Recommendations of protective measures for orthopedic surgeons during COVID-19 pandemic

Yulong Wang¹,#, Lian Zeng¹,#, Sheng Yao¹, Fengzhao Zhu¹, Chaozong Liu², Anna Di Laura², Johann Henckel², Zengwu Shao¹, Michael T. Hirschmann³, Alister Hart², Xiaodong Guo¹,*

¹Department of orthopedics, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, People’s Republic of China

²University College London (UCL) Stanmore Campus, Royal National Orthopaedic Hospital (RNOH) NHS Trust, Brockley Hill, Stanmore, Middx HA7 4LP, London, UK

³Department of Orthopaedic Surgery and Traumatology, Kantonsspital Baselland (Bruderholz, Liestal, Laufen), Bruderholz, Switzerland.

*Corresponding author: Xiaodong Guo

Email: xiaodongguo@hust.edu.cn

#Yulong Wang, Lian Zeng have contributed equally to this paper, and consider as first co-authors.
Abstract

**Purpose:** It was the primary purpose of the present systematic review to identify the optimal protection measures and orthopedic treatment during COVID-19 pandemic and provide guidance for orthopaedic surgeons. The secondary purpose was to report the experience of an orthopaedic trauma center in Wuhan, China during the pandemic.

**Methods:** A systematic search of the PubMed, Cochrane, Web of Science, Google Scholar was performed for studies about COVID-19, fracture, trauma, orthopedic, healthcare workers, protection, telemedicine. The appropriate protective measures for orthopaedic surgeons and patients were reviewed (on-site first aid, emergency room, operating room, isolation wards, general ward, etc.) during the entire diagnosis and treatment process of traumatic patients.

**Results:** Eighteen studies were included, and most studies (13/18) emphasized that orthopedic surgeons should pay attention to prevent cross-infection. Only four studies have reported in detail how orthopedic surgeons should be protected during surgery in the operating room. No detailed studies on multidisciplinary cooperation, strict protection, protection training, indications of emergency surgery, first aid on-site and protection in orthopedic wards were found.

**Conclusion:** Strict protection at every step in the patient pathway is important to reduce the risk of cross-infection. Lessons learnt from our experience will help others to manage orthopaedic patients with COVID-19, to reduce the risk of cross-infection between patients and to protect healthcare workers during work.
Keywords: 2019 novel coronavirus; Novel coronavirus disease; 2019-nCoV; COVID-19; Fracture; Treatment and diagnosis; Cross-infection; Protection; Orthopaedic surgery; Traumatology.

Level of Evidence: Review, level IV
Introduction

In December 2019, the Coronavirus Disease 2019 (COVID-19) caused by coronavirus (2019-nCoV) was found in Wuhan (Hubei, China) [1] and then became a worldwide pandemic on 11th March 2020. Compared with severe acute respiratory syndrome (SARS) coronavirus, COVID-19 has a lower mortality, but it is more infectious and pathogenic [2-5]. According to statistics from Johns Hopkins University [6], a total of 3257520 cases of COVID-19 have been confirmed globally until 11am on 1 May, 2020. Due to the high infectivity of 2019-nCoV, the source of infection can be COVID-19 patients and asymptomatic infected people. The main routes of transmission of 2019-nCoV are respiratory droplets, close contact and aerosol transmission [2-5, 7-10]. Furthermore, COVID-19 has a latent period of 1-14 days, up to 24 days [10]. Therefore, in the process of patient treatment and diagnosis, there is a high risk of cross-infection to healthcare workers [12].

The pandemic of COVID-19 has brought great challenges at every step in the patient pathway, from pre-hospital, emergency diagnosis and treatment, emergency surgery, anesthesia, and perioperative management. In every step of treatment, the strategies for the treatment of trauma patients should be formulated and protective measures should be taken. What PPE should be worn, and what preventive steps should be undertaken by healthcare workers in different areas of the patient pathway? To date, there is only little guidance provided by WHO and evidence based literature about protective measures or guidelines addressing the entire treatment process of orthopedic trauma patients.

Hence, it is the primary purpose of the present systematic review to identify the optimal protection measures and orthopedic treatment during COVID-19 pandemic and provide
guidance for orthopaedic surgeons. The secondary purpose was to report the experience of an orthopaedic trauma center in Wuhan, China. As of March 26, 2020, a total of 23187 cases with COVID-19 including rescuing 1134 cases of acute and critical illness and more than 400 patients with ventilators have been treated in our institution (Hubei, China) located in the center of the epidemic, meanwhile, more than 300 cases with COVID-19 have underwent a various operation. The Orthopedic Department has handled more than 260 emergency cases. At our center guidance was developed in a learning by doing and consensus process [5, 7-11, 13, 24-26, 30]. Here it is described what was done and how it was implemented.

Materials and methods

A systematic review of the available literature was performed for articles published up to April 27, 2020 using the keyword terms “COVID-19”, “fracture”, “trauma”, “orthopedic”, “surgeon”, “healthcare workers”, “protection”, “telemedicine” in several combinations. The following databases were assessed: PubMed, Cochrane, Web of Science, Google Scholar, and all the publications were searched. The search was limited to English studies only. Studies in other languages were not included in this review.

Study selection

All peer-reviewed articles were considered. Randomized controlled trials (RCTs), prospective trials and retrospective studies as well as reviews and case reports were included in this systematic review. Two authors independently screened the titles and abstracts of all the
articles were identified. If the abstract and the full-text was unavailable, the paper was excluded. In the event of disagreement, a consensus was reached by discussion, if needed with the intervention of the senior author.

