of renal dysfunction has been described in COVID-19 patients.[9] As a result, serum potassium may be increased, putting them at a higher risk of developing critical hyperkalaemia after receiving succinylcholine. Our patient, despite having renal dysfunction, had a potassium of 4.0 mM days before the intubation, and her highest registered potassium value was 6.4 mM, below the 6.5 mM hyperkalaemia threshold defined as the critical value for cardiac arrhythmia.[10] It is highly likely that we missed the peak potassium concentration as the epinephrine administered may have driven the potassium intracellularly. Despite a long ICU stay, our patient had not been diagnosed with critical illness myopathy.

The ongoing COVID-19 pandemic has led to unprecedented shortages of anaesthetic drugs in many countries. This led the Royal College of Anaesthetists to issue guidance on alternative drugs for COVID-19 patients, which included the use of succinylcholine rather than rocuronium for tracheal intubation. In our mind, succinylcholine was the primary cause of cardiac arrest in this patient. We recommend use of rocuronium as the first-choice neuromuscular blocking agent for RSI in critically ill COVID-19 patients.

Declarations of interest

The authors declare that they have no conflicts of interest.

References

1. Martyn JA, Richtsfeld M. Succinylcholine-induced hyperkalemia in acquired pathologic states: etiologic factors and molecular mechanisms. *Anesthesiology* 2006; **104**: 158–69
2. Jensen AG, Callesen T, Hagemo JS, Hreinsson K, Lund V, Nordmark J. Scandinavian clinical practice guidelines on general anaesthesia for emergency situations. *Acta Anaesthesiol Scand* 2010; **54**: 922–50
3. Tran DTT, Newton EK, Mount VAH, et al. Rocuronium vs. succinylcholine for rapid sequence intubation: a Cochrane systematic review. *Anaesthesia* 2017; **72**: 765–77
4. April MD, Arana A, Pallin DJ, et al. Emergency department intubation success with succinylcholine versus rocuronium: a national emergency airway registry study. *Ann Emerg Med* 2018; **72**: 645–53
5. Guihard B, Chollet-Xémard C, Lakhnati P, et al. Effect of rocuronium vs succinylcholine on endotracheal intubation success rate among patients undergoing out-of-hospital rapid sequence intubation: a randomized clinical trial. *JAMA* 2019; **322**: 2303–12
6. Higgs A, McGrath BA, Goddard C, et al. Guidelines for the management of tracheal intubation in critically ill adults. *Br J Anaesth* 2018; **120**: 323–52
7. Quintard H, l'Her E, Pottecher J, et al. Experts' guidelines of intubation and extubation of the ICU patient of French society of anaesthesia and intensive care medicine (SFAR) and French-speaking intensive care society (SRLF): in collaboration with the pediatric association of French-speaking anaesthetists and intensivists (ADARPEF), French-speaking group of intensive care and paediatric emergencies (GFRUP) and intensive care physiotherapy society (SKR). *Ann Intensive Care* 2019; **9**: 13
8. Blanié A, Ract C, Leblanc PE, et al. The limits of succinylcholine for critically ill patients. *Anesth Analg* 2012; **115**: 873–9
9. Yang X, Yu Y, Xu J, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *Lancet Respir Med* 2020. https://doi.org/10.1016/S2213–2600. . [Accessed 24 February 2020]
10. Weisberg LS. Management of severe hyperkalemia. *Crit Care Med* 2008; **36**: 3246–51

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Rapid training of healthcare staff for protected cardiopulmonary resuscitation in the COVID-19 pandemic

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Editor—The coronavirus disease 2019 (COVID-19) outbreak has precipitated a global pandemic. ICU admissions are required in 16–32% of the patients hospitalised for COVID-19.[1–3] Healthcare worker infection was reported to be as high as

20% in various countries, especially when they were unprepared or had not donned adequate personal protective equipment (PPE).[4,5] We sought to mitigate risks to our patients and healthcare personnel by conducting group simulation sessions aimed at identifying unanticipated issues that arise during a Protected Code Blue while caring for COVID-19 patients, which involved rapid cohort training and workflow improvements.[6] The Singapore National Healthcare Group Domain Specific Review Board Ethics Committee approved this study.

