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ORIGINAL PAPER

Operational strategies of a trauma hub in early coronavirus disease 2019 pandemic

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Abstract

Purpose The "Spedali Civili", one of the largest hospitals in the Italian region most affected by SARS-CoV-2 infection, is managing a large number of traumatic injuries. The objective of this article is to share our operational protocols to deliver an appropriate hospital trauma care in the context of the COVID-19 pandemic.

Methods We changed our work shifts, in consideration of the high number of patients; colleagues from smaller hospitals in the area joined us to increase the number of surgeons available. Thanks to the collaboration between orthopaedists, anaesthesiologists, and nurses, we created a flow chart and separate routes (in the emergency room, in the wards, and in the operating rooms) to optimize patient management. Our protocols allow us to always provide healthcare professionals with the correct personal protective equipment for the task they are performing.

Results Our strategies proved to be practical and feasible. Having a well thought plan helped us to provide for the most robust response possible. We have not yet been able to study the effectiveness of our protocols, and our recommendations may not be applicable to all healthcare facilities. Nonetheless, sharing our early experience can help other institutions conducting and adapting such plans more quickly.

Conclusions Having a clear strategy during the COVID-19 pandemic kept our systems resilient and effective and allowed us to provide high-quality trauma care. We offer this approach for other institutions to adopt and adapt to their local setting.

Keywords COVID-19 · Coronavirus · SARS-CoV-2 · Trauma · Orthopaedic · Surgery

Introduction

COVID-19 emerged from Wuhan, China, and it was declared a pandemic by the World Health Organization on March 11, 2020. The first reported cases in Italy were confirmed on January 30, 2020 in Rome. On March 19, 2020, Italy overtook China as the country with the most SARS-CoV-2-related deaths in the world, after reporting 3405 fatalities from the pandemic [1, 2]. Currently, on April 7, 22,837 COVID-19 patients are hospitalized in Italy and the number of deaths has risen to 16,523.

Severe trauma care in Lombardy is normally based on six specialized trauma centres, for a population of about 9,850,000 inhabitants. According to trauma registers, it is possible to estimate 1800 major trauma patients per year, who need an average of 6.2 days of intensive care unit hospitalization each, and an overall requirement of 20–25 intensive care beds [3].

After SARS-CoV-2 infection outbreak, Lombardy has been the first and most affected Italian region. On March 8, 2020, the Regional Government approved a temporary reorganization for healthcare assistance activities [3]. Inspiring principles were redistribution of human and technological resources to pneumology, infectious disease, and intensive care

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units, to face rapid SARS-CoV-2 infection spread [4–8]. All elective and non-urgent outpatient and inpatient activities were closed. However, some time-dependent clinical conditions were identified, such as stroke, cardiovascular emergencies, neurosurgical emergencies, and trauma. For those services, an organization based on a "hub-and-spoke" model was adopted.

Three "hub" hospitals for major trauma were identified in the region, where all trauma activities that could not be postponed were concentrated. The three hub hospitals guarantee 24/7 acceptance of emergency cases, and they were chosen on geographical bases, by covering roughly one third of Lombardy territory each, divided into western, central, and eastern. The other hospitals were assigned to one of the three hubs as "spokes." A fourth hub hospital, the regional centre for paediatric major trauma, has been re-allocated for urgent paediatric patients coming from all the other hospitals of the region.

Requirements for being selected as hub included the presence of an integrated trauma team 24/7 on active duty and supplementary surgical teams available on call, fast-track access to Emergency Department to reduce interpersonal contact between patients, activation of separated pathways to assist and operate on COVID-19 and non-COVID-19 patients, and integration of local medical teams with those of the spoke centres [9–11].

The purpose of the present study was to describe organization and operational strategies of trauma service in a hub hospital for major trauma in Lombardy, the "Spedali Civili" Hospital in Brescia.

Methods

Assuring an adequate level of service is difficult given the limited human, material, and financial resources. The "four S's" theory for surge capacity (staff, stuff, structures, and systems) [12, 13] was considered in guiding the development of a trauma care strategy in response to the COVID-19 pandemic.