This systematic review was conducted in accordance with the established guidelines from Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA). However, due to the heterogeneity of available data it was decided to present the review in a narrative manner.

Data extraction

One author extracted data from all the selected original articles, which was repeated by two other authors. If there was no agreement between the three, the senior author was consulted. Where required, the corresponding authors were contacted for additional information. This review focused on protective measures in the entire diagnosis and treatment process.

Results

The initial literature search found 176 articles. After removing 23 duplicates, 153 studies were screened. Of the 153 studies, 126 were excluded after screening of the title and abstract. Additional 9 studies were excluded after full-text review. Thus, 18 articles were finally eligible for data extraction. Agreement between the reviewers on study selection was substantial at the title review stage (k = 0.705; 95% CI 0.563–0.828), almost perfect at the abstract review stage (k = 0.871, 95% CI 0.475–0.999), and perfect at the full-text review
stage \((k = 1.0)\). Based on the analysis of levels of evidence, one study was classified as level III, fourteen studies were classified as level IV and the remaining three studies were classified as level V. Due to study design heterogeneity it was not possible to pool results across studies and perform a meta-analysis.

One case series study of the characteristics and early prognosis of COVID-19 infection in patients with fractures found that the mean age of 10 fracture patients (8 women and 2 men) with COVID-19 was 68.4±17.5 years old (range, 34 to 87). Eight (80\%) with complications such as hypertension, diabetes, brain injury, etc., needed multi-disciplinary cooperation and comprehensive treatment, however, 4 (40\%) patients eventually died [14]. One study from Italy advised to strengthen multidisciplinary teamwork (MDT) [15]. But there is no study that specifically reported which specialties needed to participate in the MDT and how to divide the work load. Many studies [16-20, 22] reported that using video or teleconference for morning rounds, electronic consultations, videoconferencing, digital outpatient and other telemedicine methods to provide medical guidance and follow-up instruction for patients can reduce unnecessary contact, limiting the spread of the virus and save protective materials.

One survey comprised 47 hand surgeons working in 34 countries [21], and found that the majority wore varying personal protective equipment (PPE) in the OR and outpatient clinics. Only 59.6\% (28/47) of surgeons used body temperature monitoring by a thermal scanner or equivalent to screen COVID-19 patients. The medical treatment protocols without a consensus varied in terms of visitors, health professionals in the operating theatres, patient waiting areas, wards and emergency rooms [21]. One international survey of COVID-19 and
spinal cord injury (SCI) and disease found 5.8% of participants had screened their outpatients with SCI for COVID-19 and only 4.4% reported having a patient with SCI with the virus [22]. The other finding of this survey is that 53.3% of participants worked at an inpatient facility reported that only individuals with symptoms were screened [22]. Another survey of COVID-19 disease among orthopaedic surgeons from 8 hospitals in Wuhan found a total of 26 surgeons were diagnosed with COVID-19 [12], and the incidence varied from 1.5% to 20.7%. Training on prevention measures was found to have a protective effect (odds ratio (OR), 0.12). Wearing of respirator masks was also found to be protective (OR, 0.15). Not wearing an N95 respirator was a risk factor for infection with COVID-19 (OR, 5.20 [95% confidence interval (CI), 1.09 to 25.00]) as well as severe fatigue due to work overload (OR, 4 [95% CI, 1 to 16]) [12].

Delaying and cancelling elective surgery, and the clear-cut definition of emergency surgery are still under debate [14, 16, 18-21, 23-26, 29]. By delaying elective surgery, the risk of nosocomial infection of patients undergoing elective surgery can be reduced, and medical resources can be saved to deal with COVID-19 [24-28]. Emergency surgery in the context of the current crisis can be defined as urgent pathologies that could result in long-term disability and/or chronic pain if surgery is postponed [25]. The Ohio Hospital Association suggested that criteria for emergency surgery is “threat to the patient’s life if surgery or procedure is not performed, threat of permanent dysfunction of an extremity or organ system, risk of metastasis or progression of staging, risk of rapidly worsening to severe symptoms (time sensitivity)” [26, 28]. Trauma related fractures are the most common cause of
emergency surgery. The WHO and evidence-based literature have not given any detailed recommendations for emergency orthopedic treatment during COVID-19 pandemic.

There was no study concerning the management of an outpatient clinic and surgical activities and the challenges in handling with a high-volume practice during epidemic. Only one article offered important points and strategies to provide the highest level of safety to healthcare workers during the start-up phase. [29]

Most studies (13/18) emphasized that orthopedic surgeons should pay attention to personal protection when facing the COVID-19 pandemic to prevent cross infection [12, 15, 16, 18-21, 23-25, 28-30]. Four studies have reported in more detail on personal protection [19, 23, 28, 30]. Dedicated paths to quickly transfer urgent patients with suspected or confirmed COVID-19 to the designated operating room need to be established, and appropriate PPE in operating room established to reduce the occupational risk in treatment [19, 28]. Rodrigues-Pinto et al. shared their experience in operating room organisation: dividing the designated operating room into five zones (Entry dressing room; Anteroom, where the disinfection and surgical dressing take place; Operating room; Exit room and Exit dressing room) and performing different sterile procedures in different zones to reduce the risk of cross-infection [28]. Hirschmann et al. reviewed the current evidence and recommendations for PPE for orthopaedic and trauma surgeons [30]. The evidence found suggested that orthopaedic and trauma surgery using power tools, pulsatile lavage and electrocautery might lead to surgical aerosol generation and all body fluids contain a varying amount of virus particles. Strict protective measures should be taken during surgery.
The most commonly suspected areas of exposure during the entire diagnosis and treatment process were general wards (79.2%) followed by public places at the hospital (20.8%), operating rooms (12.5%), the intensive care unit (4.2%), and the outpatient clinic (4.2%) [12]. However, there are no studies about which level of protection for orthopedic surgeon should be recommended from on-site emergency to patient discharge. Only Hirschmann et al. [30] gave an evidence-based recommendation which PPE should be used to avoid occupational transmission of COVID-19 during surgery. Guidance at our center was developed in a learning by doing and consensus process. [5, 7-11, 13, 24-26] In summary, appropriate protective measures of orthopaedic surgeons during pandemic should be taken in different sites during the entire diagnosis and treatment process of traumatic patients (Table 1, Table 2).

