THE ORTHOPAEDIC FORUM

COVID-19 Orthopaedic Safe Care Toolset

Guidelines for the Diagnosis and Management of Patients with Fracture and COVID-19

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Abstract: The SARS-CoV-2 (severe acute respiratory syndrome-coronavirus 2) was reported in Wuhan, Hubei Province, People's Republic of China, and, subsequently, in other provinces and regions across the People's Republic of China and >212 countries. COVID-19, the disease caused by this coronavirus, was declared a worldwide pandemic by the World Health Organization (WHO). The incidence of patients with fracture who are also positive for COVID-19 is on the rise. The diagnosis and management of such patients can be complicated as their clinical characteristics are heterogeneous. Furthermore, a surgical procedure can be particularly challenging given that the use of high-speed devices results in aerosol generation. In this study, we develop and propose globally applicable guidelines to fill this knowledge gap and we identify and propose the necessary protective strategies for medical personnel in an orthopaedic emergency department and in the inpatient wards. We also introduce diagnostic criteria, surgical complication management, and follow-up strategies for infected patients. These guidelines may be helpful to decrease the infection rate of orthopaedic trauma personnel and to provide diagnosis and treatment therapy for patients with fracture and COVID-19.

The emerging coronavirus pneumonia (COVID-19) is a unique respiratory infection caused by the 2019 novel coronavirus (SARS-CoV-2 [severe acute respiratory syndrome coronavirus 2]). Since a cluster of patients with COVID-19 was reported in Wuhan, Hubei Province, People's Republic of China, in December 2019, an outbreak of COVID-19 has occurred throughout the People's Republic of China and in >212 countries and has become a worldwide pandemic and was declared as such by the World Health Organization (WHO)[1,2].

Briefly, morphological analysis has shown that COVID-19 has characteristics typical of the coronavirus family, binding to the angiotensin-converting enzyme 2 receptor in humans[3]. SARS-CoV-2 is structurally similar to another coronavirus carried by bats, leading to the speculation that bats may be an intermediate host of the novel virus[4]. It is highly contagious, with proposed person-to-person transmission routes including droplet, aerosol, and contact transmission[5]. During the incubation period, some patients with COVID-19 are infectious while displaying no specific symptoms. This is challenging, in

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terms of both early detection of COVID-19 carriers and early isolation[6].

COVID-19 poses a great challenge for orthopaedic surgical procedures. First, given the prevalence of COVID-19, orthopaedic patients, as well as medical staff, may be infected with COVID-19. Transmission from patient to surgeon, as well as from surgeon to patient, has been demonstrated. It should be noted that, from our experience, some patients with fracture became infected with COVID-19 after hospital admission. Compared with most other types of surgical procedures, an orthopaedic surgical procedure is particularly prone to aerosol generation, given the use of high-speed operative devices and Bovie electrocautery.

In addition, the patient cohort that we are currently seeing is different from the usual orthopaedic surgery cohort. To contain the outbreak, the Chinese government imposed a series of isolation and quarantine regulations and restrictions, including a complete lockdown of the epicenter of Wuhan. During the lockdown period, the mechanism of trauma-related fractures changed from high energy to low energy; for example, traffic accidents and falls from a height have decreased. The majority of cases seen were from stumbles and falls from a standing height, particularly in elderly patients with osteoporosis. With the resumption of work in the People's Republic of China, the worldwide spread of the virus, and the opening of schools in the near future, the number of patients with fracture and COVID-19 is likely to increase.

To ensure appropriate treatment for patients with fracture and COVID-19, while minimizing health-care worker infections, we orthopaedic surgeons on the front line share our first-hand experience to propose a COVID-19 Orthopaedic Safe Care toolset, including specific guidelines for emergency surgical procedures, a patient management path, and key protective measures to ensure adequate containment of the infection during the outbreak of COVID-19.

Step 1: Diagnosing Patients with Fracture and COVID-19 Infection

Typical Clinical Features of COVID-19

The diagnosis of suspected COVID-19 cases should be based on a defined distinct medical history and clinical symptoms. The medical history should be investigated to establish whether cases had any contact with an exposed or infected person or a relevant environment in the past 14 days. The typical clinical characteristics of COVID-19 infection are fever or respiratory symptoms, imaging features of viral infection, and normal or decreased leukocyte count in the early stage of onset. The confirmation of a case is done via establishment of pathogeny or serology of COVID-19 through quantitative reverse transcription-polymerase chain reaction (qRT-PCR), gene sequencing, and antibody analysis.

