrhagic surgical emergency, it is necessary to prepare sufficient blood for intraoperative use. The delivery personnel and channel are prepared in advance.

6.1.2 General Surgery (Including Vascular Surgery)

Yong Zhang

Acute abdomen in general surgery refers to rapid pathological changes in abdomen, pelvic cavity, retroperitoneal tissues, and organs, resulting in clinical syndromes mainly manifested as abdominal symptoms and signs accompanied by systemic
reactions, which is a common disease in emergency surgery and requires timely and effective treatment.

### 6.1.2.1 Nonsurgical Treatment

Acute abdomen patients infected with COVID-19 do not need emergency surgery since they have stable vital signs, mild local symptoms, no peritonitis, or active bleeding, such as acute simple appendicitis, acute simple cholecystitis, incomplete intestinal obstruction, etc., can be considered for outpatient observation or hospitalization to receive nonsurgical medical treatment including fasting for solids and liquids, GI decompression, anti-inflammatory therapy and nutrition support, and receive close observation of the changes in their conditions. Temporary nonsurgical treatment may be considered for the abdominal aortic aneurysm patients with no significant abdominal pain or mild abdominal pain, tumor diameter <5 cm on CTA, and superior mesenteric artery dissection or thrombosis without peritonitis. Conservative treatment or interventional embolotherapy is preferred to the advanced liver cancer patients with ruptured hemorrhage and mild simple splenic injury.

### 6.1.2.2 Surgical Treatment

Surgical treatment should be considered if nonsurgical treatment fails and the condition is progressively aggravated. The patients with significant abdominal signs, even diffuse peritonitis or massive active bleeding, must immediately step into the processes of emergency surgery once the indications for emergency surgery has been confirmed.

Intraoperative protection: In case that emergency surgery is required to the patients with COVID-19, all the contacts shall enter the negative-pressure operating room via a specific channel following level III preventive measures. Emergency surgery must be finished in a rapid and effective manner to reduce the time of operation and exposure of medical staff as far as possible while relieving the source of the patient's disease. Excised surgical specimens should be directly placed in double-sealed specimen bags and immersed in the fixative in the operating room. The specimen bags should be marked with “COVID-19” and then placed at the specified position. Strict disinfection of operating room, devices, and anesthesia machines should be timely performed after the surgery. For the patients who cannot be ruled out from COVID-19, it is also necessary to take standard protective measures in postoperative recovery period, especially when removing laryngeal masks and transferring with higher risk of exposure and infection. During the transfer, it is necessary to take surgical and ward elevators to avoid contact between the patients and other personnel.

Selection of anesthesia methods: For the patients not infected with COVID-19, anesthesia methods can be selected by routine, while for the patients with suspected and confirmed COVID-19, the anesthesia methods can be selected according to the patient’s condition, surgical method, and operation scale: ① For level-3 surgery such as appendectomy and repair of gastroduodenal perforation, epidural anesthesia can be applied for laparotomy, and the patient must wear a mask correctly during the anesthesia; ② For level-4 surgery such as colectomy, general anesthesia can be
applied, during which a laryngeal mask is recommended to establish an artificial airway to avoid increased risk of infection due to a large amount of aerosol in lungs excreted from the body as the conventional tracheal tube penetrates into the airway. Anesthetists must wear masks when performing tracheal intubation or removing the catheter to prevent airway secretion ejection caused by patient coughing.

Selection of surgical methods: Laparotomy should be applied as much as possible, as laparoscopic surgery that requires intubation under general anesthesia will increase the risk of cross-infection caused by aerosol excretion from the lungs; in addition, CO₂ pneumoperitoneum established by laparoscopic surgery may carry body fluids out of the abdomen, increasing the risk of aerosol transmission in the confined operating room, which may lead to the infection of medical staff if there is any improper operation [2].

Emergency surgery of gallbladder and biliary tract:

Percutaneous gallbladder drainage under local anesthesia can be considered for patients with acute cholecystitis and gallbladder empyema who are in very poor physical condition and cannot tolerate surgery at all. If the drainage effect is poor and the infection is aggravated, laparotomy should be timely performed.

For patients who can tolerate anesthesia and surgery, open cholecystectomy and/or bile duct exploration are preferred, with basic surgical process same as that of regular surgeries. However, since being susceptible to the interference of visual field and sense of touch when taking level III protective measures, surgeons should try to identify the bile duct structure during the surgery; if it is difficult to dissect the Calot’s triangle, partial cholecystectomy can be performed after gallstones are removed to avoid common bile duct injury.

The presence of gallstones in common bile duct should be carefully evaluated before and during the surgery to avoid omission. For patients in good pulmonary and general conditions with satisfactory anesthetic effect, intraoperative choledochoscopy is feasible, and a T tube should be placed after gallstone removal. For patients in critical condition who cannot tolerate a long period of surgery, the T tube can be placed for drainage immediately after the removal of most of gallstones. Potential intraoperative biliary problems should be considered for the patients with gallbladder diseases; it is still recommended to prepare the equipment and devices for bile duct exploration to reduce handling and time consumption.

For biliary obstruction caused by malignant tumors, PTCD is preferred. Surgical treatment can be considered in patients who fail to respond to conservative treatment and can benefit from choledochotomy and drainage after imaging evaluation.

Rupture hemorrhage of liver and spleen:

Blood loss and blood product consumption should be adequately assessed before the surgery to ensure a smooth channel for blood product delivery. Take preventive measures for blood splashing when opening the abdomen.

Since intraoperative vision is limited and operations are more difficult, the incision should be fully exposed, so as to find bleeding points as soon as possible for subsequent hemostasis.

Care should be taken to avoid omission or accidental injuries due to poor vision.

Type B aortic dissection and abdominal aortic aneurysm.
Minimally invasive endovascular surgery under local anesthesia + sedation: 
DSA-guided aortic endovascular stent-graft exclusion.
Superior mesenteric artery dissection or thrombosis.
Minimally invasive endovascular surgery under local anesthesia + sedation: 
DSA-guided superior mesenteric arteriography, and superior mesenteric artery 
stenting or catheter-directed thrombolysis according to the angiographic condi-
tions [3, 4].