Medical team

As required in Regional Decree XI/2906 [3], we organized medical shifts in order to be able to manage an increased number of severe trauma patients and to perform surgical activity on a 24 hour basis. Our orthopaedic surgical team included one senior consultant, another consultant, and one resident on duty for emergencies 24/7. Moreover, three consultants were available on call 24/7. During dayshifts, four consultants, and two residents were active in surgical activity in two operating rooms (OR) from 8 a.m. to 8 p.m.; one consultant and two residents took care of the ward; one consultant was in charge for isolated minor trauma care, and one consultant carried on outpatient activity for post-surgical and urgent consultations, three days a week in the morning. According to the organization model proposed by the Region, medical staff from spoke centers was included in the hub shifts.

Patient evaluation

Patients with a diagnosed fracture and surgical indication were evaluated by our anaesthesiology team, after obtaining history, chest radiography, blood exams, ECG, and PCR SARS-CoV-2 RNA swab test. In order to assess risk related to surgery, correct timing, and adequate anaesthetic procedure, we based patient's staging upon clinical conditions, as described by the Italian Society of Anesthesiology and Intensive Care (SIAARTI) [14] (Table 1).

Brescia COVID Respiratory Severity Scale (BCRSS) [15, 16], a staging system created at our hospital in cooperation with the Italian Society for Infectious and Tropical Diseases (SIMIT), was also adopted (Fig. 1).

Our anesthaesiologists merged criteria from both systems to define a flow chart that was shared with surgical teams for patient management (Fig. 2).

Surgical unit

Surgical activity was organized in order to reduce to a minimum the risk of transmission between SARS-CoV-2 infected and non-infected patients and to protect healthcare operators and professionals. We adapted two existing surgical units to our needs. Issues we had to face were avoiding direct contact between patients and healthcare workers, persistence of SARS-CoV-2 on surfaces [17], risk of delayed transmission between different patients, structural characteristics of already existing settings, costs, and saving of resources like personal protective equipment (PPE).

Reducing contact

We performed surgical procedures in two different surgical units, on two different floors. Patients with negative swab, normal chest radiograph, and absence of fever, cough, or history of contact were treated in a clean surgical unit, according to usual pre-operative, intra-operative, and post-operative procedures. COVID-19, suspected COVID-19, and patients without swab results, who needed rapid access to the OR, were operated on in a specific surgical unit. The unit was divided into three areas. The operating theatre was defined as contaminated area, or "red zone," in the presence of an infected patient. The corridor between the ward and the OR, including recovery area, was considered partially contaminated area, or "gray zone." The space including locker rooms, storage areas, relax zone, computer, and surgical report facilities was uncontaminated, or "white zone." The patient, coming from the ward, wearing a surgical mask, was brought directly into the operatory room, passing through a gray

Table 1 Adapted SIAARTI staging for COVID-19 clinical presentation in adults [15]

Stage	Description
Stage 1 Mild disease	Patients with uncomplicated upper respiratory tract viral infection, unspecific symptoms as fever, cough (productive or unproductive), fatigue, anorexia, sore throat, nasal congestion, headache, muscle pain, discomfort; rarely diarrhea, nausea or vomiting.
Stage 2 Pneumonia	Patients with pneumonia, no signs of severe pneumonia, no need for oxygen therapy.
Stage 3 Severe Pneumonia	Fever or suspected respiratory tract infection associated to at least one of the following: respiratory rate > 30/min, severe dyspnea, $SpO_2 < 93\%$ in air. The diagnosis is clinical; chest imaging can exclude complications.
Stage 4 ARDS	Outbreak or worsening of respiratory symptoms within 1 week after first clinical manifestation. Imaging: bilateral radiopacity not related to effusion, atelectasis or consolidations. Origin of edema: respiratory failure not related to heart failure or fluid overload. Oxygenation: - mild ARDS: 200 mmHg < PaO_2 / $FiO_2 \leq 300$ mmHg - moderated ARDS: 100 mmHg < $PaO_2/FiO_2 \leq 200$ mmHg - severe ARDS: $PaO_2/FiO_2 \leq 100$ mmHg - When PaO_2 is not available, $SpO_2/FiO_2 \leq 315$ suggests ARDS
Stage 5 Sepsis	Organ failure caused by deregulated host response to infection. Signs of organ failure include altered mental status, difficult or superficial respiration, increased respiratory rate, low O_2 peripheral saturation, oliguria/anuria, tachycardia, cold extremities, hypotension, and cutaneous alterations, and laboratory findings including altered coagulation, thrombocytopenia, acidosis, hyperbilirubinemia, and increased lactates.
Stage 6 Septic shock	Hypotension not responsive to volume expansion; need for vasopressors to keep MAP ≥ 65 mmHg and lactates ≥ 2 mmol/l

zone, without any stop in recovery areas. All anaesthesiologic, surgical, and radiological procedures on the patient were performed inside the OR. At the end of the procedures, the patient left the theatre, and through the "gray zone" was brought directly to the ward (Fig. 3).