Discussion

Establishment of a multidisciplinary team (MDT) for trauma and infection

When orthopedic trauma is caused by high-energy injury [33, 44], there may also be craniocerebral, thoracic and abdominal trauma [14, 31, 32], which is life-threatening and is usually managed by a multidisciplinary team (MDT), the so-called trauma team. In a COVID-19 environment this should also include the infection department. In COVID-19 designated hospitals it might be a combined trauma and infection MDT. The core members should consist of senior physicians and infectious disease prevention specialists who have received professional training in advanced trauma life support. The team needs to diagnose
and treat patients with trauma suspected or confirmed of COVID-19, and provide adequate
guidance for strengthening pre-hospital and intra-hospital prevention and control of
cross-infection according to the relevant documents and guidelines [5, 7-10, 24-26, 44].

On-site first aid

In principle, all patients with fractures which occurred in pandemic areas should be treated as
suspected COVID-19 cases [2, 44]. The ambulance requires sufficient protective equipment
and rescue equipment [9]. All medical personnel should be familiar with the symptoms of
COVID-19 and should have received professional training in level-three personal protective
equipment (PPE) [5, 8, 12, 14, 15, 23, 28, 30] (Table.1). In addition, all should be well
educated in wearing and taking off a disposable hat, disposable protective clothing, long shoe
cover, N95/FFP2 mask, goggles, double-layer gloves and protective face screen. PPE is
important to minimise the chance of contact with body fluids of the wounded. Before arriving
at the scene, all the healthcare workers and drivers involved in the pre-hospital emergency
should take level-two PPE. For patients with contact with COVID-19 patients or exhibiting
the symptoms of fever and/or respiratory symptoms, the pre-hospital emergency healthcare
workers and drivers in the non-pandemic area should take level-two PPE in advance.

Transportation of the trauma patient to hospital

In principle, all the injured patients should be transported to the nearest hospital with proper
isolation facilities, adequate levels of PPE and the ability to diagnose and treat COVID-19
patients. The ambulance is exposed to high concentration of aerosol for a long time in a relatively closed environment, and must be cleaned and disinfected thoroughly [2, 3, 5, 7-10]. Negative pressure ambulances are preferred. Ambulance drivers need at least level-two PPE. Only patients with excluded infection of COVID-19 can be sent to the general emergency department, the rest should be sent to the COVID-19-designated hospital for treatment.

Protection of healthcare workers in the emergency room (ER)

All staff who receive patients with suspected or confirmed COVID-19 need at least level-two PPE in the emergency room (ER) [5, 8, 19, 23, 28] (Table 1). If the patient is unconscious, or his/her family members cannot describe the epidemiological history, the suspected cases shall be treated as COVID-19. During pandemic, all patients should be treated as suspected cases of COVID-19 (Table 2). Adequate PPE and disinfection of medical equipment is paramount [7-10].

Diagnosis of COVID-19

If possible, the hospital personnel should take sputum, nasopharynx swab or blood samples, using real-time fluorescent RT-PCR to rapidly detect viral nucleic acid or gene sequencing to make the final diagnosis. According to the guidelines [7] the MD team should make a suspected or confirmed diagnosis of COVID-19. If the patients who are sent to the emergency room are preliminarily assessed as suspected COVID-19, they might be transferred immediately to complete a chest CT scan [5, 7, 29]. All patients admitted should be screened
for 2019-nCoV (Table 3) [5, 20, 22, 29], and COVID-19 needs to be differentiated from traumatic wet lung.

*Indications for emergency surgery*

After the patient has arrived at the hospital, the pre-alerted infection-trauma MDT starts with their standard operating procedures such as checking vital signs, oxygen saturation, and treating life-threatening hemorrhage and combined injuries. If necessary, immediate emergency surgery should be performed. The main indications for emergency surgery are:

- trauma seriously endangering life or limb, such as fracture with hemorrhagic shock, suspected large blood vessel injuries and fracture with important organ injuries; Gustilo II-III open fractures, closed fracture with compartment syndrome, fracture with severe infection;
- unstable spine fracture with spinal cord injury (AIS grade C or below), or progressive aggravation of neurological dysfunction [18, 24-28, 34].

Patients with mild to moderate COVID-19 are treated as above, whereas those with severe COVID-19 are more likely to be treated non-operatively (Table 4). In other words, severe COVID-19 is a relative contraindication for emergency orthopaedic surgery. Patients with critical COVID-19 or those who are intolerant to operation or anesthesia are an absolute contraindication [7, 26, 28, 44].

*Patient transfer to the operating room*
The COVID-19 testing is difficult to get quickly enough in an emergency setting. All emergency patients are protected according to suspected or confirmed patients [5, 19, 28]. All medical personnel should take level-two protective measures, using the special transfer vehicle with disposable sheets to lead patients to transfer to the negative pressure operation room through a special channel and a special lift [5, 9, 13, 19, 28, 46, 47].

