respiratory syndrome coronavirus 2 in ‘throat swabs’ by reverse transcriptase-polymerase chain reaction (RT–PCR). It is not clear if these were nasopharyngeal samples or from the oropharynx. While it has been established that there can be fairly high false-negative rates with viral testing, could this very low positive RT–PCR rate be explained by these being oral throat swabs? Data suggest nasopharyngeal swabs are more likely to be positive.[5] The authors do discuss the false-negative rate. While it is likely all or nearly all of these patients did have COVID-19 based on radiographic signs, the false-negative rate may impact the interpretation of the transmission rates. It would be interesting to know if there was evidence that patients who tested positive by RT–PCR, and who therefore might have possessed a higher viral load, were more infectious.

The implied transmission rates to anaesthesiologists wearing Level 1 personal protective equipment (PPE), and for those wearing Level 3 PPE, during management of spinal anaesthesia seem very high compared with other reports. It seems quite likely that in Wuhan there were multiple other opportunities for acquiring this virus through contact with asymptomatic carriers of the virus, so this report may exaggerate the risk of transmission of COVID-19 via anaesthetist–patient interaction, and should be interpreted with caution. It is unlikely that a single exposure to a patient undergoing spinal anaesthesia for Caesarean delivery or other procedures could result in a 57% transmission rate to those in Level 1 PPE. Given the ~25% positive RT–PCR rate among the presumed positive patients in this study, one can extrapolate that these anaesthetists were exposed to many other viral-positive patients who either did not have severe or noticeable symptoms, but could still have been infectious, or were suspected but did not test positive and were therefore treated as virus-negative.

None of the above concerns should detract from our gratitude for the guidance that we can obtain from the Chinese experience regarding management and protection of patients and healthcare providers as we confront COVID-19 around the world.

Declarations of interest

The author declares that they have no conflict of interest.

References

1. Zhong Q, Liu YY, Luo Q, et al. Spinal anaesthesia for patients with coronavirus disease 2019 and possible transmission rates in anaesthetists: retrospective, single-centre, observational cohort study. *Br J Anaesth* 2020; **124**: 670–5
2. Chen R, Zhang Y, Huang L, Cheng BH, Xia ZY, Meng QT. Safety and efficacy of different anesthetic regimens for parturients with COVID-19 undergoing Cesarean delivery: a case series of 17 patients. *Can J Anaesth* 2020. https://doi.org/10.1007/s12630-020-01630-7. Adv Access published on March 16
3. Xia H, Zhao S, Wu Z, Luo H, Zhou C, Chen X. Emergency Caesarean delivery in a patient with confirmed COVID-19 under spinal anaesthesia. *Br J Anaesth* 2020; **124**. e216–e8
4. ASA Physical Status Classification System. https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system. accessed 7 May, 2020
5. Xie C, Lu J, Wu D, et al. False negative rate of COVID-19 is eliminated by using nasal swab test. *Travel Med Infect Dis Adv* 2020. https://doi.org/10.1016/j.tmaid.2020.101668. Access published on April 11

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Rational perioperative utilisation and management during the COVID-19 pandemic

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Keywords: COVID-19; critical care; elective surgery; operating theatre utilisation; Premier healthcare database; surge planning

Editor—Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease 2019 (COVID-19), is challenging healthcare capacity worldwide. Initial reports suggest that 5–12% of patients require critical care[1,2] and, given the spread of COVID-19 thus far, this may represent a massive number of critically ill patients. The experiences in both Italy and China suggest that this is possible. Entire critical care hospitals needed to be constructed in China to handle the surge of patients that presented to the healthcare system; in Italy, the exponential growth in ICU admissions was described as ‘overwhelming’.[2] Therefore, it is imperative to start planning for a supply/demand mismatch in hospitals, and the operating theatres (OTs) will be a critical component in this battle.

Non-essential surgery, downstream hospital utilisation, and supply/demand matching

In response to broad calls to curtail elective surgical procedures from multiple societies, including the American College of Surgeons,[3] the Centers for Medicare & Medicaid Services (CMS) released recommendations to ‘limit all non-essential planned surgeries and procedures … until further notice’.[4] Unfortunately, the duration of time needed for surge capacity planning for US hospitals is unclear, with some reports suggest an outbreak duration of 12–18 months under ‘worst-case scenario’ conditions.[5] Whilst a blanket policy to restrict non-essential surgery is appropriate for acute outbreak conditions, this may need to be modified if the pandemic continues for a prolonged duration, as a long wait for elective surgery could begin to result in harm for some patients. Therefore, it is essential to begin to gain a more nuanced understanding of the basic epidemiology of elective surgery in the USA and the burden of these surgeries on acute healthcare utilisation in the USA. These data are vital to make evidence-based decisions to match supply and demand during prolonged pandemic conditions.

