Use of in situ simulation to evaluate the operational readiness of a high-consequence infectious disease intensive care unit

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Summary

On 30 January 2020, the World Health Organization (WHO) declared that the outbreak of a coronavirus disease-2019 (COVID-19) was a public health emergency of international concern. The WHO guidance states that patients with (COVID-19) should be managed by staff wearing appropriate personal protective equipment; however, working whilst wearing personal protective equipment is unfamiliar to many healthcare professionals. We ran high-fidelity, in-situ simulation of high-risk procedures on patients with COVID-19 in a negative-pressure side room on our intensive care unit (ICU). Our aim was to identify potential problems, test the robustness of our systems and inform modification of our standard operating procedures for any patients with COVID-19 admitted to our ICU. The simulations revealed several important latent risks and allowed us to put corrective measures in place before the admission of patients with COVID-19. We recommend that staff working in clinical areas expected to receive patients with COVID-19 conduct in-situ simulation in order to detect their own unique risks and aid in the creation of local guidelines of management of patients with COVID-19.

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In December 2019, the first group of patients infected with a novel coronavirus known as coronavirus disease-2019 (COVID-19) was identified in the city of Wuhan in Hubei province, China [1]. The COVID-19 virus had never previously been detected in humans and it spread rapidly, firstly to other regions within China and then to other countries across the world. On 30 January 2020, the World Health Organization (WHO) declared the COVID-19 outbreak to be a Public Health Emergency of International Concern [2]. As of the 20 March 2020, 245,484 people have been infected with COVID-19, including 164,234 outside of China and 2717 in the UK [2]. The total deaths stood at 10,031 which gives a case fatality rate of 4.1%, but because mild infections are under-reported; the infection fatality rate is likely to be lower [3].

Eighty percent of patients with COVID-19 report mild illness [1], but among those who are seriously unwell, the most common symptoms are: cough (82%); fever (73%); expectoration (58%); myalgia or fatigue (58%); and headache (45%) [4]. A retrospective review of the first 99 patients with COVID-19 in Wuhan showed that 17% developed acute respiratory distress syndrome and 4% required mechanical ventilation [5].

During the severe acute respiratory syndrome (SARS) epidemic of 2003, 21% of the people infected were healthcare workers [6]. COVID-19 is known to spread from human-to-human by droplets, by direct contact and by aerosols. Therefore, aerosol-producing procedures such as tracheal intubation may put anaesthetists and intensivists at high risk of infection [7, 8]. In 2020, there are reports from
Wuhan that anaesthetists have been infected after they intubated the tracheas of patients with COVID-19 [9].

The WHO issued guidance on the prevention and protection strategies that healthcare workers treating COVID-19 patients should adopt in order to protect themselves and to prevent further transmission of the virus to other vulnerable people [10]. Particularly for those performing aerosol-generating procedures, they issued guidance on the level of personal protective equipment (PPE) which includes: respirators; eye protection; long-sleeved gowns; and extra water-resistant aprons. In addition, WHO guidance states that the management of patients with suspected or confirmed COVID-19 should be based upon clear communication and minimising the number of people in the room [11].

In the UK, COVID-19 is classified as a high-consequence infectious disease (HCID) and the Royal Free Hospital, London, contains one of the four principal contact airborne HCID centres in the country [12]. Patients with COVID-19 who require critical care are looked after in isolated, negative-pressure side rooms on our intensive care unit (ICU), which has 15 air changes per hour.

We recognised the real possibility that a patient with COVID-19 would deteriorate clinically and require tracheal intubation and mechanical ventilation. Although our isolation rooms have been deemed functional, no prior real-time assessment of the unit had been conducted. Nor had the challenges of performing time-sensitive, potentially highly infective procedures while wearing PPE with reduced staff who have never been in this situation been tested. Therefore, in order to assess our operational readiness, we conducted a series of high-fidelity, in situ simulations in one of the ICU HCID rooms. Our aim was to identify potential problems, test the robustness of our systems and modify our standard operating procedure for the likely event of a patient with COVID-19 requiring tracheal intubation.

Methods

This project was discussed with our local research and development department who stated that this is simulation with no patient involvement and therefore no formal ethical approval was required. Written, informed consent was obtained from all participants.