**PPE in the operating room**

The door of the operating room should be marked with a COVID-19 sign. Staff numbers should be minimized in the operating room [19, 23, 28]. Visitors to the OR should be restricted and medical personnel should not enter or leave the operating room to avoid interrupting the negative pressure. Level-three PPE is required in the operating room for all staff [5, 13, 48], except patrol nurses / runners who can use level-two PPE. The operating room must be in a state of negative pressure (-5pa) before the operation [13, 23, 29, 46, 47]. The buffer room should be closed, and equipment should be minimized in the operating room. Staff wearing PPE in the operating room are forbidden to leave the operating room until the PPE has been removed and the operation has finished.

After the operation, the healthcare workers should first disinfect their hands, and then remove the PPE, discarding them in the double-layer yellow medical waste bag marked with COVID-19. It is necessary to wash hands with flowing water after removing protective gowns and gloves for at least two minutes.
Patients with non-generalized anesthesia should wear surgical masks throughout the operation [13, 15, 23, 47]. For patients under general anesthesia, a breathing filter should be installed between the anesthetic mask and the respiration loop, and a breathing filter should be installed at the inhalation and exhalation ends of the anesthesia machine respectively [13, 46, 47].

Operating room management

The high-efficiency particulate air (HEPA) filters must be in use and the room should have a negative pressure [13, 28, 46, 47]. After surgery, the room should be disinfected by spraying peracetic acid or hydrogen peroxide for more than two hours, and the laminar flow should be off and air supply closed. Sampling of the surfaces and air in the operation room should be tested by the hospital infection control team after the disinfection process. The next operation can be continued only after the monitoring results are qualified [7, 13, 47].

Prevention of surgical aerosol during surgery

Surgery using the electrocautery, ultrasonic bone knife, drill, pulsatile lavage and other powered equipment result in aerosolization of blood, bone, and tissue fluid [30]. COVID-19 is present in all body fluids and so will be present in this aerosol. Limitation of the use of these procedures will minimize the aerosol [30, 48]. Hirschmann et al. reported that orthopaedic surgery in particular to the lower limb, produces vast amounts of aerosols when high-speed power tools are used, and orthopaedic surgeons should use FFP2-3 or N95-99 respirator masks [30].
The ability for the aerosol to cause infection of the surgical team is unknown and dependent on the PPE worn by the surgical team. Smoke generated should be removed by an aspirator (note that suction also generates an aerosol) [48]. During the operation, normal saline for flushing should be minimised, splashing of the patient's body fluids should be avoided, and the residue of the fluid should be reduced as much as possible to prevent the pollution of the surrounding environment [30, 48]. The surgical team need to cooperate closely to prevent smoke from electrocautery, splashing of the patient's body fluid, and sharp instrument injury [13, 19, 23, 28].

**Disinfection of surgical instruments**

Surgical instruments that have been directly exposed to the patient's body fluid should be immediately scrubbed with 1000-2000mg/L chlorine containing preparation, and then placed into double-layer yellow medical waste bags, labeled with 2019-nCoV, and immediately inform the disinfection and supply center to take them away [7, 9].

**Emergency pre-operative plan**

The pre-operative plan should fully consider the complex situation of fracture management combined with COVID-19 status [44]. The aim is to comprehensively develop a personalized operation plan. The preoperative consent should inform the patients that the mild or moderate COVID-19 may aggravate to the severe and critical type, and there is no correlation with the operation [2, 5, 11, 44]. According to patient's condition, trauma, injury type, stability,
neurological function, medical equipment and technical conditions, the purpose of operation should be completed in a single approach or minimally invasive surgery as far as possible [33, 35, 38, 45]. The team should take measures to reduce the influence of time, trauma, hemorrhage and anesthesia on patients with COVID-19. Disposable surgical instruments should be used where possible and non-operative treatment should be strongly considered [7, 11].

Pelvic and acetabular fracture

For unstable pelvic fractures, non-invasive or minimally invasive measures such as pelvic belt or traction are preferred to maintain pelvic stability. For pelvic fractures with unstable hemodynamics, in principle, invasive operations such as external fixator or open surgery should not be performed, and limited fluid resuscitation treatment should be taken first [31-33]. Determine the location of bleeding timely with targeted treatment. If bleeding is excluded, the pelvic belt should be applied first. If hemodynamics is still unstable, surgeries included external fixator, gauze packing, angiography/embolization, and hemostasis can be used [5, 13]. Debridement should be done quickly and effectively to open pelvic fracture at an early stage and covered by vacuum sealing drainage, and Morel-Lavelle lesion should be vigilant [38-42].

Closed reduction should be performed timely for acetabular fracture with dislocation of hip joint. If difficult, emergency closed or open reduction in the operation room should be performed. If no contraindication, elective and definite operation for acetabular fracture can
be performed later. A single surgical approach [40, 41] with minimal trauma, the least possible complications and morbidity is preferred. In terms of internal fixation, the novel acetabular quadrilateral surface buttress plates [42, 43] were developed based on the concept of "frame and buttress" fixation and have good biomechanical properties, which may be a better choice for acetabular fractures involving quadrilateral surface.

