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Review Article

Hospital surge capacity in a tertiary emergency referral centre during the COVID-19 outbreak in Italy

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Summary

The first person-to-person transmission of the 2019 novel coronavirus in Italy on 21 February 2020 led to an infection chain that represents one of the largest known COVID-19 outbreaks outside Asia. In northern Italy in particular, we rapidly experienced a critical care crisis due to a shortage of intensive care beds, as we expected according to data reported in China. Based on our experience of managing this surge, we produced this review to support other healthcare services in preparedness and training of hospitals during the current coronavirus outbreak. We had a dedicated task force that identified a response plan, which included: (1) establishment of dedicated, cohorted intensive care units for COVID-19–positive patients; (2) design of appropriate procedures for pre-triage, diagnosis and isolation of suspected and confirmed cases; and (3) training of all staff to work in the dedicated intensive care unit, in personal protective equipment usage and patient management. Hospital multidisciplinary and departmental collaboration was needed to work on all principles of surge capacity, including: space definition; supplies provision; staff recruitment; and ad hoc training. Dedicated protocols were applied where full isolation of spaces, staff and patients was implemented. Opening the unit and the whole hospital emergency process required the multidisciplinary, multi-level involvement of healthcare providers and hospital managers all working towards a common goal: patient care and hospital safety. Hospitals should be prepared to face severe disruptions to their routine and it is very likely that protocols and procedures might require re-discussion and updating on a daily basis.

[Correction added on 1 May 2020, after first online publication: Affiliations for A. Protti and M. Cecconi have been updated from 6 to 8.]

[Correction added on 28 July 2020, after first online publication: The author affiliations for the authors listed from M. Greco to M. Cecconi have been corrected in this version]

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Introduction

As of 11 April 2020, there have been 152,271 officially reported confirmed cases of the 2019 novel coronavirus (nCoV) infection causing coronavirus disease 2019 (COVID-19) in Italy. Of these active cases, 57,592 are from the Lombardy region, with 1174 (2%) currently admitted to an

intensive care unit (ICU) [1]. The first person-to-person transmission in Italy was reported on 21 February 2020 and led to an infection chain that represents one of the largest known COVID-19 outbreaks outside Asia [2]. From previous reports and current data, we anticipated a critical care crisis due to a shortage of intensive care beds similar to that reported in China [3]. Considering the rapid spread of the disease, it was then paramount for hospitals, units and providers to plan ahead and prepare as much as possible while the infection had not reached uncontrolled rates [4]. As a response to the COVID-19 outbreak in the Lombardy region, a regional critical care task force was created on 21 February 2020 [5]. The aim of the task force was to develop governance guidelines for the emergency response and to co-ordinate the allocation of resources for all patients with COVID-19 requiring a critical care bed among hospitals in the region. The task force, which is led by the intensive care team at the Policlinico Maggiore Hospital in Milan, is active 24 h a day, 7 days a week and is staffed by a group of consultant intensivists. It receives bed request calls for COVID-19–positive patients and makes the calls to COVID-19 intensive care units asking for beds on a regional basis. This is also co-ordinated with the regional pre-hospital emergency medical service which manages all pre-hospital and interhospital transfers [6]. A regional directive required hospitals, as of 23 February 2020, to urgently prepare for a mass influx of COVID-19–positive critically ill patients. The choice was to cohort these patients at the ward or unit level and the receiving hospitals were asked to create dedicated wards and ICUs.

In this review, we report our experience of preparing the reception, assessment and critical care areas of our hospital to admit a large number of COVID-19 critically ill patients. Our aim was to increase hospital surge capacity to offer the appropriate level of care to the maximum number of patients, doing our best to maintain biocontainment of confirmed and suspected cases while still providing safe critical care to non-COVID-19 patients and ensuring a safe working environment for the healthcare providers involved.

Our setting

Our centre is a large, multidisciplinary, academic hospital in the south of Milan. It has a strong surgical prepondrance with a focus on cancer and immune disorders. It also has a third level emergency department and is part of the extracorporeal life support network. Totalling more than 700 beds, it usually operates two ICUs: a general neuro-trauma ICU with 15 beds and a cardiothoracic ICU with 9 beds. Under normal conditions, the ICU bed usage is always above 90%. It is worth mentioning that although there is a team of clinical microbiologists and infectious disease specialists, the hospital does not usually have dedicated infectious disease beds.