Each session consisted of an *in situ* simulation conducted utilising a negative-pressure room within the ICU. The target participants included medical and nursing practitioners from ICUs and high dependency units. A standardised scenario was used in all simulation sessions: 30 yr-*old woman with COVID-19 presenting with worsening respiratory distress prompting a first responder nurse to attend to her. She subsequently develops a pulseless electrical activity (PEA) arrest secondary to hypoxaemia leading to code blue (cardiopulmonary resuscitation) activation by the first responder nurse*. The simulation was facilitated by an intensivist and a nurse educator. Each simulation session consisted of eight to 10 participants: two doctors and three nurses (total of five) were actively involved in the scenario, while the rest were observers. Each simulation session involved new participants who had not observed or participated in previous sessions. A total of six sessions of simulation were conducted over 2 weeks with a total of 50% of the nurses and 80% of the doctors in the unit completing the cohort training.

Before each simulation session, participants were briefed on our institutional PPE protocol. The first responder dons PPE, which includes an N95 respirator mask, goggles, disposable full-body protective gown, and head cover.[7] The code blue responders don a powered air-purifying respirator (PAPR) in addition to PPE as per institutional guidelines for all aerosol-generating procedures. Debriefing was conducted after each simulation session. The lessons learnt from each simulation session were quickly disseminated to all staff in the unit through daily huddles in the ICU.

We evaluated team competency on the following components: appropriate PPE precautions for first responder, appropriate PPE and PAPR for code blue responders, effective brief handover of patient from first responder nurse to code blue responders, appropriate airway manipulation strategies, communication between staff in isolation room and runner nurse, adequacy of conduct of basic cardiac life support (BCLS) and advanced cardiac life support (ACLS), prevention of unnecessary equipment, and consumables from contamination, transfer of medications or samples to or from isolation room, appropriate doffing of PPE, and equipment check. These attributes were graded based on pass–fail that were predesigned by a team of intensivists. Team competency improved from an initial score of 40% to 60–70% with subsequent simulations (Supplementary Appendix S1).

Time taken for each of the key steps performed by the code response team was recorded. Time taken for the first responder to don PPE and attend to the patient ranged from 40 to 170 s. Time taken from code blue activation to first code blue responder attending to the patient wearing PPE and PAPR ranged from 3 min 11 s to 5 min 41 s. Average time taken for other code blue responders from code blue activation to attending to the patient wearing PPE and PAPR ranged from 3 min 50 s to 8 min 30 s. Time taken from cardiac arrest to successful intubation ranged from 5 min 7 s to 11 min 52 s. There was a reduction in total time taken for each of these key steps with the conduct of subsequent simulation sessions (Supplementary Appendix S2).

The following observations were made from the simulations on the ideal roles assumed by the response teams. Most experienced doctor's role: airway management; second code response doctor: medications; first code response nurse: assist with airway management; second code response nurse: relieve first responder nurse to do chest compressions; and first responder nurse: activated code blue and performed chest compressions. When the code response team arrived, the first responder nurse handed over the case to the code response team and functioned as a runner nurse outside the isolation room after proper doffing of PPE. The runner helped to limit staff movement between the isolation room and the rest of the ICU. During the resuscitation, flexibility of roles was required to optimise protection of staff and efficiency of resuscitation.

Pertinent issues identified included N95 masks were poorly applied, particularly during chest compressions, inappropriate donning of PPE by first responder, failure to comply to the standards of hand hygiene, failure to remove goggles appropriately particularly for staff who wear spectacles, failure to remove PAPR hood without dislodging N95 mask, and inappropriate decontamination of PAPR after usage. We have since conducted N95 mask fitting sessions and PPE and PAPR training sessions[8] for all the acute care teams. To facilitate communications between staff inside the isolation room and the runner nurse, we implemented the use of a white board to minimise the need for opening of the isolation room door and its associated risk of cross contamination. PAPR battery failures and flow check failures were reported; hence we implemented a daily PAPR calibration check and procured replacement and standby batteries. Most issues were identified during the first two simulation sessions and were promptly addressed. Issues encountered are detailed in Supplementary Appendix S3.

Through these observations during *in situ* simulation sessions, we made key modifications to our existing practice to optimise workflows and infection prevention measures. We implemented intubation as a priority in resuscitation to minimise the extent and duration of aerosol-generating mask ventilation. We developed pre-packed COVID-19 packages for common procedures such as intubation, and intra-arterial and central venous line insertions to minimise the need for staff movement and associated risk of cross contamination. We also modified the layout of our ICU rooms with specific considerations for seamless donning and doffing of PPE and PAPR and provisions for hand hygiene (Fig 1).