Whilst we agree that all available medical and logistical information at an organisational level should be used, we also believe that downstream healthcare utilisation from certain operations predictably impairs COVID-19 surge capacity. Examining the 2018 data from the Premier healthcare database during the relevant time period of the current COVID-19 pandemic (April–June), it is apparent that joint replacement, bariatric surgery, and spine surgery represent some of the most common inpatient elective procedures (Fig 1). To gain a more nuanced understanding of the burden of elective surgeries on downstream acute care utilisation, we provide an example using the joint replacement surgery population. First, examining 379 829 patients hospitalised for surgery across 667 facilities within the Premier Perspective database[6] from April to June 2018, we found that 61 889 (16%) were admitted for joint replacements, making this a very common operation. Second, considerable downstream hospital bed-days become available with a temporary moratorium on joint replacements. For example, the average length of stay after a joint replacement was almost 2 days; thus, suspending joint replacements for the 3 month period of April–June 2018 would translate to 123 778 hospital bed-days available for hospital surge capacity in the Premier alliance alone. Lastly, with more than 75% of patients over 60 yr of age, admission to hospitals for joint replacement surgery puts such patients at risk for hospital-acquired COVID-19. Using this simple example, we can extend this logic to examine other common elective surgeries and other markers of acute care utilisation (ICU admission, ventilator days, blood transfusion, and vasopressor utilisation) to identify elective surgical procedures that may be need to be delayed to fulfil health system needs at a given time (such as ICU beds). When these data are combined with robust local outbreak modelling data, data-driven decisions on elective surgery delays can be made to match supply and demand in the setting of a prolonged pandemic.

OT space and personnel

Should pressure on critical care services, produced by increased demand in the face of limited supply, require relief, OTs can provide backup. Given the availability of ventilators, monitoring equipment, and critical care drugs, OTs can serve as a physical location for the provision of critical care. According to the 2020 data from the American Hospital Association, there are currently only 69 785 adult intensive care beds (composed of medical, surgical, cardiac, burn, and other) in US non-federal hospitals.[7] In addition to acute care spaces opened up through delays of non-essential surgeries, OTs can provide additional physical space for the care of critically ill patients.

Whilst the idea of using OTs (both in hospitals and ambulatory surgery centres) for additional hospital capacity is no longer a novel suggestion, given worldwide implementation of this concept during the COVID-19 pandemic, specific

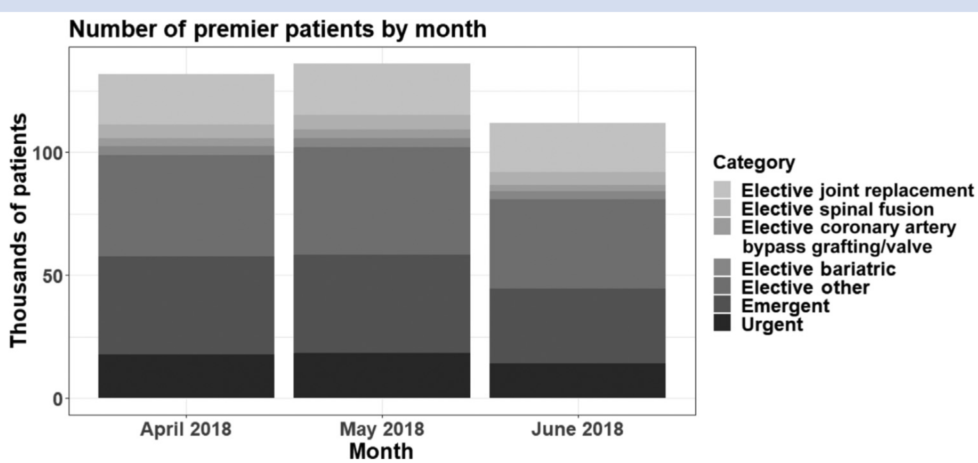

Fig 1. Surgical categories of 379 829 patients undergoing inpatient surgery at 667 US hospitals within the Premier database from April to June 2018. CABG, *coronary artery bypass grafting*.