Healthcare operators and professionals dressed differently according to the area they were operating in. In the white zone, allowed dressing consisted in clean scrubs, cuff, surgical mask, and clean clogs. Before accessing the red zone, it was mandatory to wear the "COVID-19 kit" (Table 2).

In order to leave the red zone, all healthcare professionals stepped over a puff embedded with chloro-derivate solution. Undressing procedure consisted in removing one pair of gloves, head cap, goggles/visor, gown, radiological protections, one pair of long shoe covers, and the remaining pair of gloves. Friction with hydro-alcoholic solution after every step and quick exit from the gray zone were recommended; before entering the white zone, the remaining pair of long shoe covers had to be removed and, after washing hands, a new surgical mask was worn.

Reducing environment contamination

Several procedures were adopted in order to reduce contamination of surfaces [17]. Beside standard disinfection practice, we minimized the amount of equipment inside the OR to operatory bed, lamps, anaesthesiology ventilator, and monitor. All implants, screws, drugs, sutures, and every disposable device were stored outside the red zone. Great attention had to be payed to keep OR doors closed since the patient entered the red zone, as our ventilation system warrants a complete air change over a four minute period and our surgical unit consists in positive pressure theatres. Every OR has a window that opens on the white zone, through a double sliding glass with a "no man's land" space in between; therefore, it was possible to bring all the necessary to the theater reducing contaminated air leaks. Scrub nurses communicated across the window, using walkie-talkies or writing on magnetic boards. After the end of every surgical procedure, as the patient left the surgical unit, disinfection of every horizontal and vertical surface, using a solution of dichloroisocyanurate (2 tbs in 3000 ml of water, equal to 1000 ppm chlorine) or electrolytic chloroxidant 2.8% (40 ml in 1000 ml of water, equal to 1100 ppm chlorine) and chlorhexidine 0.5% + alcohol 70% for metallic surfaces, started. Complete disinfection time was 60 min. Furthermore, every 60 min or after every patient transited, all surfaces in the gray zone were cleaned with chloro-derivate solution.

Ward

Patients with surgical indication, coming from the Emergency Department or from spoke hospitals, were hospitalized in our ward. During SARS-CoV-2 spread in Lombardy, most available