Postoperative treatment: Closely observe the condition and change of drainage 
tube after surgery, monitor the patient’s body temperature, and regularly re-examine 
blood routine, procalcitonin, and C-reactive protein. Special attention should be 
paid to patients with fevers to timely identify the cause.

After surgery, patients with COVID-19 should receive simplified treatment as 
much as possible with efficacy guaranteed, so as to reduce the contact between doc-
tors and patients and avoid cross infection; only 1 caregiver is allowed, the access 
control should be strict, and visiting should be declined. The patients and caregivers 
should be required to take protective measures (publicity and education, correct 
wearing of masks, daily body temperature measurement) and sign a COVID-19 
informed consent form and a letter of commitment. As COVID-19 is mainly trans-
mittted by droplets and contact, all the medical staff, patients, and their families must 
wear masks correctly, and medical staff should take level III protective measures in 
strict accordance with the protection requirements when performing a short-distance 
operation or invasive operation. For patients inserted with nasal cannulas for oxygen 
inhalation or gastric tubes, appropriate masks should be selected to completely 
cover their mouths and noses as far as possible. Positive viral nucleic acid can be 
detected in the feces of patients with COVID-19, suggesting that COVID-19 may be 
transmitted by fecal–oral route. Therefore, disposable items, vomitus, feces, and 
drain fluid of patients with suspected or confirmed COVID-19 should be placed in 
double-sealed yellow garbage bags labeled as “COVID-19”, and then disposed as 
infectious medical wastes. Medical staffs and caregivers exposed to the patients 
with COVID-19 should be subjected to medical observation for 14 days in princi-
ple, and receive timely treatment in case of any discomfort.

6.1.3 Orthopedic Trauma

Yong Liu

COVID-19 has spread the world since December 2019 and now has become a pan-
demic [5, 6]. COVID-19 patients could develop other conditions such as orthopedic 
disease. For instance, those elderly, especially those with chronic diseases, are more 
likely to develop serious orthopedic diseases. In this special outbreak, hospitaliza-
tion for regular orthopedic patients should be avoided in general to decrease the risk 
of transmission, but operations are still necessary for some of them. This chapter 
shares some experience in the diagnosis and treatment of COVID-19 patients with 
traumatic and orthopedic disease.
First, people with chronic orthopedic diseases are not recommended for surgical treatment generally if the symptoms are not severe and bearable, such as lumbar disc herniation, femoral head necrosis. In those situations, selective surgery is preferable [7, 8]. The COVID-19 virus can directly damage the lungs, and cause inflammatory storms, attack lymphocytes that cause immune deficiency. As a result, the risk of surgery will increase, and surgeries become will be a huge threat to life. Therefore, we do not recommend surgery during the spread of COVID-19. However, we could treat pneumonia first until nucleic acid test becomes negative, symptoms like fever and cough disappear, IgG antibody is positive. After a further 14 days of quarantine after discharge, the patient could be admitted to the non-COVID-19 designated hospital after a repeat nucleic acid test and chest CT. Patients can be admitted and prepared for surgery only when the repeat tests are normal.

However, some patients may suffer from severe and even life-threatening disorders, such as fast-growing tumors not suitable for radiotherapy and chemotherapy, spinal cord compression in spinal stenosis which caused respiration difficulty and cauda equina syndrome, and acute joint infection which may cause shock. Under those circumstances, the symptoms could gradually develop and may lead to serious complications if proper surgery is not timely performed. For these patients, we should have a joint consultation with anesthesiologists, respiratory doctors and ICU doctors, and try our best to guarantee the safety of their lives. Moreover, minimal-invasive surgery is highly recommended, and the duration of operation should be shortened as much as possible. After the COVID-19 is cured, a second stage of operation could be further considered if needed.

If an emergency relevant to orthopedic disease occurred, conservative treatment is the first choice. For example, for those patients suffering from closed fractures without obvious vascular and nerve injury, we should try to choose noninvasive, rapid, and effective techniques such as close reduction, brace fixation, closed reduction external fixation, or homeopathic traction external fixation for fracture fixation. These strategies could restore limb length, correct deformity, achieve the purpose of reducing the patient’s pain. At the same time, try to satisfy the following three points: (1) Correct fracture deformity and maintain the basic counterpoint of fracture end; (2) Reduce the patient’s pain as much as possible and avoid obvious psychological discomfort; (3) Ensure a relatively stable fixation of the fracture end. For patients with active bleeding at the fracture end or who are over 65 years old and in poor physical condition, or patients with fracture types such as stable fractures of pelvis, supportive treatment should be included such as blood transfusion and so on.

During COVID-19’s bursting, emergent surgery is applicable to patients suffering from unstable vital sign, gradually developing symptoms and injuries so as to save life and body function, such as patients with open fractures combined with vessel and nerve injury, open reeducation for a major joint dislocation patient after a failed close reduction, unstable vertebrate fracture with developing spinal cord injury symptoms or even respiratory dysfunction caused by high-level cervical fracture. It is necessary to improve the relevant examination. In addition, before surgery, multiple departments such as respiratory department, intensive care unit, and anesthesiology department should coordinate the consultation to assess the patient’s
physical condition and surgical risk with surgeons. As lifesaving comes first, minimal-invasive and short-time surgery is also the first choice for surgeons when selecting the operation methods. Second stage surgeries to improve body functions such as internal fixation could be performed after the COVID-19 is cured. The anti-coagulant treatments are needed while with great caution for patients with active bleeding. In addition, activities of lower limbs should be encouraged to prevent deep venous thrombosis of lower limbs.

At last, we would like to make a notice that some lab tests are very important for doctors to predict the prognosis of the patients before and after surgery. As studies have indicated that plasma cytokine storm was associated with pulmonary inflammation such as IL-6, TNF-α, and so on [9]. Those cytokines such as IL-6 could further target immune cells such as regulatory T cells (Treg) [10]. As a result, patients are more vulnerable to poor prognosis. In our hand, we performed four surgeries on COVID-19 patients until now. Three patients recovered well, with relatively normal Il-6 level and lymphocyte counts before and after surgery (detail of one case at the end of the chapter). However, one old man aged 80 years died of acute respiratory dysfunction. He developed 50-fold increment of Il-6 level and a dramatic 60% decrease of lymphocyte counts after surgery. Although the invasive ventilation and various supportive treatments were performed, he passed away 9 days post surgery. Therefore, we greatly suggest that doctors should regularly check lymphocyte numbers, lymphocyte subgroups, and serum cytokines, especially IL-6 level. If there is an obvious abnormality of those results, doctors must pay very close attention and try to intervene as early as possible.