Command, control and co-ordination

A dedicated task force of our hospital experts was created on 24 February 2020 with the task of increasing the hospital surge capacity, defined as the combination of space, staff and supplies needed for safely admitting a large number of critically ill patients with COVID-19 [7]. The task force was guided by two key principles: increased surge capacity for COVID-19–positive patients and strict containment of the suspected and positive cases. Isolation of patients and working areas planning was guided by the European Centre for Disease Control Coronavirus Hospital guidance [8].

The task force was formed of physicians, senior critical care nurses and representatives from the medical directorate, hospital management and hospital infection control. Following this initial meeting, the team split into three working groups: operations; procedures; and training. Each group was tasked with one of the above-mentioned items. Each team had direct involvement with a group of support teams from different departments including: pharmacy; diagnostics; logistics and procurement; building engineering; biomedical technologies; information technologies; waste management; and medical education and simulation. Representatives from each department were asked, through hospital management, to be constantly available for on site and on call availability during the whole unit activation process.

A meeting was held on the morning of that same day, and also following a review of the literature [9–13], a response plan was designed as follows:

1. Establishment of cohorted ICU(s), emergency department and wards dedicated to the treatment of COVID-19–positive patients while maintaining clinical care of non-COVID-19 patients in other dedicated ICUs and wards
2. Design of appropriate procedures for reception, assessment, isolation and movement of suspected and confirmed cases
3. Training of all staff expected to work in this dedicated ICU on personal protective equipment (PPE) usage and patient management in this special situation

On the same day, the hospital shut down 85% of its elective surgical activity. It was decided that the dedicated COVID-19 ICU would be located in one of the temporarily closed day surgery units. It was decided to observe a step-up approach starting with four operational bays by the early morning of 27 February 2020. We received the first patient

on the afternoon of 1 March 2020 and have since implemented a median increase of 2 beds per day reaching the capacity of 12 occupied beds as of 6 March 2020, with a further expansion into our anaesthetic rooms in the operating theatres and 39 occupied level 3 beds as of 25 March 2020.

Space

This first cohorted ICU was selected on the ground floor for its proximity to the emergency department and the computed tomography (CT) scanner; the ability to maintain negative pressure within its premises; and the limited number of access points allowing easy to control access to the new unit. Negative pressure for all involved areas was created ad hoc by the building engineers. The selected area consists of a surgical area of five operating theatres, all with a common pre-operative area, which is also connected to a large 24-bay recovery area, which was selected as the main area for the COVID-19–dedicated ICU. Access to the area was confined to one entry and one exit point for staff and one entry–exit point for patients. All other doors leading outside were locked or zip-tied from the inside, and access badges for non-authorised staff members were disabled. The men's changing room in the theatre area was chosen as the donning area, and the women's changing room became the doffing area. Both led to the same corridor to the isolated unit. Personal protective equipment was stockpiled in a locked cabinet within the locked changing room to prevent theft.

Two medical wards, both on the ground floor with 25 beds each, were initially dedicated to patients not requiring level 3 care. Negative pressure was generated in these areas similar to that produced in the ICU. Daily operations in these wards were run by respiratory consultants with the support of a multidisciplinary internal medicine team. Approximately 20% of the ward beds were dedicated to level 2 care (high dependency unit), with monitors and the capacity to deliver non-invasive ventilation with the support of a critical care outreach team. Clear goals of care were instituted and discussed early during the admission to these wards to avoid any delay in escalation to level 3 care if appropriate and needed.

Available beds, both on the ICU and in medical wards, were activated gradually, trying to forecast daily needs over a period of 2–3 days each time and predicting an average 15–20% unplanned additional cases every day. This proved particularly challenging as the set-up of new bays had to be performed wearing full PPE. After saturation of the isolated intensive care, the escalation plan was as follows: closure of the cardiothoracic intensive care; reduction in the overall non-COVID-19 critical care beds to 10 beds; and the opening of a second dedicated COVID-19 ICU in the cardiothoracic ICU (with six occupied beds as of 13 March 2020). After saturation of the two medical wards, a further two wards with the same characteristics as above were opened to patients not requiring level 3 care with a total of 106 patients admitted as of 13 March 2020.

Supply

Each bay of the new ICU was fitted with basic intensive care equipment including a bed, a monitor, a ventilator and syringe drivers. Most of these items did not have appropriate stands but were placed on surgical tables or laparoscopic shelves which served as suitable alternatives. Ergonomics of this area were a concern during set-up. Moreover, as the equipment had to be procured from different locations within the hospital (i.e. from other closed-down surgical areas), doctors and nurses working here needed to use a broad range of devices from different manufacturers. For example, the ventilators in the unit come from three different manufacturers and within them there were five different interfaces. This must be considered, especially when admitting patients who will require frequent ventilator manipulation.