In conclusion, *in situ* simulation resulted in rapid cohort training evidenced by improvements in the time to key events in resuscitation and team competencies with each subsequent simulation session. The simulation sessions allowed testing and improvement of processes and training of staff through prompt sharing of lessons learnt from previous sessions to all staff, attributing to the improvement observed over the six sessions. A comparable approach emphasising the importance of infection prevention[9] with similar findings has recently been reported from Hong Kong.[10] We also achieved higher levels of educational outcomes (Level 4a BEME-Modified Kirkpatrick's level) with change in organisational practice or delivery of care, attributable to an educational program.[11]

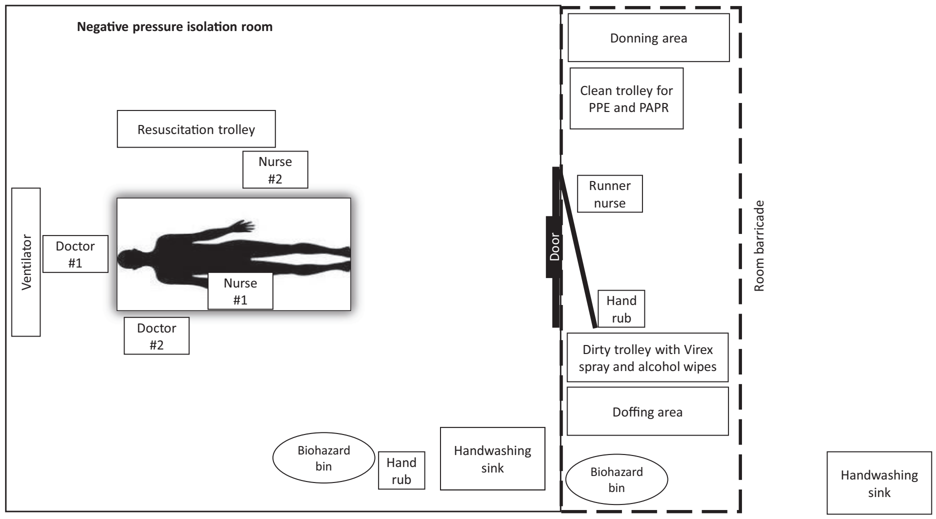

Fig 1. Modified layout of the ICU room for seamless donning and doffing of personal protective equipment and powered air-purifying respirator and for hand hygiene. PAPR, powered air-purifying respirator; PPE, personal protective equipment.

Declarations of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2020.04.081.

References

1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020; **395**: 497–506
2. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA* 2020; **323**: 1061–9
3. Guan W-J, Ni Z-Y, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med* 2020; **382**: 1708–20
4. Lancet. COVID-19: protecting health-care workers. *Lancet* 2020; **395**: 922
5. Wang J, Zhou M, Liu F. Reasons for healthcare workers becoming infected with novel coronavirus disease 2019 (COVID-19) in China. *J Hosp Infect* 2020; **105**(1): 100–1
6. Abrahamson SD, Canzian S, Brunet F. Using simulation for training and to change protocol during the outbreak of severe acute respiratory syndrome. *Crit Care* 2006; **10**: R3
7. WHO. *Rational use of personal protective equipment for coronavirus disease (COVID-19): interim guidance. World Health Organization, Geneva*. Available from, https://apps.who.int/iris/bitstream/handle/10665/331215/WHO-2019-nCov-IPCPPE_use-2020.1-eng.pdf. [Accessed 23 March 2020]
8. Chen Q, Lim B, Ong S, Wong W-Y, Kong Y-C. Rapid ramp-up of powered air-purifying respirator (PAPR) training for infection prevention and control during the COVID-19 pandemic. Br J Anaesth Adv Access Published on April 15, 2020, doi:10.1016/j.bja.2020.04.006
9. Odor PM, Neun M, Bampoe S, *et al.* Anaesthesia and COVID-19: infection control. Br J Anaesth Adv Access Published on April 8, 2020, doi:10.1016/j.bja.2020.03.025
10. Choi GYS, Wan WTP, Chan AKM, Tong SK, Poon ST, Joynt GM. Preparedness for COVID-19: in situ simulation to enhance infection control systems in the intensive care unit. Br J Anaesth Adv Access published on April 10, 2020, doi:10.1016/j.bja.2020.04.001
11. *Kirkpatrick Then and Now: a strong foundation for the future.* Scotts Valley California: CreateSpace Independent Publishing Platform; 2009

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