*Extremity fractures*

Fractures of extremities with uncontrolled hemorrhagic shock and arterial damage, should have angiographic embolization, or an exploratory operation to repair or reconstruct vessels should be performed with simple fixation of the fracture. For patients with Gustilo II-III open fractures, thorough debridement should be performed, the fractured of limbs should be fixed with a combined external fixator, and important vessels and nerves of the limb should be repaired. If necessary, osteofascial decompression should be performed. An open wound with large skin defect should be closed by vacuum sealing drainage therapy. For patients with severe limb destruction, amputation should be performed when limb salvage is impossible [35, 36].

*Postoperative management*

Preoperative chest CT scan [5, 29, 44] is an important investigation for clinical diagnosis of COVID-19, as well as diagnosing lung injury caused by high-energy trauma. Nevertheless, nucleic acid testing for COVID-19 or virus sequencing should be done as soon as possible
after surgery. In addition to symptomatic and supportive treatment, complications, basic diseases secondary infection and thrombosis should also be controlled and treated; furthermore, early rehabilitation [33, 38-43] will help promote functional recovery and enable patients to return to a normal life as soon as possible.

The body temperature of patients should be monitored at least three times a day after operation. For patients with COVID-19, wound infection should not be judged only by the results of blood tests and body temperature [37]. Consider whether fever is caused by a wound infection or COVID-19 [44].

For patients with fractures, the bleeding risk of patients should be assessed correctly, and the prevention of deep vein thrombosis (DVT) should be carried out as early as possible. However, referring to Prevention and Control Protocols of Novel Coronavirus Pneumonia (Pilot version 7 modified) [5], DIC and multiple organ failure will occur in patients with critical COVID-19. Therefore, we suggest avoiding anticoagulant therapy [5, 44] to adult patients with critical COVID-19.

**Management of elective surgery**

In the pandemic area, the patients who do not need emergency surgery are admitted to the emergency buffer ward in single room isolation, and treated as suspected cases of COVID-19. After screening for COVID-19 (Table 3), COVID-19 negative patients can be transferred to the general ward in a single room, minimizing the number of family caregivers (at most 1 member) and forbidding other family members to visit [20, 22]. Caregivers should be
screened for COVID-19 [20, 25] (Table 3), and must be negative. Confirmed cases can be admitted in the same negative-pressure isolation ward with multiple persons. Severe or critical patients can be admitted to the intensive care unit as soon as possible [5, 44].

For patients undergoing a routine operation, if COVID-19 has been excluded, the surgery should be arranged with the normal treatment procedure according to the patient's priority; healthcare workers should take level 1 protective measures at least during surgery. For patients with surgery contraindicated in the early stage or other reasons such as conservative treatment failure, fear of hospitalization during the pandemic, etc., surgery can be performed according to treatment experience for delayed union [45, 49, 50], referring to the aforementioned protective measures. During the transition period, it is necessary to strengthen the monitoring and protection of patients and family caregivers [20, 22, 29]. If coughing and other symptoms suspected of COVID-19 occur, laboratory tests, chest CT scans and viral etiology tests should be performed immediately to rule out the possibility of COVID-19 infection [5, 20, 22, 29, 44].

**Discharge and post-discharge management**

For patients without COVID-19, discharge should be scheduled time after surgery to reduce cross-infection in the hospital [5, 15]. After being discharged from the hospital, an online outpatient clinic or telemedicine can be used to guide the patient's follow-up treatment [16-20, 22]. At the same time, it is necessary to continue to strengthen the monitoring and protection
of patients and family caregivers, and pay attention to the possibility of positive viral etiology test results in patients recovered from COVID-19 [5, 11, 25, 44].

Conclusion

Strict protection at every step in the patient pathway is important to reduce the risk of cross-infection during pandemic. Lessons learnt from our experience will help others to manage orthopaedic patients with COVID-19, to reduce the risk of cross-infection between patients and to protect healthcare workers.

Funding: This study was supported by National Natural Science Foundation of China (81873999, 81672158) and National Key R&D Program of China (2016YFC1100100). These funding agencies had no role in study design, collection/analyses of data, decision to publish, or manuscript preparation.

Ethical Statement: Not applicable.

Conflicts of interest: The authors declare that they have no conflict of interest.

Acknowledgments: The authors wish to thank healthcare workers who are fighting in the war of prevention and control of COVID-19.
References

1. World Health Organization (WHO). Novel coronavirus (2019-nCoV) situation report - 1.2020 Jan 20. https://www.who.int/docs/defaultsource/coronaviruse/situation-reports/20200121-sitrep-1-2019-ncov.pdf?sfvrsn=20a99c10_4

2. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, et al (2020) Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 395(10223):497-506. https://doi.org/10.1016/S0140-6736(20)30183-5

3. Cai J, Sun W, Huang J, Gamber M, Wu J, He G (2020) Indirect virus transmission in cluster of COVID-19 cases, Wenzhou, China, 2020. Emerg Infect Dis. https://doi.org/10.3201/eid2606.200412

4. Rothe C, Schunk M, Sothmann P, Bretzel G, Froeschl G, Wallrauch C, et al (2020) Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. N Engl J Med 382(10):970-1. https://doi.org/10.1056/NEJMc2001468

5. National Health Commission of the People’s Republic of China, State Administration of Traditional Chinese Medicine. Prevention and Control Protocols of Novel Coronavirus Pneumonia (Pilot version 7 modified). http://www.nhc.gov.cn/zyyjgs/s7653p/202003/46e9294a7dfe4cef80dc7f5912eb1989/files/ce3e6945832a438eaae415350a8ce964.pdf

6. Johns Hopkins University. Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. https://www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48
7. National Health Commission of the People’s Republic of China. Notice on Printing novel coronavirus infection prevention and control technical guidelines (First Edition) in medical institutions.
http://www.nhc.gov.cn/xcs/yqfkdt/202001/b91fdab7c304431eb082d67847d27e14.s html