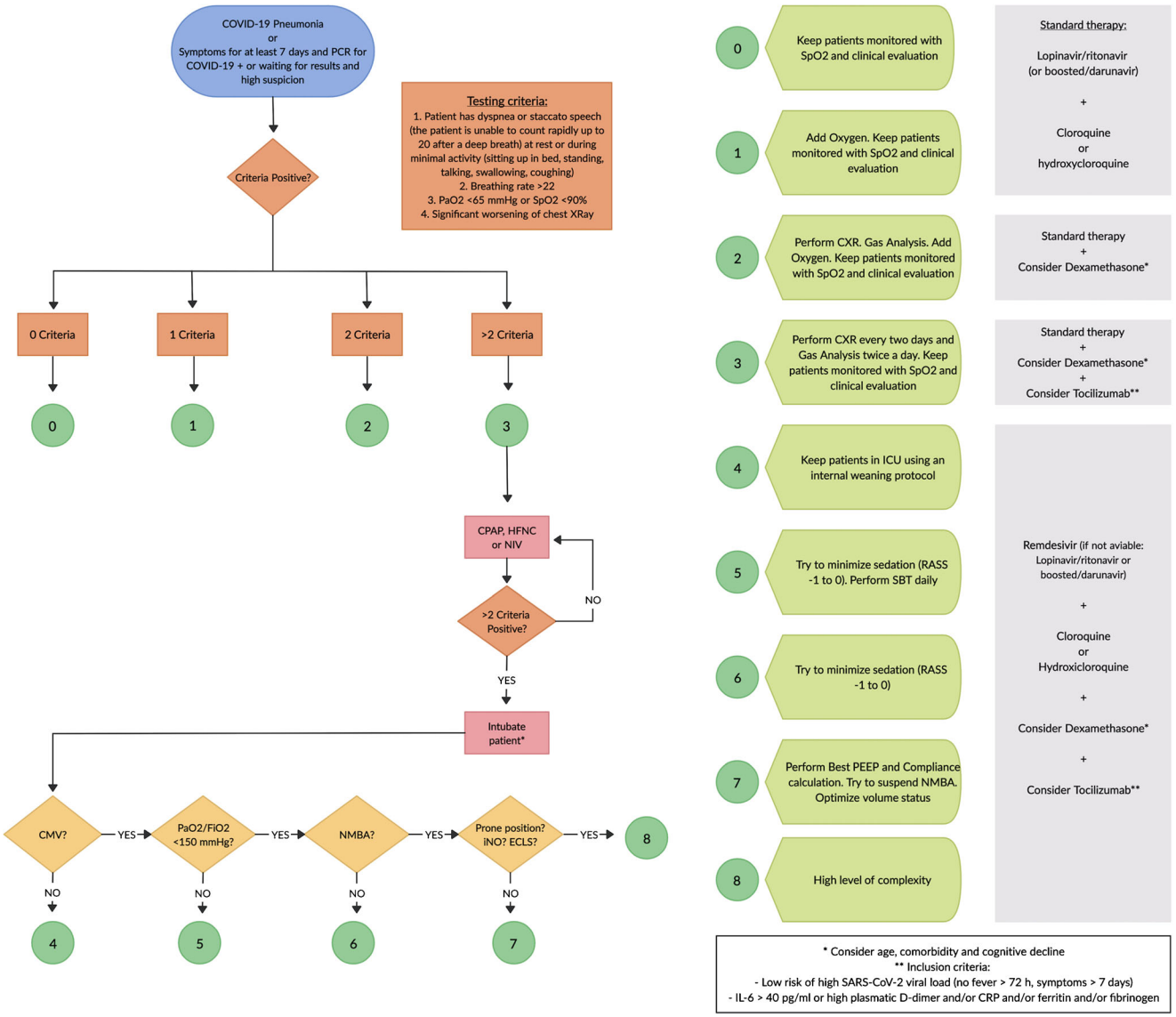

Fig. 1 Adapted SIMIT Brescia COVID Respiratory Severity Scale (BCRSS) [16]

beds were employed to treat severe complication of COVID-19. Thus, our facilities were reduced and limited.

We hosted patients in two different wards, on to different floors of our hospital. Patients who were considered not infected by SARS-CoV-2, without history of fever, cough, or dyspnea, with normal chest radiography and negative swab, were hospitalized in a 40-bed ward. This environment, also defined as "white zone," functioned as a normal trauma ward. Every patient and all healthcare staff wore a surgical mask. Clinical evaluation, laboratory tests, and chest radiography were performed on a regular basis and according to any clinical worsening.

Patients with confirmed SARS-CoV-2 infection or who showed suspected clinical course were hospitalized in a special 15-bed "trauma COVID-19" ward. In this setting, healthcare operators were equipped with COVID-19 kit PPE during patients' assistance.

Clinical features of SARS-CoV-2 infection overcame trauma and orthopaedic surgeons' medical education; therefore, the ward activity was managed by a heterogeneous medical team, formed by one internist and one orthopaedic surgeon; one infectious disease specialist briefed with the medical team every day, for two hours. In cases of severe respiratory impairment, an ICU specialist was on call and rapidly available. The medical team briefed with the nursing team every day, at 8 a.m., 2 p.m., and 8 p.m. All clinical documentation was locked in the medical office; the informed consent module, after being signed by the patient, was stored in a plastic closed bag. Patients who needed emergency surgical treatment, or with laboratory and radiological findings inconsistent with clinical course, were treated with high suspicion and isolated in a "gray zone," waiting for a clear diagnosis and distribution in white or red zone.