Table 1 Actionable next steps for preparing operating theatres for coronavirus disease 2019.

Examine downstream healthcare utilisation from common elective surgeries using contemporary national data.
Couple healthcare utilisation data and patient factors with local outbreak models to make data-driven decisions surrounding perioperative care.
At the local level, determine which critically ill patients will be cared for in the perioperative environment.
Deliver brief, evidence-based education on the care of critically ill patients to perioperative providers using existing platforms.
Establish a local organisational structure for critical care delivery in the perioperative environment, preferably with a board-certified intensivist available for consultation (either in person or virtually) 24 h a day.
Conduct rigorous research using data derived from this pandemic to inform planning for future pandemics.

considerations are necessary. First, appropriate staffing models need to be employed for care of critically ill patients within OTs; given delays in elective surgery, the workforce of perioperative clinicians will likely be available. Thankfully, the daily tasks of anaesthesiologists and nurse anaesthetists include ventilator management, sedation, and haemodynamic management, all of which are essential for the management of critically ill patients. Given the debate surrounding shortages in intensivists[8] and concerns about a further loss of providers through illness, anaesthesia professionals can be used to build surge capacity. Second, appropriate organisational principles to manage this 'critical care extension' and educational outreach will need to occur as soon as possible. To accomplish this goal, existing models, including a model endorsed by the Society of Critical Care Medicine (SCCM), could be implemented rapidly.[9] In the SCCM model, a board-certified intensivist will always be available for consultation (either in person or virtually) to on-the-ground healthcare providers. Leveraging existing SCCM educational materials for healthcare providers (such as their Fundamental Critical Care Support series) can be used to bridge knowledge gaps. Lastly, appropriate patient types must be carefully selected for critical care management in OTs. Critical illness as a result of COVID-19 has the potential to directly affect available critical care space for other common critical illnesses (such as severe sepsis, pneumonia, decompensated heart failure, surgical critical illness, and trauma). The latter conditions are likely to either stay the same in terms of incidence, or increase, given disruptions in the supply of caregivers, medications, and equipment. Care for these patients within the perioperative infrastructure may be needed if traditional critical care units (given their availability of negative-pressure rooms and specialised staff) are needed to care for critically ill COVID-19 patients.

Actionable next steps

We provide a framework for actionable next steps to prepare perioperative teams for a surge of critically ill patients as a result of COVID-19 (Table 1). As we have shown in the aforementioned example using elective joint replacements, we advocate building a robust understanding of the impact of individual non-elective surgeries on healthcare utilisation, using population-based national data. We advocate using currently available epidemiologic outbreak models at the state and county levels to match critical care supply to demand using data-driven strategies rather than blanket policies in the case of a prolonged pandemic. We suggest detailed planning at the health system level (taking into account local organisational factors) to leverage OTs and OT personnel to care for critically ill patients. Important considerations include the following: (i) What types of critically ill patients will be cared for in perioperative spaces? (ii) How will education be provided to prepare perioperative providers to care for critically ill patients? (iii) What organisational infrastructure (including intensivist consultation and regionalisation of care) will work best in the local environment? Lastly, we must rigorously study the data derived from this 'natural experiment' (utilisation, organisation, cost, outcomes, etc.) to inform health system planning for future pandemics.

Given the experience in other countries, early planning for surge capacity for critically ill COVID-19 patients is essential.[10] With rational decisions regarding allocation of non-essential surgery in the USA, OTs not only provide necessary physical space to care for patients, but also provide a workforce that is trained in critical care management. The time is now to start planning how we leverage the perioperative environment to allow health systems to adapt to care for the inevitable surge in critically ill COVID-19 patients.

Declarations of interest

The authors declare that they have no conflicts of interest.