Step 2: Emergency Orthopaedic Surgical Procedures

During the epidemic, patients with fracture who come to the orthopaedic emergency department should first be asked about the etiology of the fracture and the history of infection. Doctors should also measure the patient's body temperature to determine whether further treatment is required. Patients with fever or respiratory symptoms should be immediately transferred to a designated medical institution or fever clinic. Based on clinical experience, mild cases can be discharged with simple symptomatic treatment. Radiographic or computed

TABLE I Classification of Fracture Severity During the COVID-19 Pandemic

Emergency surgical procedure	1. Contaminated trauma: open injury in need of debridement, suturing, and negative-pressure drainage 2. Hemorrhagic trauma: fracture with vessel or nerve damage (e.g., severe unstable pelvic fracture) 3. Stress trauma: osteofascial compartment syndrome 4. Fracture with other kind of severe trauma: severe head trauma, abdominal trauma, or urogenital trauma
Urgent surgical procedure*	Closed fractures requiring hospitalization and a surgical procedure to avoid severe malformation, dysfunction, and activity compromise: 1. Displaced and unstable fracture of upper limbs 2. Other types of pelvic fracture, fracture of femoral neck or shaft, intertrochanteric or subtrochanteric fracture, intra-articular fracture of the patella, and pilon fracture 3. Obvious displaced or unstable fracture of the distal part of the femur, tibial plateau, tibial shaft, and ankle
Elective surgical procedure	Any types of fractures other than those listed above in which a surgical procedure would improve function and activity but is not immediately necessary

*This is not an emergency surgical procedure but is a nonelective surgical procedure.

tomographic (CT) imaging is needed to ascertain the orthopaedic diagnosis. Our classification regarding the necessity of an orthopaedic surgical procedure is shown in Table I. However, patients with a fracture for which either operative or nonoperative treatment would be suitable would be treated nonoperatively before discharge. If patients need to be hospitalized for a surgical procedure, a pulmonary CT scan, a COVID-19 nucleic acid test, and its antibody test should be immediately performed. If an emergency orthopaedic surgical procedure is required, in addition to a pulmonary CT scan, a COVID-19 nucleic acid test, and its antibody test, an expert panel, including the orthopaedic surgeon, chief physician, anesthesiologists, intensive care unit (ICU) physicians, respiratory physicians, ethicists, and a supply chain person, must assess the overall condition of the patient. The operating room should meet the requirements of having negative atmospheric pressure or an independent airflow system. Pulmonary CT and COVID-19 antibody analysis are also necessary for accompanying family members. Any detection of positive results of a COVID-19 test should be immediately reported and patients must be transferred to the designated hospital for further treatment prior to the surgical procedure. If the results of the COVID-19 analysis are negative but the patient has typical characteristics on a pulmonary CT scan, the patient must be immediately admitted to the infectious diseases department for isolation. Consultation with an expert panel is needed to exclude COVID-19 from the differential diagnosis, and the necessity for a surgical procedure can be reassessed. During hospitalization, the daily rounds of the wards and consultation of other specialists are necessary. Only when the COVID-19 nucleic acid test is negative on 2 separate occasions can patients be permitted to undergo an urgent (nonemergency and nonelective) surgical procedure. The patient should be admitted to a private room for treatment first and then should be transferred to a patient ward after 3 days of observation. Patients with perioperative fever and/or respiratory symptoms should be immediately isolated and investigated with a pulmonary CT scan, a COVID-19 nucleic acid test, and its antibody test. Patients who require an emergency surgical procedure but have no symptoms or exposure concerns are assumed to be COVID-19 positive, and the surgical procedure is performed in the designated operating rooms with appropriate air flow, limited personnel, and protective respirator equipment (powered air-purifying respirator [PAPR]) (Fig. 1).

During the COVID-19 outbreak, the first priority is saving patient lives. The safety of the medical personnel, including the overall safety of the medical team participating in the rescue, must also be prioritized. To reinforce personal protection, orthopaedic trauma medical personnel must abide by the principle of Standard Precautions[7] and 3 levels of prevention. Considering the possibility of contamination from the patient's blood, body fluids, secretions (except sweat), open wounds, and mucosa, standard precautions including hand hygiene, respiratory hygiene, cough etiquette, and safe injection should be subsumed into the preventive measures[8,9]. Graded prevention is based on the Standard Precautions, while adopting isolation precautions regarding transmission by contact, droplet, and air. All personnel involved in the emergency traumatic orthopaedic surgery should select different levels of personal protective equipment (PPE) according to their risk assessment (Table II).