A Successful Case of Surgery on COVID-19 Patient with Thoracolumbar Fracture

On February 18, 2020, a patient with COVID-19 complicated with thoracolumbar fracture and incomplete paralysis was transferred to Wuhan Union Hospital. He initially presented to Wuhan Hanyang District Hospital after a convulsive episode and found himself unable to move lower extremities after that. The patient reported that when he was resting on the sofa on the day of initial presentation, he suddenly developed convulsion with teeth clenching and limb shaking, but symptoms resolved spontaneously after a few seconds. When he was trying to get up, he noticed back pain and was unable to move his lower limbs. He sought medical attention at Wuhan Hanyang District Hospital and was hospitalized, underwent Magnetic resonance image of thoracolumbar spine which showed 12th thoracic vertebra burst fractures, first lumbar vertebral compression fractures. Incidentally on the CT, it showed bilateral pulmonary exudative changes, indicating a possible COVID-19 infection.

On February 17, 2020, the patient developed a cough without fever, and throat swab nucleic acid test turned out to be positive later. There was also no improvement in his paralysis after conservative treatment in that hospital. Subsequently, he was transferred to the Wuhan Union Hospital for COVID-19 treatment.
At the time of presentation to Wuhan Union Hospital, the patient had stable vital signs, with body temperature 36.6 °C, blood pressure of 124/86 mm Hg, pulse rate 87/min, breathing rate 16/min, oxygen saturation 98% in ambient air and normal mentation. Physical examination revealed bilateral lungs coarse breath sounds with some rales. There was tenderness in the thoracolumbar spine, hyperalgesia below the level of bilateral groin area with left side more severely involved, preserved cremasteric reflex, no saddle anesthesia, and normal anal sphincter tone. As for muscle strength: bilateral flexion hip strength 1/5, left ankle dorsiflexion and toe extensor muscle 2/5, right ankle dorsiflexion, and toe extensor muscle strength 2+/5. The bilateral knee tendon reflexes and Achilles tendon reflexes were reduced, and pathological reflexes were not elicited. Both ASIA and Frankel’s spinal cord injuries were grade C per guideline.

From day 2 to day 9 of hospitalization, the patient’s vital signs remained stable, afebrile and pulse oximetry remained above 97%, cough also improved slightly. His hospitalization was complicated by the left common iliac vein thrombosis identified by venous duplex, for which an inferior vena cava filter was placed before the orthopedic surgery.

On February 22, 2020, the patient underwent surgery with posterior open reduction and pedicle screw internal fixation of thoracolumbar fracture with standard three-level protection of all personnel in the operation room. In the morning, a physician wearing level two personal protective equipment (PPE) transported the patient from quarantine ward to the entrance of the operating room, then the anesthesiologist and operating room nurse took over. After successful general anesthesia, the surgeon upgraded PPE from level 2 to level 3. The C-arm was used to locate the injured vertebra, followed by incision of the skin and subcutaneous fascia, kyphotic deformity of T12 and L1 was seen. Screws and longitudinal rod were placed from T11 to L2 and retracted, with the kyphosis deformity resolved. The incision was rinsed with saline multiple times, and vancomycin was evenly sprinkled on the incision. After surgery, patient was transferred to ICU for recovery from general anesthesia. The whole operation lasted 2 hours and 43 min.

On post operation day 1, the patient was transferred from ICU back to the general quarantine ward. His vital signs remained stable, afebrile. Anti-inflammatory and analgesic medications were given. There were no signs of infection or abscess formation around the wound. Spinal cord function was evaluated on Post-op day 3: The hyperalgesia of both lower limbs was significantly alleviated, muscle strength gradually improved to 4/5, he could almost stand up with some assistance 3 weeks after surgery.

During the postoperative period, to understand the 2019nCoV, we checked patients’ lymphocyte subsets, plasma cytokines, and 2019-nCoV antibodies. On the 3rd, 6th, and 14th day after the operation, the 2019-nCoV nucleic acid test was all negative, his cough resolved, remained afebrile, and an oxygen saturation of 98%. Repeat CT of thoracolumbar spine revealed that the lung exudation was absorbed, and the spinal reduction appeared satisfactory. He was discharged 3 weeks after surgery.
6.2  Pediatric Diagnosis and Treatment

Fang Zheng

Based on the existing epidemiological data, the incubation period of SARS-CoV-2 infection in children is between 1 and 14 days, mostly ranging from 3 to 7 days. It has been reported that the present data supports the possibility of maternal–fetal transmission [11]. Ninety percent of children have relatively mild clinical manifestations, without fever or pneumonia, and mostly recover within 1–2 weeks [12].

6.2.1 Diagnosis [13, 14]

Suspected case: Those with 1 epidemiological history plus 2 clinical manifestations.

Confirmed case: Suspected cases with one of the etiological diagnosis items.

Clinical classifications: There are five types of COVID-19 based on severity, including asymptomatic infection, acute upper respiratory tract infection, mild pneumonia, severe pneumonia, and critical cases, see Table 6.1.

6.2.2 Differential Diagnosis

It is mainly differentiated from other pathogen infections.

6.2.3 Treatment

The principle of treatment in children is the same as that of COVID-19 in adults, but the following matters should be paid attention to during the treatment of children:

6.2.3.1 Symptomatic Treatment

Acetaminophen and ibuprofen are recommended to control the active hyperpyrexia at the appropriate dosage, but should not be used in combination. Aspirin is not recommended as antipyretics. For patients with increased airway secretions, expectorants can be taken orally or by aerosol inhalation to dilute secretions to facilitate coughing up. Antitussive drugs should be used with caution. For patients with diarrhea, fluid replacement, probiotics, intestinal mucosal protective agents, and zinc supplementation should be given as supportive treatment, but antidiarrheal drugs should be used with caution.
### 6.2.3.2 Antiviral Therapy

There is no specific antiviral drug. At present, interferon α spray or aerosol inhalant is recommended; since the efficacy of anti-influenza drugs including Abidol and Oseltamivir remains to be clarified, attention should be paid to their adverse reactions such as nausea, diarrhea, elevated liver enzyme and bradycardia during trial.