As with the Chinese experience, a list of dedicated medical equipment was prepared and the relevant equipment permanently moved and exclusively assigned to that unit [10]. These items were left in the unit at all times. These included: disposable bronchoscopes; a videolaryngoscope; a blood gas machine; a portable X-ray machine; a three-probe ultrasound machine; a laptop and tablets for staff; and a refrigerator. A limited quantity of consumables was stockpiled within the infected areas and restocking of consumables had to be planned accordingly. Due to the high anticipated work-load during the response, we decided not to routinely offer extracorporeal membrane oxygenation (ECMO). We aimed to offer standard intensive care to all critically ill patients rather than very resource-consuming treatments only to some of them (with the inherent risk of being unable to adequately treat some others). We maintained a case-by-case screening of potential ECMO patients for very select cases, that would be referred to the regional ECMO network after shared decision-making.

Staff

Departmental administrators worked on designing dedicated rotas (shifts) for these newly created areas. Staffing was planned with a one-to-two nurse-to-patient ratio and one-to-five or six physician-to-patient ratio. A common shift system was agreed among all those working

in the new ICU. Considering the discomfort of working in PPE, including overheating and the inability to access food, water or bathroom facilities, we developed a four-shifts-a-day system, with teams handing over every 6 h. At this stage we planned two physicians for each one of the daytime shifts (6 am–12 pm; 12 pm–6 pm and 6 pm–12 am) and only one for the night shift (12 am–6 am). The COVID-19 team on shift was not allowed to leave the unit to assess or consult patients; this was allocated to an independent team. Only confirmed cases of COVID-19 were brought to the unit.

The core critical care consultant team staffed the COVID-19 ICU and some shifts on the general ICU, while anaesthetists covered the remaining general ICU shifts which remained unchanged in terms of number and structure. The pool of experienced critical care nurses was moved to the new COVID-19 ICU, with the general ICU being staffed by a large pool of nurses from the surgical operating theatres having been made available by the drastic reduction in elective surgical activity. Nurses and doctors had to be relocated from their usual places of work to allow full staffing of the ICU and wards.

Ward staffing had to be adapted to the new cohort model. Rotas of nurses dedicated to COVID-19 wards were reinforced with personnel from other areas, such as outpatient clinics or diagnostic services, that were shut down. On average, ward staffing was increased by 33% to meet the increased demands of care of these patients and to allow proper resting times between shifts. Medical doctors no longer involved in elective hospital activities were assigned to cohorted wards, regardless of their specialty. The hospital retained a small amount of elective non-deferrable oncologic cases, amounting to < 10% of the usual surgical volume. Surgeons not involved in these activities assisted with the management of COVID-19 patients, supported other medical areas and put in place one COVID-19 operating room and dedicated surgical pathways [14].

Open communication and appropriate shift design and mixing experienced and unfamiliar personnel were fundamental to the sustainability of the process. The communication strategy involved emails every evening by hospital managers to present what had been achieved that day. These were complemented by departmental meetings held in the evening which were extremely well attended. Meetings were used to present protocols and answer questions. Subsequent significant changes in protocols and procedures in accordance with the developing national or regional law and guidelines were communicated and adopted by all staff members. It should be noted that, as in any disaster response, communication plays a key role in response success.

Training

Training of medical doctors, nurses and healthcare assistants consisted of lectures with live demonstrations and in-situ simulation. Not only was every staff member due to work in the COVID-19 ICU required to attend the training but it was also required for other staff members who might intervene in case of escalation as second-line healthcare providers. The first cohort of staff was chosen from critical care consultants and experienced critical care nurses and healthcare assistants. The 60-min training programme was designed and delivered by a group of critical care consultants and infection control nurses with the support of a simulation specialist from the simulation centre. It was designed so that it could be attended by all the healthcare providers during their shift, either while on a break or while being covered by a colleague. The training curriculum was

Table 1 COVID-19 healthcare workers training scheme.