To protect front-line medical workers from COVID-19 infection, hospitals should have sufficient storage and allocation of protective supplies[10]. Medical personnel in orthopaedic trauma must keep up to date with the most recent knowledge and skills on epidemic prevention. It is also important to avoid overworking the medical personnel. Active cooperation by medical staff and surveillance of their health status should be ensured, including monitoring their temperature, reporting suspected symptoms, performing a lung CT examination, and conducting frequent COVID-19 nucleic acid tests. The usefulness of psychological counseling should not be underestimated, as it will be helpful for overcoming the fear and anxiety due to the epidemic.

Operation Management

Preoperative Discussion

Preoperative discussion should be multidisciplinary and include senior surgeons from the orthopaedic trauma department and experts from the respiratory, infectious diseases, anesthesia, and other relevant departments. During this discussion, key issues should be outlined, such as the patient diagnosis, their COVID-19 status, pulmonary function classification and infectivity, the proposed surgical method, the staff undertaking the operation, the required surgical instruments and equipment, likely blood transfusion requirement, and antibiotic plan. For patients with COVID-19 pneumonia with severe and critical diseases, the first task should be life preservation, followed by surgical treatment.

Patient Transport

Designated carts, protective garments, disinfecting solution, and quick hand disinfectant should be provided for hospital transportation. Patients with suspected COVID-19 should follow secondary protection while transferring, and patients with confirmed COVID-19 should follow tertiary protection. Patients must wear surgical masks. Hospital transport requires medical staff to travel together to ensure the shortest distance and the fastest time to avoid any stops along the way.

Anesthesia Management

Simple anesthesia, such as local anesthesia or a nerve block, must be chosen when possible. If general or intraspinal anesthesia cannot be avoided, pay careful attention to avoid contamination from patients. As patients undergoing an orthopaedic trauma emergency surgical procedure often have multiple injuries, including multiple soft-tissue injuries, and massive blood loss, general anesthesia is often required. After entering the operating room, patients must be administered nasal catheter oxygen inhalation combined with a surgical mask cover for oxygen inhalation. After endotracheal intubation, the anesthesiologist shall discard the disposable intubation appliance in the designated bin and shall not take it