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#### Table 6.1  Clinical types of COVID-19 in children

| Evaluation item            | Asymptomatic infection | Acute upper respiratory tract Infection | Mild pneumonia | Severe pneumonia |
|----------------------------|------------------------|----------------------------------------|----------------|-----------------|
| General condition          | Good                   | Good                                   | Good           | Poor            |
| Consciousness disturbance  | No                     | No                                     | No             | Yes             |
| Hypoxemia                  | No                     | No                                     | No             | Cyanosis; shortness of breath: <2 months of age, respiratory rate (RR) ≥60 times/min; 2–12 months of age, RR ≥50 times/min; 1–5 years of age, RR ≥40 times/min; >5 years of age, RR ≥30 times/min, except for the effects of fever and crying. Assisted respiration (moaning, flaring nares, three concave sign). Intermittent apnea. Oxygen saturation < 92% |
| Fever                      | No                     | Severe case criteria not met            | Severe case criteria not met | Hyperthermia for ≥5 days |
| Dehydration signs/apastia  | No                     | No                                     | No             | Yes             |
| Chest CT                   | No                     | No                                     | Severe case criteria not met | Bilateral pulmonary infiltrates or multilobar infiltrates, with rapid progression within 24–48 h, or pleural effusion |
| Extrapulmonary complications | No                     | No                                     | No             | Yes             |
| Diagnostic criteria        | All of the above       | All of the above                       | All of the above | Any of the above |

Note: Critical and severe cases meet one of the following conditions: ① respiratory failure, requiring mechanical ventilation; ② shock; ③ combined with organ failure of other systems, needing admission to PICU for treatment.
6.2.3.3 Antibacterial Drugs
Avoid mindless or inappropriate use, especially in combination with broad-spectrum antibacterial drugs, chloramphenicol, tetracyclines, sulfonamides, and aminoglycoside antibiotics should be avoided. For patients with liver and renal function impairment, the dose should be adjusted according to the degree of impairment.

6.2.3.4 Immunotherapy
Glucocorticoids can be used for a short period of time (3–5 days) for severe and critical cases at a recommended dose not exceeding the equivalent of 1–2 mg/(kg.d) of methylprednisolone; human immunoglobulin may be considered as appropriate, but the efficacy still needs further evaluation.

6.2.3.5 Treatment of Neonatal Critical and Severe Cases [15]
Effective organ function supportive therapy is performed on the basis of symptomatic treatment. For children in critical condition manifesting as “white lung”, high-dose pulmonary surfactant, nitric oxide inhalation, and high-frequency oscillatory ventilation may be effective; glucocorticoids should be used with caution; 2 g/kg of gamma globulin should be administered in divided doses; CRRT and ECMO can be performed if necessary.

6.3 Rational Use of Antibacterial Drugs
Yu Zhang, Yuyong Su and Xuefeng Cai

Viral infection can cause serious damage to respiratory defense mechanism, weaken the bacterial clearance ability of the body, thus easily leading to secondary bacterial infection. It has been reported [16] that the majority of COVID-19 patients received antibacterial therapy [16]. How to avoid blindly or inappropriately using antibiotics is of crucial importance.

6.3.1 Strictly Grasps the Indications for Antibiotics Usage to Avoid Blindly or Inappropriately Using [17]

In general, antibiotics are not used for mild and moderate patients. Moderate patients may develop into a severe condition due to any of the following factors: (1) persistent high fever; (2) advanced in years (over 60 years old); (3) with severe underlying diseases; (4) significant progression of lesions >50% within 24–48 h on pulmonary images; and (5) immunosuppressed individuals. Such patients need to be checked for the infection indicators such as white blood cell (WBC), neutrophil percentage, C-reactive protein (CRP) and procalcitonin (PCT) in hemogram and evaluated for possible etiology. If there is no evidence of
infection, do not prescribe antibiotics and instead of dynamically observing the changes of infection indicators.

For moderate patients who may develop into severe type, it is necessary to identify whether there are risk factors for drug-resistant bacterial infection (out-of-hospital use of broad-spectrum antibacterial drugs for at least 3 days, structural lung disease, and positive culture of drug-resistant bacteria in airway secretions). In the absence of the above risk factors, it is recommended to select β-lactams + macrolides or respiratory fluoroquinolones alone according to the Guidelines for the Diagnosis and Treatment of Adult Community Acquired Pneumonia in China (2016 Edition) [18]. Empirical use of the antibacterial drugs for special use such as glycopeptides, carbapenems, and oxazolidinones is not recommended; if necessary, there should be laboratory evidence of bacterial infection and a consultation for the antibacterial drugs for special use. Sputum smears for bacterial and fungal staining and cultures and blood G + GM tests should be rechecked in patients who experience recurrent, long-lasting course of disease, or persistent lymphopenia. Anti-aspergillus drugs may be taken if necessary.

For severe and critical patients [19, 20]: Routine prophylactic use of antibacterial drugs, especially in combination with broad-spectrum antibacterial drugs, is not recommended. Third-generation cephalosporins/enzyme inhibitor complexes may be used empirically in patients confirmed to be complicated with bacterial infections. For patients with disease course of more than 2 weeks or low lymphocyte count, the presence of bacterial infection cannot be assessed by procalcitonin (PCT) and C-reactive protein (CRP) alone. Comprehensive judgment should be made in combination with body temperature, white blood cell count (WBC), neutrophil percentage, pulmonary imaging, and oxygenation function.