8. World Health Organization. Infection prevention and control during health care when COVID-19 is suspected. Interim Guidance – 19 March 2020.
https://www.who.int/publications-detail/infection-prevention-and-control-during-health-care-when-novel-coronavirus-(ncov)-infection-is-suspected-20200125

9. National Health Commission of the People’s Republic of China. Transport plan for novel coronavirus infection cases (Trial).
http://www.gov.cn/zhengce/zhengceku/2020-01/29/content_5472894.htm

10. General Office of the national health and Health Commission. Notice of novel coronavirus infection office in the office of the national health and Health Commission for medical waste management.
http://www.gov.cn/zhengce/zhengceku/2020-01/28/content_5472796.htm

11. Li Y, Li ZF, Mao QX et al (2020) Consensus on emergency surgery and infection prevention and control for severe trauma patients with 2019 novel coronavirus pneumonia. Chin J Trauma 36(2):97 - 103.
https://doi.org/10.3760/cma.j.issn.0253-2352.2020.05.003

12. Guo X, Wang J, Hu D et al (2020) Survey of COVID-19 Disease Among Orthopaedic
13. Zhao S, Ling K, Yan H et al (2020) Anesthetic Management of Patients With Suspected or Confirmed 2019 Novel Coronavirus Infection During Emergency Procedures. J Cardiothorac Vasc Anesth 34(5):1125 - 1131. https://doi.org/10.1053/j.jvca.2020.02.039

14. Mi B, Chen L, Xiong Y, Xue H, Zhou W, Liu G (2020) Characteristics and Early Prognosis of COVID-19 Infection in Fracture Patients. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.20.00390

15. Randell PS, Compagnoni R (2020) Management of orthopaedic and traumatology patients during the Coronavirus disease (COVID-19) pandemic in northern Italy. Knee Surgery Sports Traumatology Arthroscopy. https://doi.org/10.1007/s00167-020-06023-3

16. Zou J, Yu H, Song D, Niu J, Yang H (2020) Advice on Standardized Diagnosis and Treatment for Spinal Diseases during the Coronavirus Disease 2019 Pandemic. Asian Spine J 14(2):258–263. https://doi.org/10.31616/asj.2020.0122

17. Mauffrey C, Trompeter A (2020) Lead the way or leave the way: leading a Department of Orthopedics through the COVID-19 pandemic. Eur J Orthop Surg Traumatol 30(4):555–557. https://doi.org/10.1007/s00590-020-02670-x

18. Massey PA, McClary K, Zhang AS, Savoie FH, Barton RS Orthopaedic (2020) Surgical Selection and Inpatient Paradigms During the Coronavirus COVID-19 Pandemic. J Am Acad Orthop Surg. https://doi.org/10.5435/JAAOS-D-20-00360

19. Awad ME, Rumley JCL, Vazquez JA, Devine JG (2020) Peri-operative Considerations in
Urgent Surgical Care of Suspected and Confirmed COVID-19 Orthopedic Patients: Operating rooms protocols and recommendations in the Current COVID-19 Pandemic. J Am Acad Orthop Surg. https://doi.org/10.5435/JAAOS-D-20-00227

20. Stinner DJ, Lebrun C, Hsu JR, Jahangir AA, Mir HR (2020) The Orthopaedic Trauma Service and COVID-19 - Practice Considerations to Optimize Outcomes and Limit Exposure. J Orthop Trauma. https://doi.org/10.1097/BOT.0000000000001782

21. Ducournau F, M. Arianni, S. Awwad et al (2020) COVID-19: Initial experience of an international group of hand surgeons. Hand Surg Rehab. https://doi.org/10.1016/j.hansur.2020.04.001

22. Michael D. Stillman, Maclain Capron, Marcalee Alexander et al (2020) COVID-19 and spinal cord injury and disease: results of an international survey. Spinal Cord Series and Cases 6:21. https://doi.org/10.1038/s41394-020-0275-8

23. Coccolini F, Perrone G, Chiarugi M et al (2020) Surgery in COVID-19 patients: operational directives. World J Emerg Surg 15(1):25. https://doi.org/10.1186/s13017-020-00307-2

24. Vannabouathong C, Devji T, Ekhtiar S et al (2020) Novel Coronavirus COVID-19: Current Evidence and Evolving Strategies. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.20.00396

25. DePhillipo NN, Larson CM, O'Neill OR et al (2020) Guidelines for Ambulatory Surgery Centers for Surgically Necessary/Time-Sensitive the Care of Orthopaedic Cases during the COVID-19 Pandemic. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.20.00489
26. Sarac NJ, Sarac BA, Schoenbrunner AR et al (2020) A Review of State Guidelines for Elective Orthopaedic Procedures During the COVID-19 Outbreak. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.20.00510

27. Donnally CJ 3rd, Shenoy K, Vaccaro AR et al (2020) Triaging Spine Surgery in the COVID-19 Era. Clin Spine Surg. https://doi.org/10.1097/BSD.0000000000000988

28. Rodrigues-Pinto R, Sousa R, Oliveira A et al (2020) Preparing to Perform Trauma and Orthopaedic Surgery on Patients with COVID-19. J Bone Joint Surg Am. https://doi.org/10.2106/JBJS.20.00454

29. De Caro F, Hirschmann TM, Verdonk P (2020) Returning to orthopaedic business as usual after COVID-19: strategies and options. Knee Surgery Sports Traumatology Arthroscopy. https://doi.org/10.1007/s00167-020-06031-3