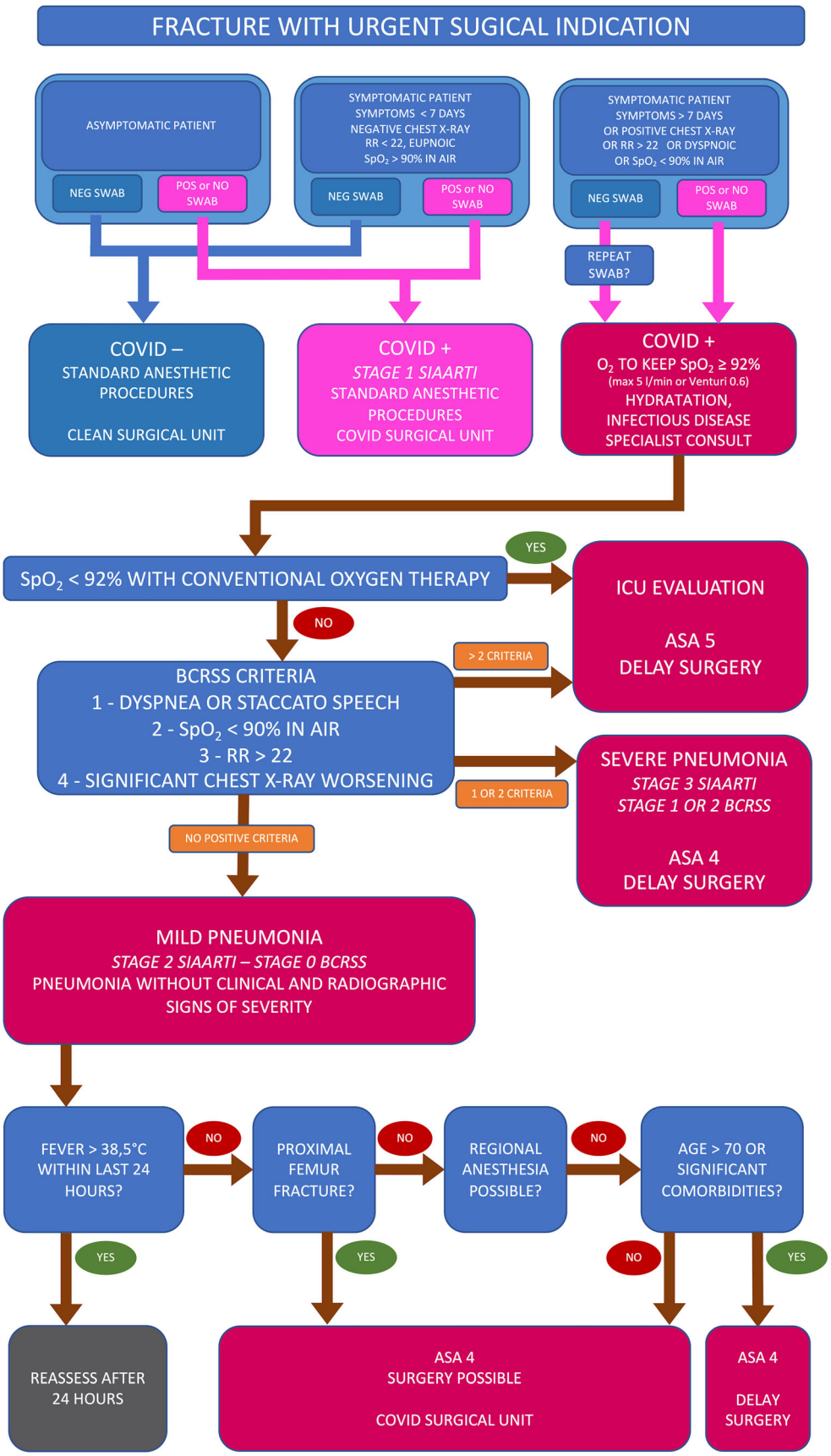

Fig. 2 Decisional algorithm in COVID-19 patients with fractures

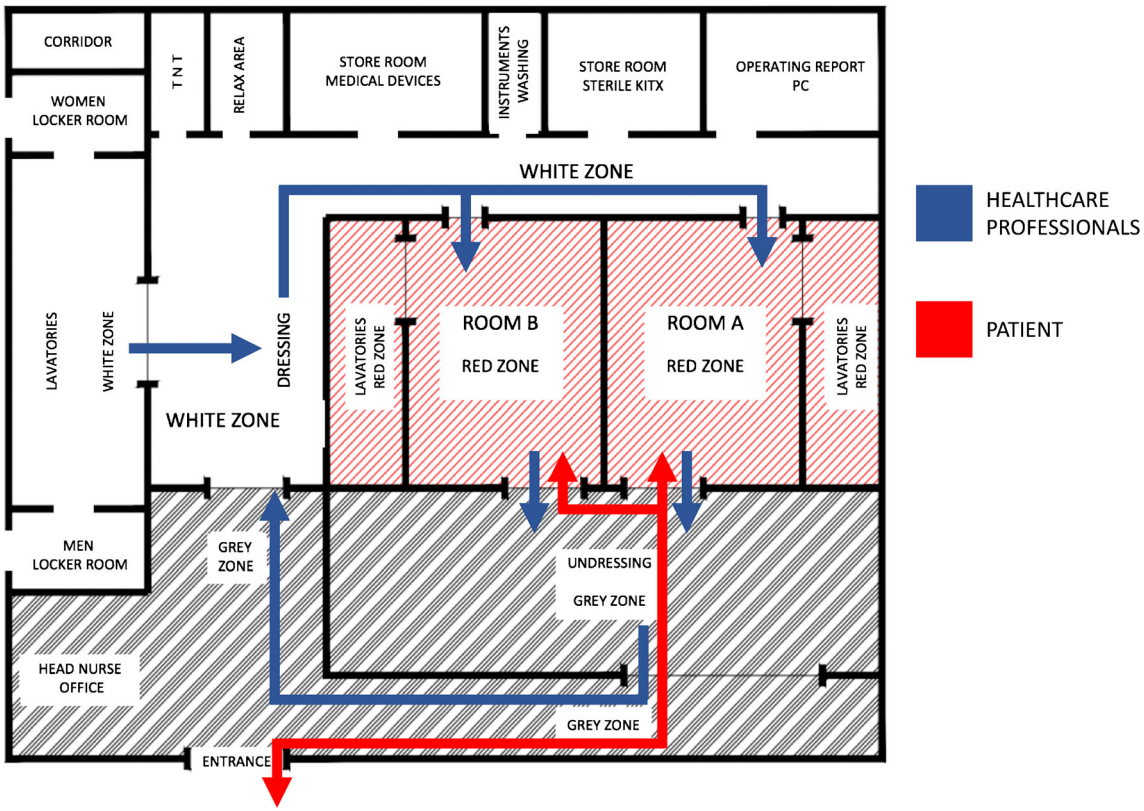

Fig. 3 Surgical unit divided into red zone (red mesh), gray zone (gray mesh), and white zone. Pathways for healthcare professionals (blue) and patients (red)

Surgical volumes

Since the breakout of SARS-Cov-2 in Lombardy, in the time frame between February 21 and April 9, 2020, we carried on our activity in trauma surgery, performing 191 procedures. We treated patients according to our usual surgical indications, related to fracture pattern, general, and local conditions. Timing, pharmacological, and support therapies were considered, according to the clinical course, following the above-mentioned protocols for COVID-19 patients. In particular, we operated on 62 fractures of the femur, 18 fractures of the humerus, 14 fractures of the acetabulum and pelvic ring, three periprosthetic fractures (2 hips, 1 knee), ten ankle fractures, 13 fractures of the radius, four fractures of the clavicle, two fractures of the scapula, four patella fractures, eight tibia diaphyseal fractures, two calcaneal fractures, 13 fractures of metacarpals and phalanges, one hip hemiarthroplasty revision for instability, 15 open tendinous lesions of the hand, and seven soft tissue procedures, including traumatic wound repair, surgical wound revision, and drainage of haematoma. Overall, 53 procedures were performed in the "COVID-19-free" surgical unit, while 138 operations were performed in the specific surgical unit for SARS-Cov-2 infected or suspected patients.