For patients in critical condition subject to airway opening such as invasive mechanical ventilation or extracorporeal membrane oxygenation (ECMO): They are susceptible to bacterial infections and fungal infections at a later stage [19]. For patients with septic shock, antibacterial drugs can be used empirically in combination before obtaining the etiological diagnosis, covering the most common infections with Enterobacteriaceae bacteria, *Staphylococcus*, and *Enterococcus*. β-Lactamase inhibitor complexes can be applied for those who experience infection after hospitalization. In case the therapeutic effect is poor, or the patient has severe septic shock, carbapenems can be used instead. If combined with enterococcal or staphylococcal infections are considered, empirical treatment with glycopeptides may be performed, and oxazolidinones can be applied if pulmonary infections are predominant. Catheter-related infections should be highly emphasized, methicillin-resistant *Staphylococcus* should be empirically covered for treatment, and glycopeptides can be selected for empirical treatment. Since some patients in critical condition often experience secondary fungal infections in the late stage, triazoles or echinocandin antifungal drugs can be used, but the combination of the two antifungal drugs is not recommended.
6.3.2 Identify the Pathogen of Secondary Infection as Early as Possible, and Select Antibacterial Drugs According to the Pathogen Types and Drug Sensitivity Test Results

Before the administration of antibacterial drugs, reasonable etiological examination and specimen sampling should be arranged for hospitalized patients to identify the pathogen and drug sensitivity results as soon as possible. When the etiological examination yields a significant positive result, target therapy (de-escalation therapy) should be performed [18, 21]. Drug sensitivity test of outpatients should be performed based on their conditions.

Before no pathogen and drug sensitivity results are obtained, initial antimicrobial therapy should be empirically performed according to the place of onset, primary lesion, age, underlying disease, clinical characteristics, laboratory and imaging examinations, disease severity, liver and renal functions, previous medications, possible pathogens, and drug resistance risk factors of patients.

Attention should be paid to the patient’s history of antibacterial drug use, and the assessment of the effect of previous medications can assist in the identification of infectious pathogens [22].

Molecular biological techniques such as high-throughput sequencing, which can improve the sensitivity of pathogen detection and shorten the detection time, can be prudently used for etiological detection of secondary infections according to the situation of medical institutions [21].

After obtaining the results of pathogen detection, colonized bacteria should be distinguished from pathogenic bacteria according to the patient’s condition and therapeutic effect to assess the significance of positive pathogen culture [21, 23, 24].

6.3.3 Develop an Antibacterial Drug Treatment Plan in Combination with Patient’s Condition, Types of Pathogens, and Characteristics of Antibacterial Drugs

The appropriate dose of antibacterial drugs should be selected according to the site of COVID-19 secondary infection. For severe infections (sepsis, infective endocarditis, etc.), the antibacterial drugs should be given at a larger dose; while for secondary urinary tract infections, the drugs should be given at a lower dose.

The administration times of antibacterial drugs should refer to their PK/PD characteristics [25]. For time-dependent antibacterial drugs (such as penicillins, cephalosporins, monocyclic β-lactams, and carbapenems), better clinical efficacy can be achieved by multiple doses per day according to the half-life. Concentration-dependent antibacterial drugs (such as aminoglycosides, quinolones) are usually administered once a day.

The administration method of antibacterial drugs should follow the WHO medication principle of “drugs that may be taken orally shall not be administered by intramuscular injection, and drugs that may be administered by intramuscular injection shall not be done by infusion.” For patients with mild secondary bacterial infection, oral anti-infective drugs with higher bioavailability should be selected as far as possible.
Laboratory test results and the response to initial antibacterial therapy should be timely reassessed after the administration of antibacterial drugs, continuation of antibacterial therapy or adjustment of antibacterial therapy regimen will be determined based on the assessment results.

During the treatment, attention should be paid to the identification of the source of secondary infection, which should be removed in time. For example, the catheter should be timely removed in case of catheter-related bloodstream infection, and urinary catheter should be timely removed in case of urinary catheter-related urinary tract infection.

6.4 Anti-Interleukin-6 Antibody Therapy

Yong Gao

Cytokine storm, such as typically with interleukin 6 (IL-6) elevations, is an important cause of death in COVID-19 patients in critical and severe conditions. Thus, antagonism of IL-6 elevation and inhibition of the generation of inflammatory factor storm become an important method for the COVID-19 treatment in critical and severe patients. Tocilizumab is a recombinant humanized anti-human IL-6 receptor monoclonal antibody currently used to treat adult patients with moderate-to-severe active rheumatoid arthritis who have had an inadequate response to disease-modifying antirheumatic drugs. Therefore, tocilizumab is expected to treat COVID-19 patients in critical condition.

6.4.1 Evaluating Indications for Medication [26–29]

6.4.1.1 Applicable Population

(a) Patients confirmed with moderate NCP (including high-risk factors for severe cases) and severe NCP
(b) Patients aged 18–85 years
(c) Patients with elevated IL-6 (recommended to be tested by Roche electrochemiluminescence)

Note: Moderate NCP (including high-risk factors for severe cases): Moderate NCP with bilateral pulmonary multiple lesions, or significant progression of lesions showed on pulmonary images >50% within 24–48 h.

6.4.1.2 Non-applicable Population

(a) Pregnant or lactating women
(b) Patients with ALT/AST >5 times ULN, neutrophils <0.5 × 10⁹/L, platelets <50 × 10⁹/L
(c) Patients confirmed with rheumatoid immune disease, malignant tumors, and other related diseases
(d) Patients orally taking antirejection drugs or immunomodulatory drugs for a long time
(e) Patients allergic to tocilizumab or any of the excipients
(f) Patients with active hepatitis and tuberculosis complicated with definite bacterial infection and fungal infection
(g) Organ transplant patients
(h) Patients with mental disorders

6.4.2 Signing the Informed Consent Form

Informed consent form must be signed by all patients before receiving anti-human IL-6 receptor monoclonal antibody treatment.

6.4.3 Use of Tocilizumab Dosing Regimen [26–29]

The initial dose is 4–8 mg/kg. The recommended subsequent dose is 400 mg into 100 ml of normal saline for infusion over 1 h. For febrile patients, it continues to be febrile after usage within 24 h, a second dose with the same dosage can be applied at an interval $\geq 12$ h; the maximum number of cumulative doses is twice, and the maximum single dose is no more than 800 mg.