Training sessions	Activities	Duration	Participants numbers	Involved personnel
Lectures with live demonstrations	PPE donning and doffing PPE explanation	1 h 3 times a day	Small groups < 25 persons	ICU medical staff ICU nurses Healthcare assistants
In-situ simulation	PPE donning Airway management of suspected or confirmed COVID-19 patients Isolated patient handling (low-resource prone positioning) Doffing of PPE	1 h All day rotations	1–2 doctors 2–3 nurses	
Random calls	Surprise assessment with PPE checklists	20 min	1 person at the time	

PPE, personal protective equipment; ICU, intensive care unit.

designed ad hoc, balancing educational needs and time, and was also inspired by a number of previous works on emergency and pandemic training through simulation [15, 16]. Over the two core training days we trained 28 critical care physicians, 39 critical care nurses and 10 healthcare assistants. Protocols on how to use PPE, precautions to be adopted during tracheal intubation and how to rapidly turn a patient from supine to prone or the other way around with only three healthcare workers, were presented to all staff, disseminated via email and displayed in the emergency department and in the COVID-19 ICU. Details of the training programme are presented in Table 1.

Critical care area operations

The workflow for the management of suspected or confirmed COVID-19 patients is presented in Figure 1. Any patient presenting to the emergency department was subject to a pre-triage assessment, either directly in the parked ambulance or in a shelter unit created ad hoc at the entrance of the emergency department. The objective of

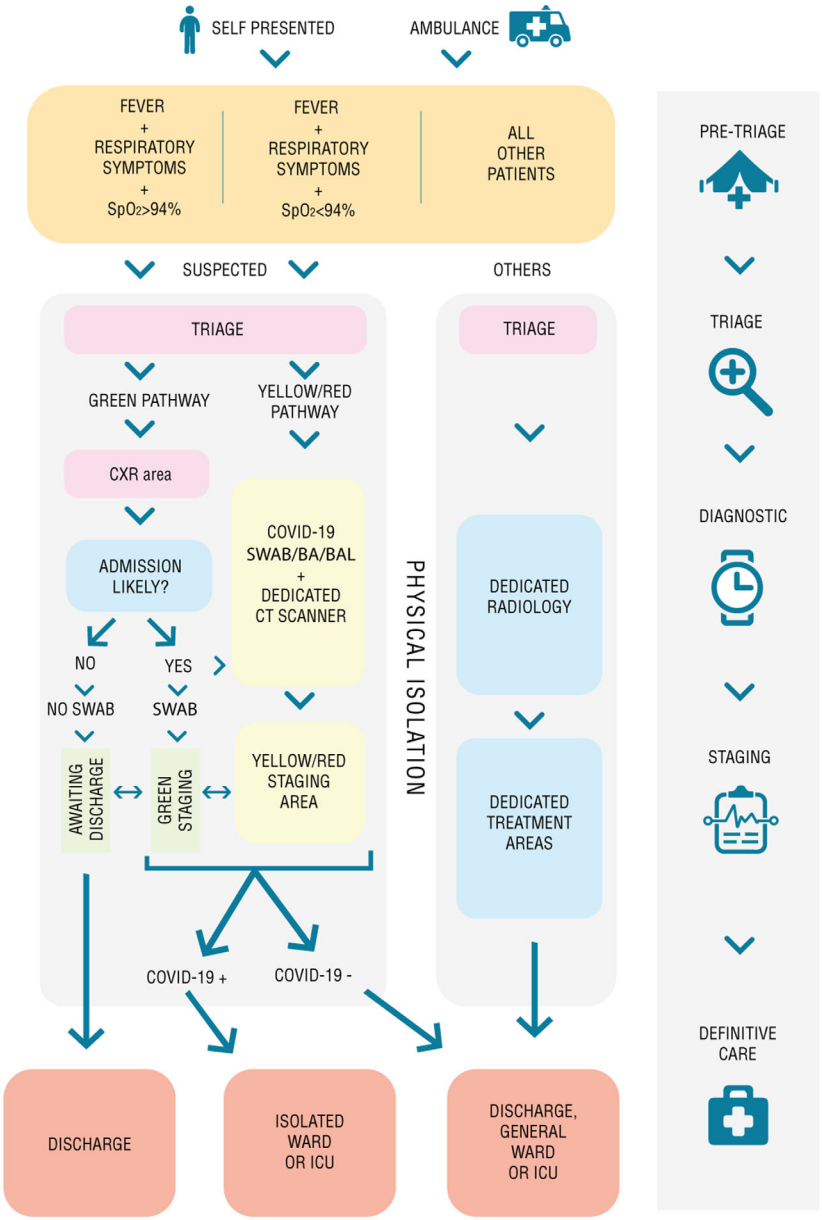

Figure 1 Patient flow within the hospitals from presentation through assessment to final disposition. Green (minor), yellow (moderate) and red (immediate) triage codes based on local emergency department triage protocol. CXR, chest X-ray; BA, bronchial aspirate; BAL, bronchoalveolar lavage; CT, computed tomography; ICU, intensive care unit.