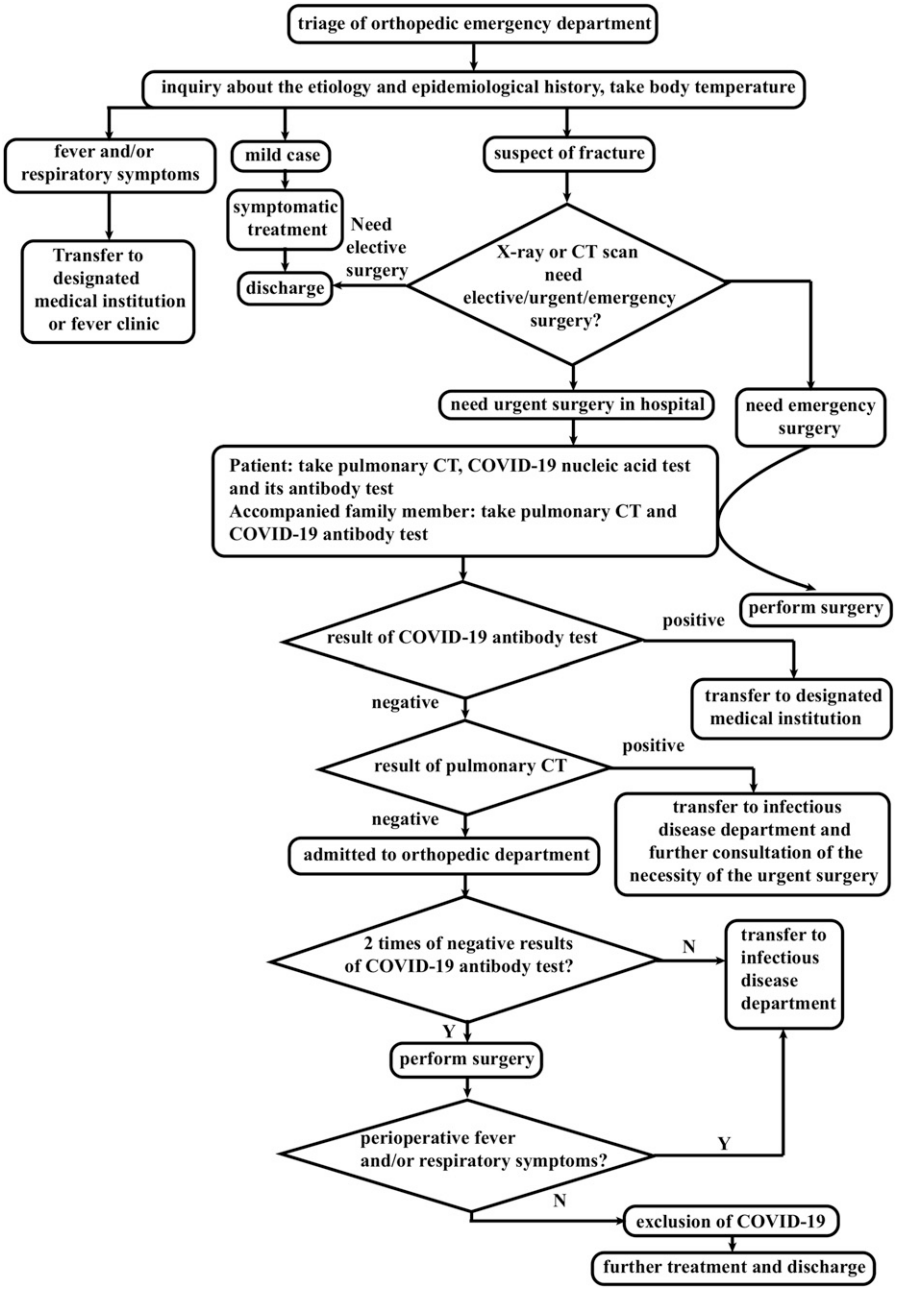

Fig. 1

Flowchart for handling of an orthopaedic emergency by medical personnel.

out of the designated operating room. Many institutions recommend waiting 15 minutes after intubation before allowing surgical personnel in the operating theater to limit transmission risk. Routine electrocardiography, blood oxygen saturation, end expiratory carbon dioxide partial pressure, invasive arterial blood pressure, body temperature, urine volume, arterial blood gas, and coagulation function must be monitored. After the operation, it is recommended to send patients to an ICU isolation ward and to remove the endotracheal tube after the condition is stable. A closed suction system should be used.

Intraoperative Management

Staff participants for anesthesia and surgery should be kept to a minimum. To reduce contamination, the operation should be simplified and the operative time should be reduced. During the operation, the surgeons and scrub nurses should implement Level-3 protection; anesthesiologists may adopt Level-2 protection, but the head and face should be covered with a visor to prevent droplet infection during tracheal intubation. Other nurses can adopt Level-2 protection and other personnel must not exit the operating room at any time during the operation.

TABLE II Levels of Personal Protection of Medical Staff

Level of Protection	Scope of Application	PPE
I	Emergency patient contact (COVID-19 status unverified)	Hair net, gloves, isolation gown, surgical mask (or respirator mask)
II	Patient contact involving patients with suspected COVID-19 and their samples	Hair net, gloves, isolation suit, medical respirator (FFP [filtering face piece] or N, R, or P), eye protection (goggles, visor), shoe covers
III	Patient contact involving confirmed COVID-19: collecting blood, respiratory tract, and other samples, or transferring patients; when performing aerosol-generating procedures, irrespective of COVID-19 status (e.g., intubation); emergency surgical procedure	Surgical gown, hair net, shoe covers, and gloves; medical respirator (FFP or N, R, or P); isolation suit; double-gloving with the second pair of gloves covering the protective clothing sleeve

Outside personnel must not enter the operating room. After the operation, the medical personnel leaving the operating room must first remove their gloves and any protective clothing and foot covers, and discard them in a designated and marked garbage bin. After removing the gloves, hands must be disinfected with a disinfectant according to the 7-step hand-washing method[11]. The mask is then removed, followed by the protective goggles or visor. The hands are then washed under water for 2 minutes after leaving the operating room. After the operation, the goggles and masks are sterilized with disinfectant paper towels and then are wiped with gauze soaked in clean water to allow reuse. All operating personnel can leave the operating room after bathing and re-dressing. In this process, it is necessary to put on and take off protective equipment in strict accordance with the requirements. After hand disinfection, protective equipment is donned in the following order: hat, surgical or respirator mask, eye protection (goggles or visor), isolation or protective clothing, shoe covers, and gloves. Taking off protective equipment involves the following steps: remove shoe covers, remove gloves, disinfect hands, remove isolation or protective clothing, disinfect hands, remove goggles or visor, disinfect hands, remove surgical or respirator mask, disinfect hands, remove hair cap, disinfect or wash hands, and don a new surgical or respirator mask and disposable hair cap.