Table 2 Personal protection equipment in every "COVID-19 kit"

COVID-19 kit
1. Two head caps
2. FFP2 facial mask (FFP3 for aerosol generating procedures such as orotracheal intubation)
3. Protective goggles or visor
4. Two pairs of gloves
5. Surgical gown
6. Two pairs of long shoe covers

Discussion

In view of the current health crisis due to COVID-19, the suspension of elective surgery and all non-urgent activities is a fundamental measure both to limit the spread of the infection and to relocate medical and nursing staff to COVID-19-dedicated departments [18]. Other fundamental measures are the drafting of precise national and intra-hospital protocols, the training of personnel, and the supply of all necessary PPE. Nonetheless, there are still significant differences between protocols in different countries regarding the organization of departments, patient management, and rules for healthcare professionals [19].

Orthopaedic surgeons are at the forefront of this emergency, and numerous cases of SARS-CoV-2 infection have been recorded among them; a Chinese study showed an incidence of COVID-19 between 1.5 and 20.7% in eight hospitals in Wuhan. The most suspected places for exposure to the virus were the wards, public places in hospitals, operating rooms, intensive care units, and outpatient clinics. A quarter of the infected orthopaedic surgeons passed on the virus to other people, including family members, friends, colleagues, and patients. Severe fatigue has proven to be a risk factor for COVID-19, so an optimal organization of health workers' shifts is of crucial importance [20].

In Italy we are experiencing a high number of COVID-19 deaths among doctors. Many surgeons feel exposed to a high risk of contagion, and the supply of PPE is not always adequate in all hospitals [21]. Thanks to the organization and protocols described above, the health workers of our unit are provided with all the necessary PPE. In addition, since we enabled these measures, we have not recorded new cases of infection among doctors and nurses in orthopedic wards and operating rooms.

In recent months, due to national measures to contain the infection, road accidents have decreased in Italy, and most of the fractures occur in elderly patients with significant comorbidities. These patients are also those most severely affected by COVID-19 [22]. Considering the high risk of rapid deterioration of their health conditions [23], it is necessary to carefully evaluate these patients to decide whether or not to undergo surgery for the treatment of fractures. The flow chart created by our anaesthesiology team (Fig. 2) is currently guiding us in the management of these patients; the measures we have adopted for our surgical activity are in accordance with the latest indications of the scientific literature [24, 25]. Although we do not yet have the numbers to demonstrate the effectiveness of this system, we are recording the data for further analysis.

Limitations

We have been adapting to a rapidly changing environment. These strategies proved to be practical and feasible. Having a well thought plan helps to provide for the most robust response possible. However, this strategy has several important limitations. First, we have not yet been able to study the effectiveness of our proposed strategies. Second, our contingency plan is a temporary emergency plan that could not resist long-scale outbreak. This plan was rapidly developed and continues to be modified and updated at "Spedali Civili" Hospital in Brescia. Finally, the isolation OR workflow and clinical care guidelines are institution- and department-specific; hence, our recommendations may not be applicable to all healthcare facilities. Nonetheless, we thought that it would be useful to share our early experience to help other institutions conducting and adapting such strategies more quickly.

Conclusions

Managing a major infectious disease crisis is a complex activity undertaken in a complex system. Sharing our planning and experiences with the scientific community is a fundamental step in identifying the most appropriate measures to respond to the current health crisis. Having a clear strategy during the COVID-19 pandemic kept our systems resilient and effective and allowed us to provide high-quality care.

Code availability Not applicable.

Author contributions All the authors worked and are still working at the "Spedali Civili" Hospital in Brescia during the COVID-19 emergency. Alessandro Casiraghi, Fabio Albertini, Stefania Avanzini, Manuela Pansi Marini, and Pierangelo Guizzi coordinated the strategies for organizing the trauma hub. Alessandro Casiraghi, Marco Domenicucci, Stefano Cattaneo, and Giuseppe Milano had the idea for the article. Marco Domenicucci, Stefano Cattaneo, Emanuele Maggini, and Giuseppe Milano performed the literature search and data analysis. Marco Domenicucci, Stefano Cattaneo, Emanuele Maggini, Claudio Galante, and Giuseppe Milano wrote the article. Marco Domenicucci and Giuseppe Milano reviewed and edited the manuscript. Alessandro Casiraghi is the guarantor.

Data availability Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This manuscript does not involve humans, or human data, or animals, so it is not accompanied by a copy of the letter from the ethical committee.

Consent to participate Not applicable.

Consent for publication Not applicable.

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