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References

1. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med* 2020. https://doi.org/10.1056/NEJMoa2002032. Advanced Access published on February 28
2. 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. *JAMA* 2020. https://doi.org/10.1001/jama.2020.4031. Advanced Access published on March 13
3. American College of Surgeons 2020. Available from: https://www.facs.org/about-acs/covid-19/information-for-surgeons/triage. [Accessed 24 March 2020]
4. Centers for Medicare & Medicaid Services. *CMS adult elective surgery and procedures recommendations* 2020. Available from: https://www.cms.gov/files/document/31820-cms-adult-elective-surgery-and-procedures-recommendations.pdf. [Accessed 24 March 2020]
5. *Coronavirus will radically alter the U.S. The Washington Post* 2020. Available from: https://www.washingtonpost.com/health/2020/03/19/coronavirus-projections-us/. [Accessed 24 March 2020]

6. Zhang L, Scott J, Shi L, et al. Changes in utilization and peri-operative outcomes of bariatric surgery in large U.S. hospital database, 2011-2014. *PLoS One* 2017; **12**, e0186306
7. American Hospital Association. *2020 AHA hospital statistics* 2020. Available from: https://www.aha.org/statistics/fast-facts-us-hospitals. [Accessed 24 March 2020]
8. Davidson BL. POINT: does the United States need more intensivist physicians? Yes. *Chest* 2016; **149**: 621−5
9. Society of Critical Care Medicine. U.S. *ICU resource availability for COVID-19* 2020. Available from: https://sccm.org/getattachment/Blog/March-2020/United-States-Resource-Availability-for-COVID-19/United-States-Resource-Availability-for-COVID-19.pdf?lang=en-US. [Accessed 24 March 2020]
10. Peng PWH, Ho PL, Hota SS. Outbreak of a new coronavirus: what anaesthetists should know. *Br J Anaesth* 2020; **124**: 497−501

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Failure modes and effect analysis to develop transfer protocols in the management of COVID-19 patients

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Keywords: COVID-19; failure modes effect analysis; patient safety; simulation; system engineering

Editor—The severe acute respiratory syndrome caused by SARS-CoV-2 has created a need for innovative approaches to novel and complex issues surrounding patient care. Emergency physicians, intensivists, and anaesthetists play an early and vital role in the management of these high-risk patients, requiring cooperation and information sharing. All NHS organisations are required to test and refine their pandemic planning.[1] However, the 'real time' organisational preparedness for these resource-exhaustive scenarios is challenging and reactive policies will be necessary to deal with new rapidly evolving scenarios. It is of paramount importance that all new guidance developed is locally adapted and tested. Failure to do so may expose both patients and staff to medical errors and harm. A system engineering approach to pathway design is necessary.

As a group of anaesthetists from Royal Free Hospital, one of the four High Consequence Infectious Disease centres in England,[2] we have considerable experience in using *in situ* simulation in conjunction with a modified failure modes and effect analysis (FMEA) tool in order to test processes and detect latent risks (system-based threats to safety) and active threats (an unsafe act that has damaging immediate consequences).[3] We propose a pragmatic and effective approach to develop and test protocols iteratively using prospective risk analysis through FMEA and repeated simulation.

FMEA is a systematic, prospective method of process mapping to identify where and how a complex task might fail, and to assess the relative impact of different failures in order to identify which corrective interventions are needed most. The first step in the FMEA process is to split a large complex goal into small simpler ones. In this case the complex goal was to transfer a coronavirus disease 2019 (COVID-19) patient from one part of the hospital to another. The ability to create a list of what tasks are necessary to complete this challenge requires a list of subgoals that need to be achieved to complete the 'how'. Examples of subgoals in the process of transferring the patient include donning personal protective equipment (PPE), allocation of staff, and appropriate equipment. These subgoals then require a set of tasks to ensure they are completed. In the case of equipment, the tasks may be to collect the transfer trolley, check oxygen cylinders, and ensure that the ventilator is available and checked. By dividing the process into smaller goals and tasks required to achieve these goals, we could then identify the possible failure modes that could impact our ability to complete the complex goal, of transferring the patient safely. This process helped our team to identify and prioritise risks in order to find ways to eliminate or mitigate their impact.[4] This is shown in Supplementary File 1.

Our team used this tool in conjunction with *in situ* simulation to perform a comprehensive hazard analysis of processes required for the transfer of COVID-19 patients. The findings of the simulation were used to generate a transfer policy, thus refining it and ensuring its safe operational suitability.

We performed two high-fidelity transfer scenarios during a full day of training. Scenario A was an urgent transfer of COVID-19 patient from ward to theatre. Scenario B was a COVID-19 patient in labour transferred to theatre for an emergency Caesarean section.

The scenarios were facilitated by experts in simulation. FMEA-generated process mapping and a structured debrief was performed on all participants.