This has potentially important implications in clinical practice. A recent report from Italy suggests that the prevalence of arterial hypertension is significantly higher amongst COVID-19 patients admitted to ICU who do not survive.[7]

Our study has several limitations related to the observational nature of the studies reviewed with all inherent biases. Few investigations have examined the link between arterial hypertension and ICU admission in COVID-19 patients, limiting the number of the studies included in the meta-analysis. No formal definition of arterial hypertension was given in the included studies. The need for ICU admission may have depended on local resources that are often different between units. No adjustments for confounders were made for other risk factors such as age or other baseline cardiovascular or chronic comorbidities. All included studies were performed in China, so we cannot exclude significant differences between other populations. Because we considered only published studies in English, we cannot exclude missing some investigations with interesting findings published only in Chinese in particular. In our analysis, the degree of increased risk of ICU admission in hypertensive patients was strongly influenced by a single study, that of Guan and colleagues.[2] The identification of those predictors indicating a need for intensive care admission could be helpful in managing the early phase of the pandemic both for clinical and ICU management. However, our results should be considered preliminary, and further research is necessary to confirm our findings.[8]

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.2020.04.056.

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doi: 10.1016/j.bja.2020.04.073
Advance Access Publication Date: 27 April 2020

Cardiac arrest in a COVID-19 patient after receiving succinylcholine for tracheal reintubation

Theodor S. Sigurdsson*, Asgeir P. Þorvaldsson, Sigrun Asgeirsdottir and Kristinn Sigvaldason

Reykjavik, Iceland

*Corresponding author. E-mail: theodorsku@hotmail.com

Keywords: cardiac arrest; cardiopulmonary resuscitation; COVID-19; hyperkalaemia; intensive care; rocuronium; succinylcholine; sugammadex

Editor—We report a cardiac arrest in a patient with coronavirus disease 2019 (COVID-19) after receiving succinylcholine for reintubation. It is well recognised that the neuromuscular blocking agent succinylcholine can lead to a life-threatening hyperkalaemia in critically ill patients. Succinylcholine causes depolarisation of the postsynaptic neuromuscular junction, resulting in efflux of intracellular potassium and a sudden increase in plasma potassium.[1] Succinylcholine sensitivity can be increased in certain conditions as a result of up-regulation of the nicotinic acetylcholine receptors. Predisposing conditions include neuromuscular wasting disorders, severe burn injury, spinal cord trauma, and ICU immobilisation. Although succinylcholine is commonly used, there are surprisingly few studies and well documented case reports published on this subject.[2]

A 66-year-old woman was hospitalised in our ICU for 17 days on a mechanical ventilator with serious acute respiratory distress syndrome as a result of a COVID-19 infection. She had been weaned off the ventilator in gradual stages as her clinical situation improved, but 1 day after extubation, she had sudden respiratory deterioration with severe haemoglobin oxygen desaturation as a result of bronchial secretions, and became unresponsive but was still breathing. Despite receiving oxygen 100% via a facemask, oxygen saturation only reached 80%–85%. As hypoxaemic cardiac arrest was imminent, the decision was made to reintubate the patient using rapid sequence induction (RSI). A blood gas sample obtained moments before intubation revealed hypoxaemia and respiratory acidosis (pH 7.28, P_{O_2} 8.4 kPa, P_{CO_2} 9.0 kPa, and serum potassium 4.7 mM). Anaesthesia was induced with propofol 1 mg kg^{-1}, fentanyl 1.5 μg kg^{-1}, and succinylcholine 1 mg kg^{-1}, and the patient was successfully intubated with a videolaryngoscope within 30 s. About 60 s after intubation, heart rhythm converted into a wide complex polymorphic ventricular tachycardia that resulted in cardiac arrest (Fig 1a). Resuscitation was started immediately with effective chest compressions and ventilation. Rhythm check 2–3 min after arrest confirmed ventricular fibrillation, with defibrillation immediately after one shock of 200 J. A single bolus of epinephrine 1 mg and magnesium sulfate 10 mmol i.v. was administered. A second rhythm check 2–3 min later showed a stable arterial pulse and invasive systolic BP above 110 mm Hg. A wide complex rhythm in association with a narrow complex was identified (Fig 1b). As hyperkalaemia attributable to succinylcholine was immediately suspected, calcium chloride 10 mmol was administered i.v. A blood gas sample (obtained about 4–5 min after the succinylcholine) revealed a potassium of 6.4 mM. Over the next 10 min the patient stabilised, and the ECG normalised to normal sinus rhythm as potassium decreased to 4.2 mM (Fig 1c).