the pre-triage was to separate patients with respiratory symptoms from all others. Patients were classified into three subsets: (1) with respiratory symptoms and $S_pO_2 \geq 94\%$ on room air; (2) with respiratory symptoms and $S_pO_2 < 94\%$; and (3) without respiratory symptoms. A structural redesign of the emergency department was performed. Two physically separated areas were created: one dedicated to any respiratory case and the other for non-respiratory cases. The emergency department CT scanner was dedicated exclusively to respiratory patients, and central radiology was used for all the other emergency department patients. Walking patients with respiratory symptoms underwent portable chest X-ray in a dedicated area just after triage and were then assessed by a physician who decided whether they required admission or could be discharged.

It was decided that patients requiring critical care would enter the dedicated ICU only with a confirmed laboratory diagnosis of COVID-19 either via the emergency department or using secondary transport through the regional COVID-19 coordination network.

For this reason, a fully isolated 'pending-confirmation' staging area was prepared in the emergency department for patients with respiratory symptoms, separating those with hypoxaemia from the others. The emergency department staging for the most severe hypoxaemic patients (red area) was equipped with mechanical ventilators and staffed by critical care nurses from the unit, with the medical support of a critical care consultant on call for the emergency department. Once a diagnosis of COVID-19 was confirmed, patients were transferred directly from the ambulance or the emergency department staging area via a dedicated pathway to their assigned unit by fully donned staff members. If indicated, CT scan of the chest was performed during the same transfer as patients passed next to the dedicated scanner. The patient was then handed over to the ICU team. The hallway connecting the emergency department and the ICU could not be locked down at all times for hospital logistics. Hospital security with lightweight PPE secured each end of the hallway before any transport. After each patient move, the hallway was sanitised with chlorine-based disinfectants.

Due to limited staffing within the COVID-19 ICU and the complexity of these patients, a telemedicine system was deemed essential for the running of the critical care service. Two tablets were prepared with teleconferencing software; one was placed in the COVID-19 ICU and the second in the general non-COVID-19 ICU. Two other tablets were given to the co-ordinators of the unit who were alternately on call during the night from home. This was an easy, cheap and practical solution, as it allowed the physicians to move around and show clinical findings, screens and monitors to the outside team. A daily ward round was run at 12 pm with all consultants on duty, and external consultations took place 24 h a day. Other tablets were prepared for awake patients to communicate with their relatives who were not allowed to enter the unit and who were themselves either self-isolated or admitted to hospital.

At the same time, hospital managers and clinicians worked to increase the overall safety and surge capacity of the whole hospital, including areas other than critical care. All entrances were check-pointed and any person entering the facility, including healthcare professionals, was questioned about recent illnesses and contacts with subjects with respiratory symptoms; their body temperature was measured via a contactless device. Those screened as 'at risk' were either asked to return home with appropriate instructions or sent to the emergency department as appropriate. Access to the hospital was limited to emergency patients or outpatients with an urgent clinic appointment.

Conclusions

We have reported our brief experience with the process of opening a new dedicated cohorted COVID-19 ICU while also guaranteeing a safe option for patients admitted with other pathologies. This manuscript was prepared during the actual response while increasing our bed surge capacity on a daily basis and experiencing a constant increase in affected patients and healthcare needs. On 6 April 2020 our hospital has used the approach described here to open other ICUs for invasive ventilatory support and level 2 areas for non-invasive ventilatory support. At this date our capacity was: 45 level 3 beds for COVID-19 patients; 10 level 3 ICU beds for non-COVID-19 patients; 40 level 2 beds and 200 level 1 beds for COVID-19 patients outside of the ICU. We have prepared another level 3 area ready to be open for another 10 beds and another level 2 area in case of need. Our data and experience suggests that hospitals have to prepare for at least for a 4–5 times increase in ICU capacity compared with baseline.