6.5 Convalescent Plasma Therapy

Yong Gao

Convalescent plasma therapy [30–34] is a very effective and important method for severe and critical cases. Convalescent plasma therapy has been included in the fifth edition of the Diagnosis and Treatment Plan, and further refined in the sixth and seventh edition of the plan. Convalescent plasma therapy refers to reduce the virus content in patients by virus-specific antibodies of a certain titer in the plasma of survivors, so as to achieve the anticipated therapeutical purpose. At present, the treatment of existing cases has shown good efficacy in clinical practice. The convalescent plasma is subject to strict quality control requirements from its collection, preparation, and storage to clinical application.

6.5.1 Collection

COVID-19 survivors who voluntarily donate plasma should not only meet the common health requirements for voluntary blood donation, but also follow the corresponding procedures, and meet the criteria for release from isolation and discharge in the COVID-19 Diagnosis and Treatment Plan (Version 6):
Collecting subjects: Post recovery and discharge >14 days, no fever or other medical history, no history of hazard exposure or close contact within 14 days; age 18–55 years; male weight > 50 kg, female weight > 45 kg; glucocorticoid withdrawal ≥1 week; interval from the previous plasma collection >14 days; no blood-borne diseases; being able to donate plasma as assessed by clinicians.

Collection method: Single collection; 200–400 mL of plasma is collected from a donor each time according to the donor’s own willingness as determined by clinicians evaluation; the medical staff should closely observe the conditions of donors on the spot. In case of adverse reactions, the reactions will be timely prevented and treated according to the conditions on the spot.

Post-collection test: In addition to general quality test and the tests related to blood-borne diseases, plasma samples should also be submitted for test:

1. Single-sample detection of SARS-CoV-2 nucleic acid: negative.
2. It is recommended that the IgG antibody titer in SARS-CoV-2 serum should be no less than 160. The virus neutralization test can be applied, or the sample should be diluted by negative plasma by 160 times before testing to determine the total antibody level.

6.5.2 Clinical Indications of Convalescent Plasma Therapy

It is suitable for COVID-19 patients in severe and critical conditions with rapid disease progression and disease course of less than 7 days as follows:

1. Age ≥ 18 years.
2. COVID-19 patients confirmed by PCR, with positive nucleic acid within 48 h after plasma therapy.
3. Rapid disease progression or clinical indications conforming to severe case criteria.
4. Critical and severe patients must also meet the following:
   (a) Mechanical ventilation ≤ 48 h.
   (b) Creatinine clearance >50 Ml/min; ALT/AST <2× upper limit of normal; cTNI <2× upper limit of normal.
   (c) IL-6 and/or IL-2 < 2× upper limit of normal.

6.5.3 Inappropriate Clinical Indications

1. Patients who refuse to sign the informed consent for plasma therapy.
2. Patients under the age of 18 years.
3. Pregnant and lactating women.
4. Patients with the history of allergy to plasma infusion, sodium citrate, methylene blue, and immunoglobulin.
5. Patients with the history of autoimmune diseases and selective IgA deficiency.
6. Patients with severe underlying diseases.
7. In areas where conditions permit, high-titer COVID-19-RBD antibodies can be detected.

6.5.4 Infusion Dose

Usually, 100–500 mL (4–5 mL/kg body weight) of infusion may be given once or in two divided doses, depending on the clinical condition, the patient’s weight, etc.

6.5.5 Principle of Infusion

Blood type: The blood of the same type (ABO) is preferred, followed by the blood of compatible types.

Infusion rate: Slowly first and then faster, no more than 20 drops/min in the first 15 min. If there is no discomfort, the infusion can be adjusted to the normal rate. Observe closely during the infusion; suspend or stop the infusion if any adverse reactions occur.

6.6 Traditional Chinese Medicine

Rui Chen

6.6.1 Period, Pattern, and Syndrome Differentiation

According to the COVID-19 Diagnosis and Treatment Plan (Trial Version 7) [35] issued by the National Health Commission of the People’s Republic of China, COVID-19 can be divided into the cases in medical observation period and the cases in clinical treatment period. The cases in the medical observation period refer to preventive or suspected cases, which are divided into the cases with predominance of wetness and predominance of heat; while the cases in the clinical treatment period referring to confirmed cases, are divided into mild, moderate, severe, critical, and convalescence cases based on syndrome differentiation. Mild cases are divided into cold-damp constraint in the lung pattern and damp-heat accumulation in the lung pattern, moderate cases into damp-toxin constraint in the lung pattern, severe cases into epidemic toxin blocking the lung pattern and blazing of both qi and ying pattern. Critical cases only refer to internal blockage and external desertion pattern, and convalescence cases are divided into lung–spleen deficient qi pattern and qi-yin deficiency pattern.
6.6.2 Pattern Identification and Treatment

Cases with predominance of wetness in medical observation period: It mainly manifests as fatigue with gastrointestinal discomfort, which should be treated with *Huoxiang Zhengqi oral liquid*.

Cases with predominance of heat in medical observation period: It mainly manifests as fatigue with fever, which should be treated with *Lianhuaqingwen* capsules.

Universal formula in clinical treatment period: It is applicable to the diagnosed patients at all stages; they can be treated with No. 1 formula of the Wuhan Union Hospital (West Campus) which is same as the *QingfeiPaiduGranule* (Decoction), if their syndromes cannot be timely differentiated.

Cold-damp constraint in the lung pattern of mild cases in clinical treatment period: It mainly manifests as fever, poor appetite, loose stool, pale enlarged tongue with white, thick and greasy coating, which should be treated with No. 2 formula of the Wuhan Union Hospital (West Campus) combined with *Maxing Yigan* Decoction, *Dayuan* Decoction, and Peptic Powder.

Damp-heat accumulation in the lung pattern of mild cases in clinical treatment period: It mainly manifests as fever, sore throat, muscle pain, nausea, and light red tongue with thin and yellow coating, which should be treated with No. 5 formula of the Wuhan Union Hospital (West Campus), i.e., *JinqiangXuanfeiJiedu* Mixture.

Damp-toxin constraint in the lung pattern of moderate cases in clinical treatment period: It mainly manifests as fever, chest tightness, and distressed cough with little sputum, constipation, dark-red, and enlarged tongue with yellow greasy or dry coating, which should be treated with the No. 1 formula of Wuhan Union Hospital (West Campus) at double dose.