The depolarising neuromuscular blocking agent succinylcholine remains the first choice for RSI because of its short and predictable time of onset, and its rapid recovery time. However, as succinylcholine has several adverse effects, the newer non-depolarising agent rocuronium has gained favour in recent years. A Cochrane systematic review of RSI showed that succinylcholine was superior to rocuronium using standard doses (1.0 mg kg^{-1} and 0.6 mg kg^{-1}, respectively).[3] However, this difference disappeared when the rocuronium dose was increased (0.9–1.2 mg kg^{-1}). Recent studies on RSI in prehospital and emergency department settings have not shown any difference between succinylcholine and rocuronium.[4,5] As sugammadex, a reversal agent for rocuronium, is now widely available, the lasting effect of rocuronium compared with succinylcholine is no longer of clinical relevance. There are different national guidelines about the first-choice neuromuscular blocking agent in emergency situations. The UK guidelines have recommended rocuronium as a first-choice agent for RSI in critically ill patients,[6] while both the Scandinavian[2] and French guidelines[7] recommend succinylcholine as the first choice (critical illness is not clearly defined as a specific contraindication in the guidelines).

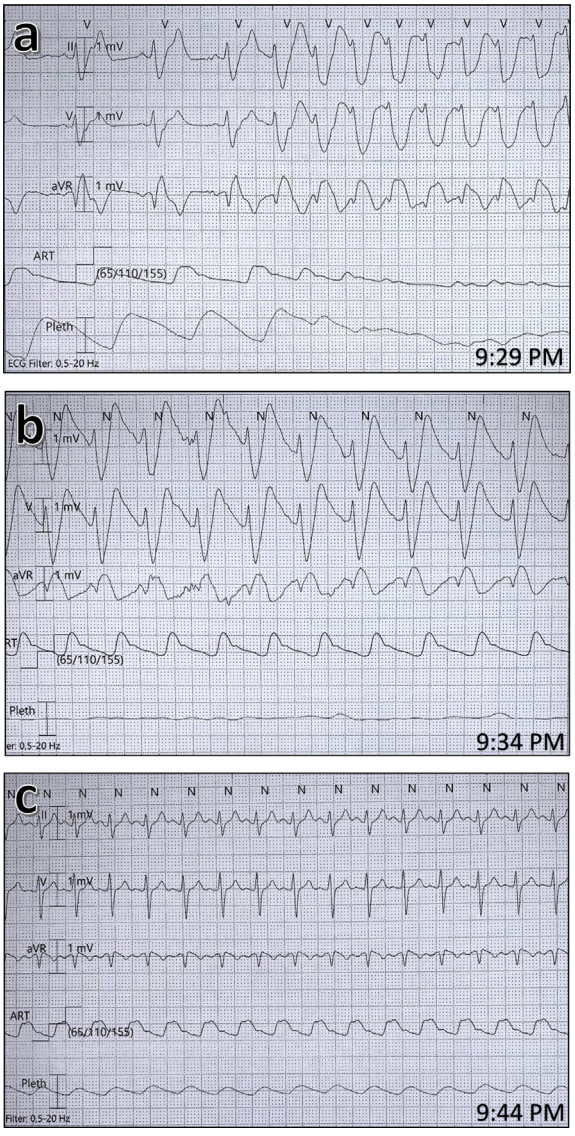

Fig. 1. Electrocardiograph showing heart rhythm at different times. (a) Heart rhythm at the time of cardiac arrest, (c) heart rhythm at return of spontaneous circulation (potassium 6.4 mM), and (c) heart rhythm after normalisation (potassium 4.2 mM).

Blanié and colleagues[8] conducted a study on the incidence of hyperkalaemia in ICU patients after receiving succinylcholine. They reported a serum potassium value above 6.5 mM in 11 out of 131 patients (8.4%). Only two patients (1.3%) experienced reversible ventricular arrhythmia. The risk of hyperkalaemia was strongly associated to length of ICU stay, showing an increase after about 2 weeks of immobilisation (an incidence of 37% *vs* 1% after 16 ICU days). A high incidence

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.

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doi: 10.1016/j.bja.2020.04.073
Advance Access Publication Date: 01 May 2020

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

Theng W. Foong*, Elizabeth S. Hui Ng, Cicely Y. Wee Khoo, Balakrishnan Ashokka, Deborah Khoo and Rohit Agrawal

Singapore

*Corresponding author. E-mail: theng_wai_foong@nuhs.edu.sg

Keywords: cardiopulmonary resuscitation; code blue; COVID-19; infection control; ICU; personal protective equipment; simulation; training

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