Opening our intensive care units and adapting the whole hospital emergency process required multidisciplinary, multi-level involvement of healthcare providers and hospital managers all working towards a common goal: patient care and hospital safety. As the infection moves around the world, certain areas which are not affected yet should use the time to prepare and train, stockpile necessary equipment and prepare their staff for sudden disruptions in their work–life balance for the upcoming weeks, including the very likely possibility of

enforced in-hospital quarantine. Hospitals should be prepared to face severe disruptions in their routine. It is very likely that protocols and procedures will require revision and updates on a daily basis. We hope this review will be useful to anyone who may have to face a similar challenge.

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References

1. http://opendatadpc.maps.arcgis.com/apps/opsdashboard/index.html#/b0c68bce2cce478eaac82fe38d4138b1(accessed 12/04/2020).
2. Carinci F. Covid-19: preparedness, decentralisation, and the hunt for patient zero. *British Medical Journal* 2020. Epub ahead of print 28 February. https://doi.org/10.1136/bmj.m799
3. Xie J, Tong Z, Guan X, Du B, Qiu H, Slutsky AS. Critical care crisis and some recommendations during the COVID-19 epidemic in China. *Intensive Care Medicine* 2020. Epub ahead of print 2 March. https://doi.org/10.1007/s00134-020-05979-7
4. Arabi YM, Murthy S, Webb S. COVID-19: a novel coronavirus and a novel challenge for critical care. *Intensive Care Medicine* 2020. Epub ahead of print 3 March. https://doi.org/10.1007/s00134-020-05955-1
5. Grasselli G, Pesenti A, Cecconi M. Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response. *Journal of the American Medical Association* 2020. Epub ahead of print 13 March. https://doi.org/10.1001/jama.2020.4031
6. Spina S, Marrazzo F, Migliari M, Stucchi R, Sforza A, Fumagalli R. The response of Milan's Emergency Medical System to the COVID-19 outbreak in Italy. *Lancet* 2020; **395**: e49–50.
7. Hick JL, Christian MD, Sprung CL. European Society of Intensive Care Medicine's Task Force for intensive care unit triage during an influenza epidemic or mass disaster. Chapter 2. Surge capacity and infrastructure considerations for mass critical care. Recommendations and standard operating procedures for intensive care unit and hospital preparations for an influenza epidemic or mass disaster. *Intensive Care Medicine* 2010; **36** (Suppl 1): S11–20.
8. European Center for Disease Control (ECDC). COVID-19 Checklist for hospital preparing for the reception and care of coronavirus 2019 (COVID-19) patients. https://www.ecdc.europa.eu/sites/default/files/documents/covid-19-checklist-hospitals-preparing-reception-care-coronavirus-patients.pdf (accessed 08/03/2020).
9. Sprung CL, Zimmerman JL, Christian MD, et al. Recommendations for intensive care unit and hospital preparations for an influenza epidemic or mass disaster: summary report of the European Society of Intensive Care Medicine's Task Force for intensive care unit triage during an influenza epidemic or mass disaster. *Intensive Care Medicine* 2010; **36**: 428–43.
10. Liao X, Wang B, Kang Y. Novel coronavirus infection during the 2019-2020 epidemic: preparing intensive care units-the experience in Sichuan Province, China. *Intensive Care Medicine* 2020; **46**: 357–60.
11. Maves RC, Jamros CM, Smith AG. Intensive care unit preparedness during pandemics and other biological threats. *Critical Care Clinics* 2019; **35**: 609–18.
12. Wong ATY, Chen H, Liu SH, et al. From SARS to Avian influenza preparedness in Hong Kong. *Clinical Infectious Diseases* 2017; **64**: S98–104.
13. Bouadma L, Lescure FX, Lucet JC, Yazdanpanah Y, Timsit JF. Severe SARS-CoV-2 infections: practical considerations and management strategy for intensivists. *Intensive Care Medicine* 2020; **46**: 579–82.
14. Kurihara H, Bisagni P, Faccincani R, Zago M. COVID-19 outbreak in northern Italy. Viewpoint of the Milan surgical area community. *Journal of Trauma and Acute Care Surgery* 2020. Epub ahead of print 20 March. https://doi.org/10.1097/ta.0000000000002695
15. Abrahamson SD, Canzian S, Brunet F. Using simulation for training and to change protocol during the outbreak of severe acute respiratory syndrome. *Critical Care* 2006; **10**: R3.
16. Ragazzoni L, Ingrassia PL, Echeverri L, et al. Virtual reality simulation training for Ebola deployment. *Disaster Medicine and Public Health Preparedness* 2015; **9**: 543–6.