On a single day (2 March 2020), we carried out simulations in one of the four negative-pressure HCID isolation rooms within the 34-bed ICU at the Royal Free Hospital. The floor plan of the room is shown in Fig. 1. The simulations were developed and run by two facilitators: a consultant intensivist with expertise in infectious disease; and a consultant anaesthetist with over 10 years of simulation training experience. The simulations occurred during the course of a normal working day and were run using a high-fidelity Laerdal 3G SimMan (Laerdal Medical, Orpington, UK).

We designed two scenarios (Table 1) to test the operational readiness of the ICU environment and staff using the Royal Free Hospital Simulation template (see also Supporting Information, Data S1–S2). The scenarios are outlined in Table 1 and were run multiple times during the course of a day with different intensive care staff members. Our primary focus was to give intensive care

![Figure 1](https://example.com/figure1.png)

**Figure 1** Floor plan of the high-consequence infectious disease side room on the intensive care unit (not to scale).

<table>
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<tr>
<th>Scenario A</th>
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<tr>
<td><strong>Setup</strong></td>
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<td><strong>Problem</strong></td>
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<th>Scenario B</th>
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<td><strong>Setup</strong></td>
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Table 1 Summary of the simulation scenarios.

COVID-19, coronavirus disease 2019; ICU, intensive care unit; HCID, high-consequence infectious disease.
clinicians who have completed their fellowship examinations and anaesthetic nurses the opportunity to test the system and also to practice the procedures in full PPE whilst following all published national and local protocols. Both scenarios involved four participants and two facilitators.

After the simulation was completed, the team were debriefed by two of the facilitators. The facilitators began the debriefing by allowing the participants to discuss their immediate reactions to the scenario. They were then asked to specifically consider the active failures (unsafe acts which have damaging immediate consequences) and latent threats (system-based risks that were previously unidentified) that were encountered during the simulation [13].

During the debrief, participants were asked to identify latent risks, hazards, equipment failures, complete all appropriate checklists and any issues with the PPE. Non-technical issues such as cognitive aids, communication issues and team working were also identified. Content experts were also present to identify any issues which could lead to patient or staff harm.

There were no planned statistical analyses and data were qualitatively assessed. There was no a priori sample size calculation performed, but a convenience sample of the maximum number of participants that could undergo the training in a single day was selected.

**Results**

We ran eight simulations involving a total of 32 participants from the departments of anaesthesia and intensive care. These included: 10 consultants; two anaesthesia trainees; two operating department practitioners; and 18 intensive care nurses.

Our series of immersive, multidisciplinary, point-of-care simulations exposed numerous operational deficiencies in the ICU HCID rooms. We uncovered active failures and latent hazards. These are summarised in Table 2.

Many of the problems revealed by our simulations were around teamwork and communication. For example, we quickly realised that once the door to the HCID room was closed, staff inside the room were unable to talk to staff outside the room. The speaker function of the telephones in the room was too quiet and staff could not lift the receiver to their ears as this would cause contamination. We could not use a ‘runner’ to get additional equipment, drugs or staff from outside the room.

The tight-fitting FFP3 masks (Easimask® Respirator Mask FFP3 FSM 18, Wellingborough, UK), used as part of the PPE, prevent the wearer from opening their mouth wide and this makes it impossible to speak loudly. This, along with the noise from the negative-pressure fans and from the ongoing resuscitation, meant there were several errors due to mishearing. For example, during one scenario, the instruction, ‘Give 1 ml of metaraminol’ was heard by the person standing adjacent as ‘Give 1 ml of adrenaline.’

The PPE restricts movement and the visor restricts vision. This meant that the effectiveness of many of the normal non-verbal indicators such as facial expression, body language, lip movement and tone of voice were reduced or lost. The PPE also made it difficult to identify individual team members.

Our simulations identified a number of equipment issues. There was no pre-prepared intubation equipment trolley dedicated to patients with COVID-19, meaning that the standard ICU intubation equipment trolley would become contaminated. Drugs used for induction of anaesthesia are normally kept in a grab-bag. However, this bag would become contaminated if it were to be brought into the ICU HCID room. We found that we had no dedicated checklists for tracheal intubation or prone positioning of patients with COVID-19. The need for a videolaryngoscope was identified in the first simulation as the most appropriate tracheal intubation method as it created a greater distance between the physician’s face and the patient’s airway. It also allowed the rest of the team to see. This required extra videolaryngoscopes to be obtained and a dedicated COVID-19 videolaryngoscope was requisitioned.