Cold-damp obstructing the lung pattern of moderate cases in clinical treatment period: It mainly manifests as low fever, fatigue, stuffy feeling in chest, vomiting, loose stool, and pale tongue with white and greasy coating, which should be treated with the No. 2 formula of Wuhan Union Hospital (West Campus) at double dose.

Severe toxin lung-blocking pattern in clinical treatment period: It mainly manifests as fever, cough with little sputum or blood-stained sputum, tachypnea and short of breath, constipation, and red tongue with yellow and greasy coating, which should be treated with the No. 3 formula of Wuhan Union Hospital (West Campus) composed of *Maxingshigan* Decoction, *HuopuXialing* Decoction, *raw rhubarb*, *astragali radix*, *semen lepidii*, and *red paeony root*.

Blazing of both *qi* and *ying* pattern of severe cases in clinical treatment period: It mainly manifests as high fever, polydipsia, tachypnea, unconsciousness, bleeding or convulsion, and crimson tongue with little coating, which should be treated with *Baihu* Decoction combined with *ShuinujiadoDihuang* Decoction.

Internal blockage and external desertion pattern of critical and severe cases in clinical treatment period: Mechanically ventilated patients, mainly manifested as unconsciousness, sweating, cold extremities; the pulse is floating and large without root; the patients should be treated by taking *Storax* Pills or *AngongNiuhuang* Pills with the No. 6 formula (*Ginseng* 15 g, *Radix AconitiPraeparata* 10 g, *Cornus*...
officinalis 15 g) of Wuhan Union Hospital (West Campus). In case of constipation or patient-ventilator asynchrony, dissolve 10 g of Raw Rhubarb powder with warm water for intragastric administration.

Lung–spleen qi deficiency pattern of convalescence cases in clinical treatment period: It mainly manifests as shortness of breath, fatigue, poor appetite, loose stool, and pale tongue with white coating during convalescence, which should be treated with the No. 4 formula of Wuhan Union Hospital (West Campus), combined with XiangshaLiujuanzi Decoction.

Qi-yin deficiency pattern of convalescence cases in clinical treatment period: It mainly manifests as shortness of breath, fatigue, dry mouth, dry cough, and red tongue with scant liquid, which should be treated with WuyeLugen Decoction or 50 ml of warm water diluted Shengmai injection for oral use.

The above formulas and decoctions are selected according to the corresponding patterns, 1 dose per day, decocted in water for oral dose, 2–4 times a day, 100–200 ml each time according to the condition.

6.6.3 Use of Chinese Patent Medicine Injection

Viral infection or complicated with mild bacterial infection: 0.9% sodium chloride 250 ml plus Xiyanping injection 100 mg, bid, or 0.9% sodium chloride 250 ml plus Reduning injection 20 ml, or 0.9% sodium chloride 250 ml plus Tanreqing injection 40 ml, bid.

High fever with altered mental status: 0.9% sodium chloride injection 250 ml plus Xingnaojing injection 20 ml, bid.

Systemic inflammatory response syndrome or/and multiple organ failure: 0.9% sodium chloride injection 250 ml plus Xuebijing injection 100 ml, bid.

Weakness and dry mouth: Shenmai Injection 100 ml, bid, or Shengmai Injection 20–60 ml, bid.

Shock and cold extremities: 0.9% sodium chloride injection 250 ml plus Shenfu injection 100 ml, bid; when shock occurs, 50 ml Shenfu injection can also be pumped.

6.6.4 Precautions for Use of Chinese Patent Medicines

1. Generally, among the same type of Chinese patent medicine injections, only one is used.
2. Traditional Chinese medicine injections can be used in combination with traditional Chinese medicine decoctions, capsules, and granules.
3. Since Xuebijing injection has a risk of bleeding, it should be used with caution when there is a tendency to bleed.
4. Only Shenfu injection should be used in shock, and Chinese patent medicines such as Xiyanping and Tanreqing should not be used in combination.
5. If it has been determined that the allergy, liver and renal dysfunction are caused by the traditional Chinese medicine, please discontinue the drug in time and provide with symptomatic treatment.

6. The use of traditional Chinese medicine injections should follow the package insert and the principle of starting from a small dose and gradually adjusting based on syndrome differentiation.

6.6.5 Typical Cases Treated with the Combination of Traditional Chinese Medicine and Western Medicine

Mr. Zhu, male, 69 years old. W8 West Ward 41.

He complained of “fever and cough for 12 days” and was admitted to the hospital on February 10, 2020, with “COVID-19.” At the time of TCM intervention, he had been hospitalized for 7 days and had an onset of 19 days.

History of present illness: The patient had fever, cough, and other symptoms without obvious etiology 12 days ago, with the Tmax of 39.2 °C. Then, the cough was progressively aggravated without temperature change, accompanying with coughing, and a small amount of blood-stained sputum. No obvious fatigue, chest distress, nasal congestion, shortness of breath, sore throat, diarrhea, abdominal distension, abdominal pain, urination discomfort, etc. The patient visited the Wuhan Union Hospital, and was given oral antiviral drugs after relevant examinations. After that, the symptoms were not improved markedly. The cough was aggravated recently and dyspnea was observed. On February 5, CT showed bilateral pulmonary multiple diffused thin patchy shadows. Infection was taken into consideration, not excluding viral pneumonia. Nucleic acid testing showed double positive. He was admitted to our hospital with diagnosis of “COVID-19.”

Past medical history: Denied any history of chronic diseases.

Treatment process: After admission, he received western medicine treatment, including oxygen therapy, ribavirin antiviral therapy, meropenem antibacterial therapy, methylprednisolone anti-inflammatory therapy, Xuebijing treatment of systemic inflammatory response, and nutrition support therapy. However, with the respiratory support gradually increasing, the improvement was not significant. Assisted ventilation with a small noninvasive ventilator for home use was applied before TCM treatment, IPAP 20 cmH2O, EPAP 4 cmH2O, FiO2 80%. ECG monitoring: HR 90 bpm, SpO2 92%, R25 times/min, Bp 130/70 mmHg.