Article Equipment and Environmental Protection

Equipment and materials should be clearly marked and placed in the designated operating room. Drugs and disposable material should flow in 1 direction, only in or out. Any non-

TABLE III Important Complications for Patients with Fracture and COVID-19

Complication	Patients Who Should Be Especially Monitored
Acute respiratory distress syndrome	All patients
RNAemia	All patients
Cycle threshold of RNAemia	All patients
Acute cardiac injury	Patients with myocardial zymogram abnormality
Kidney dysfunction (acute kidney injury)	Patients with plasma creatinine or urea nitrogen rising or proteinuria
Secondary infection	Patients with intensive or long-course antibiotics
Shock or septic shock	Patients with a mental disorder
Refractory hypoxemia	Patients with dyspnea
Multiple organ failure	Patients with kidney dysfunction
Acute respiratory injury (respiratory failure)	All patients
Ventilator-associated pneumonia	All patients using mechanical ventilation
Liver function abnormality	Patients with aspartate aminotransferase (AST) or alanine transaminase (ALT) abnormality
Pleural effusion	Chest radiograph abnormality
Nervous system involvement	Patients with severe fracture and COVID-19
Fat embolism	Patients with severe fracture and COVID-19
Vascular damage	All patients
Deep vein thrombosis	All patients

disposable equipment must be treated after use according to the relevant specifications. A surgical procedure must be performed more gently than usual to prevent blood and bodily fluid splashes. Contamination of the floor must be reduced as much as possible. When there is contaminated liquid or blood on the floor or on surfaces, assisting staff should immediately wipe it with disinfectant solution containing 2,000 mg/L of chlorine.

Postoperative Management

(1) For all of the medical personnel involved in the surgical procedure, the operation shall be carried out using Level-3 protection. Once the surgical procedure is complete, the Level-3 protection must be removed and washed or eliminated according to standard specifications. If there is no accidental exposure in the whole process, the staff can apply for exemptions from isolation. Otherwise, all medical staff involved in the operation should be quarantined and closely monitored for 14 days, and if any abnormalities arise during the observation, they should be treated in a timely fashion.

(2) After the surgical procedure, the laminar flow and air supply should be closed immediately and, after 1 to 2 hours, cleaned with peracetic acid or hydrogen peroxide spray. Sterilization can also be done with ultraviolet rays. After a 30-minute disinfection with chlorinated preparations, the floor should be mopped with water. The surfaces of instruments, equipment, and operating stations should be sterilized with a chlorinated disinfectant. A final wipe should be done with clean water.

(3) After disinfection of the negative-pressure equipment and the operating room, the infection management department must be contacted to carry out an air-sampling test, and the room should only be used again once the results show that the room is safe to reuse.

(4) After the operation, the equipment shall be placed in a double-layer, yellow medical waste bag, tied tightly with a seal, marked with "COVID-19" on the outside, and placed separately. The disinfection supply room procedure should be standardized to disinfect this room first, and then clean it, and then sterilize it.

Step 3: Postoperative Management

Managing Early Complications

Complications in patients with fracture and COVID-19 can result in serious morbidity and mortality. Some of these complications, including deep vein thrombosis and acute respiratory distress syndrome, are more likely during hospitalization and, thus, standard-practice preventive measures and treatment should be used (Table III)[1,6,12,13].

Follow-up

As it has not yet been confirmed whether systemic illness related to COVID-19 affects bone tissue, thereby delaying union and increasing the risk of nonunion, it is necessary to periodically review fracture-healing. Reexamination should focus on monitoring the prognosis of the COVID-19 pneumonia and the healing of the fracture site. Patients should return to the hospital for review at 2 to 4 weeks after discharge for follow-up, which should include routine blood analysis, blood biochemical indexes, and oxygen saturation of the patient. Concurrently, chest CT scans should be examined to observe the recovery from lung inflammation. If necessary, the etiology of the patient's COVID-19 infection should be reviewed. To monitor the healing status of the fracture site, patients should undergo radiographic or CT imaging of the fracture site. To monitor the recovery of patient motor function, the doctor should perform a physical examination on the patient. The time of the next follow-up shall be determined according to the conclusions from this examination. The patient must also self-monitor body temperature and respiratory symptoms. If symptoms of fever, sore throat, chest tightness, or other chest discomfort are found, the patient should be admitted to the hospital as soon as possible.

Summary

Although the techniques described here are based on theory and experience but not specific data, the proposed toolset is useful for front-line medical personnel working in orthopaedic trauma encountering patients with fracture who are COVID-19-positive. We outline the proper clinical diagnosis and treatment, as well as protection for the medical professionals. This toolset is not only currently relevant for COVID-19, but it is also applicable to any future highly contagious respiratory infections. ■

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