30. Hirschmann MT, Hart A, Henckel J, Sadoghi P, Seil R, Mouton C (2020) COVID-19 coronavirus: recommended personal protective equipment for the orthopaedic and trauma surgeon. Knee Surgery Sports Traumatology Arthroscopy. https://doi.org/10.1007/s00167-020-06022-4

31. Schmal H., Froberg L., Larsen M.S et al (2018). Evaluation of strategies for the treatment of type B and C pelvic fractures. Bone Joint J 100-B(7):973–983. https://doi.org/10.1302/0301-620X.100B7.BJJ-2017-1377.R1

32. Cothren CC, Osborn PM, Moore EE (2007) Preperitoneal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. J Trauma 62(4):834-9; discussion 839-42. https://doi.org/10.1097/TA.0b013e31803c7632
33. Chen K, Ji Y, Huang Z et al (2018) Single Modified Ilioinguinal Approach for the Treatment of Acetabular Fractures Involving Both Columns. J Orthop Trauma 32: e428-e434. https://doi.org/10.1097/BOT.0000000000001303

34. Jetan H. Badhiwala, Christopher S et al (2019) Time is spine: a review of translational advances in spinal cord injury. J Neurosurg Spine 30:1–18. https://doi.org/10.3171/2018.9.SPINE18682

35. Isaacs-Itua A., Sedki I (2018) Management of lower limb amputations. British journal of hospital medicine (London, England: 2005) 79(4):205-210. https://doi.org/10.12968/hmed.2018.79.4.205

36. Chen HW, Liu GD, Wu LJ (2015) Clinical and radiological outcomes following arthroscopic- assisted management of tibial plateau fractures: a systematic review. Knee Surg Sports Traumatol Arthrosc 23(12): 3464-3472. https://doi.org/10.1007/s00167-014-3256-2

37. Ban KA, Minei JP, Laronga C et al (2017) American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update. J Am Coll Surg 224(1):59-74. https://doi.org/10.1016/j.jamcollsurg.2016.10.029

38. Gereli, A., Kocaoglu, B., Ulku, K. T. et al (2015) Are pelvic anatomical structures in danger during arthroscopic acetabular labral repair? Definition of safe bone depth. Knee Surgery Sports Traumatology Arthroscopy 25(1):45–49. https://doi.org/10.1007/s00167-015-3797-z

39. Chen K, Yao S, Yang F et al (2019) Minimally invasive screw fixation of unstable pelvic
fractures using the “blunt end” Kirschner wire technique assisted by 3D printed external
template. Biomed Res Int 2019:1524908. https://doi.org/10.1155/2019/1524908

40. Yao S, Chen K, Ji Y et al (2019) Supra-ilioinguinal versus modified Stoppa approach in
the treatment of acetabular fractures: reduction quality and early clinical results of a
retrospective study. J Orthop Surg Res 14: 364. https://doi.org/10.1186/s13018-019-1428-y

41. Ayoub, M (2010) Is it possible that most of the displaced acetabular fractures can be
managed through a single ilioinguinal approach? 2–7 Years experience results. Eur J
Orthop Surg Traumatol 21(4): 259-267. https://doi.org/10.1007/s00590-010-0704-7

42. Chen K, Yang F, Yao S et al (2019) Application of computer-assisted virtual surgical
procedures and three-dimensional printing of patient-specific pre-contoured plates in
bicolumnar acetabular fracture fixation. Orthop Traumatol Surg Res 105: 877-884.
https://doi.org/10.1016/j.otsr.2019.05.011

43. Chen K, Yang F, Yao S et al (2020) Biomechanical Comparison of Different Fixation
Techniques for Typical Acetabular Fractures in the Elderly. J Bone Joint Surg Am.
https://doi.org/10.2106/JBJS.19.01027

44. Wu Z, McGoogan JM (2020) Characteristics of and important lessons from the
coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314
cases from the Chinese Center for Disease Control and Prevention. JAMA.
https://doi.org/10.1001/jama.2020.2648

45. Claudia Schlundt, Christian H. Buche, Serafeim Tsitsilonis et al (2018) Clinical and
Research Approaches to Treat Non-union Fracture. Current Osteoporosis Reports 16:155–168. https://doi.org/10.1007/s11914-018-0432-1

46. Ti LK, Ang LS, Foong TW, Ng BSW (2020) What we do when a COVID-19 patient needs an operation: operating room preparation and guidance. Can J Anaesth. https://doi.org/10.1007/s12630-020-01617-4

47. Wax RS, Christian MD (2020) Practical recommendations for critical care and anesthesiology teams caring for novel coronavirus (2019-nCoV) patients. Can J Anaesth 67(5):568-576. https://doi.org/10.1007/s12630-020-01591-x

48. Zheng MH, Boni L, Fingerhut A (2020) Minimally invasive surgery and the novel coronavirus outbreak: lessons learned in China and Italy. Ann Surg. https://doi.org/10.1097/SLA.0000000000003924

49. Kim, H, Baek, JH, Park, SM, Ha YC (2014) Arthroscopic reduction and internal fixation of acetabular fractures. Knee Surgery Sports Traumatology Arthroscopy 22(4), 867–870. https://doi.org/10.1007/s00167-013-2799-y

50. Taguchi T, Kawai S, Kaneko K et al (2000) Surgical treatment of old pelvic fractures. International orthopaedics 24(1):28-32. https://doi.org/10.1007/s002640050007