Guidance from the WHO states that the number of people in the room should be minimised. However, our early simulations were conducted with an unsuitable staff mix for the induction of anaesthesia of a critically hypoxic patient. There was confusion about role allocation which led to important information being missed. Our simulations also revealed some systems issues, namely that the electrical bed in the room did not work nor did two of the electrical sockets.

In addition to these active failures, we also identified several latent hazards. These included that the text on the posters with instructions for donning and doffing PPE was too small and hard to read. When moving, the hanging intravenous giving sets and arterial line pressure bags trailed across the anaesthetist’s neck causing contamination and the aprons we use for PPE were easily torn. The PPE itself quickly became hot and uncomfortable and some staff forgot to put on additional gloves on top of their PPE gloves before touching the patient. There was a high level of anxiety among participants due to a lack of familiarity and, overall, there was a shortage of staff available to participate in the simulation.
These in-situ simulations allowed us to rapidly put corrective measures in place before the admission of any patients with COVID-19 to our ICU. Some of these measures are listed in Table 3. We were able to use the repeated simulation sessions to rapidly create and refine our protocols and checklists for procedures on the ICU and to increase the familiarity of our staff of working in PPE.

**Discussion**

The latent hazards and problems we identified encompassed multiple aspects of operational readiness of the ICU for admission of patients with COVID-19. These included staff preparedness, equipment shortages and lack of adequate tailored guidelines to manage these patients. Communication between staff both inside and outside the HCID room was hampered by the PPE.

Staff are aware of the contact risk that patients with COVID-19 pose to their own health. The need for airway manipulation adds an extra level of stress to the operator with a higher risk of contamination due to aerosolisation of viral particles [11]. Donning PPE and working whilst wearing it is a deviation from normal practice. We found that these
factors combined to create an over-focus on the PPE itself and a high level of anxiety. This cognitive overload led to significant errors during the simulations. Fixation errors and lack of situational awareness led to delays in management of the simulated critical events.

Teams managing patients with COVID-19 should recognise that the presence of the virus and the use of PPE will cause additional anxiety and discomfort. Therefore, there should be recognition that all aspects of care will take longer and that communication will be difficult.

It is important that the clinical deterioration of patients with COVID-19 is recognised early and clinicians should have a lower than normal threshold for tracheal intubation and mechanical ventilation. If interventions are conducted on a patient in extremis, there is a greater likelihood that dangerous errors will be made.

The WHO advice is to use the safest minimal number of staff in the isolation room [11]. We found that a pre-intervention team briefing is centrally important for clarity, communication and role allocation.

We are continuing to use in-situ simulation as the COVID-19 outbreak progresses. This is to further iterate our protocols and to train more staff members in the management of the critically unwell patients with COVID-19.

Each hospital department is different and therefore each will face different problems. We highly recommend that each department that expects to treat patients with COVID-19 conducts their own in situ simulations in order to help identify their own latent risks and aid in the creation of their own, individualised protocols based on the guidance from Public Health England.

Patient and staff safety are paramount during a crisis. The dynamic and unpredictable nature of the COVID-19 epidemic needs a highly adaptable and resilient healthcare system to manage the potentially devastating consequences ahead.

The simulation exercises for intubating a patient with COVID-19 on the ICU reduced anxiety and normalised the process for when a real patient with COVID-19 required intubation on our ICU. There were no distractions. Team members, who had received this simulation training, were confident and prepared for their role. We were appropriately reactive to changes in the patient’s physiology. The process was smoother and safer for the patient and for staff.

This study suggests areas where resources need to be invested in order to ensure operational readiness of ICUs and other areas that may be called upon to manage patients with COVID-19. Translational simulation helps recognise and correct both active and latent threats in the local environment [14]. Communication and teamwork skills were identified which would help prevent safety breaches.

This project may guide other ICUs and operating departments regarding care aspects likely to require significant focus and possible modification before admission of patients with COVID-19. Departments should follow the most up to date guidance released by their governing body (17).

In conclusion, we found that in-situ simulations identified multiple operational deficiencies on the ICU isolation room and allowed us to take corrective action before the admission of our first patient with COVID-19.

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References

Supporting Information
Additional supporting information may be found online via the journal website.

**Data S1.** Simulation protocol for tracheal intubation of a patient with COVID-19 in a HCID room.

**Data S2.** Simulation protocol for turning an intubated patient with COVID-19 to the prone position.