Current symptoms: Alert but low spirit, shortness of breath, dry mouth, no fever, stool once every 2–3 days, yellow urine, dark red tongue with yellow, thick and dry coating, and slippery and rapid pulse.

After TCM consultation, it was considered that damp-heat epidemic toxin and sputum stasis are stagnated in the lungs, which was planned to be treated with HuayuJieDu Decoction (No.3 formula of Wuhan Union Hospital, West Campus) at 3 doses, one dose per day; it was decocted in water, and take 500 ml of warm liquid for intragastric administration at five times, 100 ml each time.
Subsequent visit on February 20: After the medication for 2 days, cough and suffocation were improved, with respiratory support gradually reduced. Relevant re-examination situation as this given in figures. The tongue was slightly dark red with yellow and thick coating significantly improved, and the pulse was rapid. Take another 3 doses. The administration method we same as before.

Subsequent visit on February 23: The patient stated that the symptoms were relieved, yet SpO2 was 94%. Recently, the doctor of western medicine suggested to adopt intubation assisted ventilation instead for many times since it was difficult to reduce the ventilator support; the doctor of traditional Chinese medicine suggested suspending since the patient complained that the symptoms were relieved, who found that the dark red tongue was slightly aggravated while the coating was improved. The patient continued to take another 3 doses of HuayuJiedu Decoction.

Subsequent visit on February 26: The patient reported that the symptoms were relieved, which was most obvious after the administration of traditional Chinese medicine, SpO2 was 99%, and the support of ventilator was downregulated. The doctor of Western medicine canceled the suggestion of intubation assisted ventilation, and then the patient took the HuayuJiedu Decoction for more than half a month. By March 20, the patient’s shortness of breath and chest distress were significantly improved, and nasal cannula oxygen administration was used instead, with SpO2 being 99%. Then the formula was changed to No.4 formula (convalescence) of Wuhan Union Hospital (West Campus) for body conditioning.

6.7 Bronchoscopy

Jianchu Zhang

Bronchoscopy has unique advantages in respiratory infectious diseases and in assisting airway management of critical patients. However, as COVID-19 has become a respiratory infectious disease of global concern, bronchoscopic diagnosis and treatment of such disease must follow strictly isolation and protection standards to reduce the risk of infection for medical staff. Therefore, bronchoscopy is not recommended as a routine examination for 2019-nCoV viral sampling [36]. As summarized from what we have conducted bronchoscopy during diagnosis and treatment, bronchoscopy has the following values in the diagnosis and treatment of COVID-19 patients:

1. Assist in the establishment of artificial airways and guide tracheal intubation or percutaneous tracheotomy.
2. Assist to manage the artificial airways, including sputum suction, removal of blood scab, and relief of airway obstruction.
3. Obtain samples from the lower respiratory tract to improve the positive rate of PCR testing and the accuracy of pathogen culture, and to reasonably guide the use of antibacterial drugs.
4. Assist in local treatment via bronchoscope with infusion of α-interferon and N-acetylcysteine.
Requirements for the personal protection and in the operation room: (1) When medical staffs operate bronchoscopy during diagnosis and treatment for COVID-19 patients, they are recommended to wear positive-pressure hoods in addition to level III protective measures [37]; (2) We should conduct the bronchoscopy in negative pressure wards as much as possible. For those without such conditions, it is recommended to provide well-ventilated separate rooms where are preferably equipped with air disinfectors of good performance.

In case the bronchoscopy is proposed to COVID-19 patients, medical staff should fully consider whether the patient has the indications and contraindications for the procedure, as well as the purpose and necessity of the procedure. However, the patients with established artificial airway have relatively few contraindications for the procedure. In the following cases, it is necessary to operate gently with caution to reduce the relevant complications during the procedure: (1) extremely unstable vital signs; (2) platelet count <20 × 10^9/L; the procedure also can be performed after platelet transfusion; (3) malignant arrhythmia, unstable angina pectoris, and hypertensive crisis; (4) intracranial hypertension, etc.

Bronchoscope selection [38]: In order to reduce the risk of infection for medical staff during the procedure, avoid the influence of protective articles on visual field. Portable bronchoscopes or disposable bronchoscopes with display screens should be selected.

Specimen collection: (1) For COVID-19 patients who have not established artificial airway, bronchoscopy is not recommended as a routine operation for infection sampling; (2) For COVID-19 patients with established artificial airway, bronchial secretion, or bronchoalveolar lavage fluid samples can be obtained by bronchoscopy, thus to monitor the load of SARS-CoV-2 and examine whether it is complicated with bacterial, fungal, and other viral infections, assisting to guide clinical medications. There is no guideline for bronchoalveolar lavage in COVID-19 patients. Severe imbalance of ventilation/perfusion ratio (V/Q) is found in critical patients. So a large amount of bronchoalveolar lavage may lead to further aggravation of hypoxia or spread of infection. With reference to the Chinese Expert Consensus on Pathogen Detection of Bronchoalveolar Lavage in Pulmonary Infectious Diseases (2017 Edition) [39], the total amount of lavage is 60–120 ml (20 ml each time). (3) Specimens are stored and submitted for testing: Specimens should be submitted on ice as soon as possible after collection; they should be stored at room temperature for ≤30 min, at 4 °C for ≤4 h, and at −70 °C for >4 h. Sealed specimens should be placed in transfer boxes for infectious virus samples loaded with dry ice for transport by specially assigned person, to ensure that the specimens are still covered with dry ice when delivered to the testing institution (to prevent the degradation of RNA virus) [40].

For COVID-19 patients with established artificial airway, the requirements of anesthesia and ventilator setting for bronchoscopic diagnosis and treatment are as follows: (1) sedation and analgesia: In order to avoid aerosol generation caused by patient coughing and reduce the damage to the airway during operation, deep sedation, and muscle relaxant when necessary, may be given to the patients to improve patient–ventilator asynchrony; (2) ventilator setting during operation: (1) select volume-controlled ventilation (VCV or V-A/C); (2) PEEP: PEEP needs to be reduced to 6 cm H₂O, or be turned off when necessary; (3) FiO₂: set as 100%.
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