Table 1: Levels of PPE available
| Protection Level | Personal Protective Equipment (PPE) |
|------------------|-----------------------------------|
| **Level one**    | Disposable surgical cap            |
|                  | Disposable surgical mask           |
|                  | Work uniform                       |
|                  | Disposable latex gloves or/and disposable isolation clothing if necessary |
| **Level two**    | Disposable surgical cap            |
|                  | Medical protective mask (N95)      |
|                  | Work uniform                       |
|                  | Disposable medical protective uniform |
|                  | Disposable latex gloves            |
|                  | Goggles                            |
| **Level three**  | Disposable surgical cap            |
|                  | Work uniform                       |
|                  | Disposable medical protective uniform |
|                  | Disposable latex gloves            |
|                  | Powered Air Purifying Respirator (PAPR) or |
|                  | Full-face respiratory protective devices* |

* Due to the limited quantity of PAPR, N95/FFP2 mask and full-face respiratory protective devices are sometimes used instead.
Table 2: What PPE should be worn, and what steps done, by healthcare workers in different areas of the patient pathway (prehospital, emergency room, inpatient ward, OR, outpatients)

| Sites                | Prior to COVID-19 pandemic | During a COVID-19 pandemic | Specific advice / important knowledge |
|----------------------|---------------------------|---------------------------|--------------------------------------|
|                      | No history of epidemic exposure | Epidemiological exposure history |                                               |
| On-site first aid    | Level one                  | Level two                 | Level two                             |
|                      |                           |                           | Beware: all body fluids can contain COVID-19 virus (vomit, urine, blood, sputum). |
|                      |                           |                           | When in a pandemic, all patients are suspected of having COVID-19. |
| Ambulance            | Level one                  | Level two                 | Level two                             |
|                      |                           |                           | Beware: The ambulance environment receives a high level of aerosol. |
|                      |                           |                           | Negative pressure ambulances are preferred. |
| Emergency room       | Level one                  | Level two                 | Level two                             |
|                      |                           |                           | Test for COVID-19 ASAP. |
CT scan chest for all (appearances of COVID-19 are different to traumatic wet lung).

Infection staff needed as part of the trauma team.

| Patient transfer in hospital | Level one | Level two | Level two | Use special transfer, a special channel and a special lift. |
|-----------------------------|-----------|-----------|-----------|------------------------------------------------------------|

Severe COVID-19 is a relative contra indication to emergency orthopaedic surgery and critical COVID-19 is an absolute contra indication.

| Operating room              | Level one | Level two | Level three | Level 3 PPE for all staff except runners who are level-two. |
|-----------------------------|-----------|-----------|-------------|-------------------------------------------------------------|

Label door with COVID-19.

Minimal staff numbers in the OR.
Conversion of a positive pressure to a negative pressure of -5Pa should be confirmed prior to starting surgery.

All patients should have masks if awake or exhaust filters if under general anaesthesia.

Remove the smoke from electrocautery quickly. Reduce irrigation. Minimise splashing of the patient’s body fluid.

Hand disinfection is done before removing PPE.

| Isolation wards | Level two | Level two | Level two |
|-----------------|-----------|-----------|-----------|
| General wards   | Level one | Level one | Level one |

Beware: A high level of aerosol when performing high-risk procedures such as sampling from respiratory tract, intubation, tracheotomy, CPR, and etc., Level three PPE is required.

Pay attention to body temperature, respiratory symptom, and screening
when necessary.

Small probability that incubation period may be as long as 24 days.

| Outpatients | Level one | Level two | Level two |
|-------------|-----------|-----------|-----------|
|             |           |           |           |

Online outpatient clinic is preferred.

Pay attention to body temperature, respiratory symptom and epidemiological exposure history.

Pay attention to the possibility of positive viral etiology test results in patients recovered from COVID-19.
Table 3: Screening item for all patients admitted during the epidemic period of COVID-19

| Number | Screening item                                      |
|--------|-----------------------------------------------------|
| 1      | The 2019-nCoV specific antibodies test              |
| 2      | A chest CT scan                                     |
| 3      | The 2019-nCoV nucleic acid test                     |

All patients admitted during the epidemic period of COVID-19 and caregivers should be screened by the 2019-nCoV specific antibodies test, chest CT scan, and the 2019-nCoV nucleic acid test.

The 2019-nCoV nucleic acid test can be screened twice for patients on admission if the first is negative.

Table 4: Clinical classifications of patients with a confirmed diagnosis of COVID-19 and indications for emergency surgery

| Clinical Classifications | Clinical symptoms                                                                 | Indication for emergency surgery                      |
|--------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------|
| Mild                     | The clinical symptoms are mild and no pneumonia manifestations can be found in imaging. | No contra-indication due to COVID-19                   |
| **Moderate** | Patients have symptoms such as fever and respiratory tract symptoms, etc. and pneumonia manifestations can be seen in imaging. | No contra-indication due to COVID-19 |
|-------------|-------------------------------------------------------------------------------------------------|-----------------------------------|
| **Severe**  | Adults who meet any of the following criteria: respiratory rate $\geq$ 30 breaths/min; oxygen saturation $\leq$ 93% at a rest state; arterial partial pressure of oxygen (PaO2)/oxygen concentration (FiO2) $\leq$ 300 mmHg. Patients with $>$ 50% lesions progression within 24 to 48 hours in lung imaging should be treated as severe cases. | Relative contraindication |
| **Critical** | Meeting any of the following criteria: occurrence of respiratory failure requiring mechanical ventilation; presence of shock; other organ failure that requires monitoring and treatment in the ICU. | Absolute contraindication |