Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Managing critical care during COVID-19 pandemic: The experience of an ICU of a tertiary care hospital

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ABSTRACT

Background: The COVID-19 pandemic has strained ICUs worldwide. To learn from our experience, we described the critical care response to the outbreak.
Methods: This is a case study of the response of the Intensive Care Department (75-bed capacity) at a tertiary-care hospital to COVID-19 pandemic, which resulted in a high number of critically ill patients.
Results: Between March 1 and July 31, 2020, 822 patients were admitted to the adult non-cardiac ICUs with suspected (72%)/confirmed (38%) COVID-19. At the peak of the surge, 125 critically ill patients with COVID-19 were managed on single day. To accommodate these numbers, the bed capacity of 4 ICUs was increased internally from 58 to 71 beds (+40%) by cohorting 2 patients/room in selected rooms; forty additional ICUs beds were created in 2 general wards; one cardiac ICU was converted to managed non-COVID-19 general ICU patients and one ward was used as a stepdown for COVID-19 patients. To manage respiratory failure, 53 new ICU ventilators, 90 helmets for non-invasive ventilation and 47 high-flow nasal cannula machines were added to the existing capacity. Dedicated medical teams cared for the COVID-19 patients to prevent cross-contamination. The nurse-to-patient and RT-to-patient ratio remained mostly 1:1 and 1:6, respectively. One-hundred-ten ward nurses were up-skilled to care for COVID-19 and other ICU patients using tiered staffing model. Daily executive rounds were conducted to identify patients for transfer and at least 10 beds were made available for new COVID-19 admissions/day. The consumption of PPE increased multiple fold compared with the period preceding the pandemic. Regular family visits were not allowed and families were updated daily by videoconferencing and phone calls.

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Conclusions: Our ICU response to the COVID-19 pandemic required almost doubling ICU bed capacity and changing multiple aspects of ICU workflow to be able to care for high numbers of affected patients.

Background

Coronavirus Disease 2019 (COVID-19), which is caused by a novel coronavirus, severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has led to a pandemic resulting in more than 180 million cases and almost 4 million deaths as of July 2021 [1]. It started in China in December 2019 and progressed to affect most countries in the globe. Saudi Arabia had its first COVID-19 case diagnosed on March 2, 2020. Small numbers of cases were diagnosed in the first two months. In May 2020, there was a surge in the number of COVID-19 cases in the different regions of Saudi Arabia, including the capital Riyadh. Anticipating eventual spread of SARS-CoV-2, the Ministry of Health and the healthcare institutions in Saudi Arabia started preparing for the COVID-19 pandemic since early 2020. As of July 5, 2021, 487,592 confirmed cases with 7819 deaths (1.6%) were reported in Saudi Arabia [1].

As COVID-19 can lead to severe respiratory illness which may require care in the ICU [2], our institution identified its priorities in the case of a surge in admissions due to COVID-19. The priorities included among others, expanding ICU capacity, organizing staff in a way to both maintain optimal patient care and staff safety and securing adequate supply of personal protective equipment (PPE). In this article, we describe the preparations and procedures that were implemented in the Intensive Care Department of a tertiary-care hospital in Riyadh as admissions for COVID-19 increased substantially. We reflect on lessons learned and on strengths and opportunities for improving critical care response in the future.

Methods

Setting

This case study describes the experience at the Intensive Care Department of King Abdulaziz Medical City, a more than 1000-bed tertiary-care referral hospital in Riyadh, Saudi Arabia. Riyadh is a metropolitan city with a population of >7 million people. The institution was accredited by the Saudi Central Board for Accreditation of Healthcare Institutes and Joint Commission International and had an active Infection Prevention and Control Department. The Intensive Care Department had 7 units: Unit A (8 rooms; all were negative pressure; designated as the first unit to receive patients who had severe acute respiratory illness), Unit B (21-room general ICU; four negative pressure rooms), Unit C (9-room surgical ICU, two negative pressure rooms), Unit D (8-bed neurocritical care unit; none of the rooms was negative pressure), Unit E (14-room intermediate care unit; two negative pressure rooms), Unit F (15-bed progressive care unit) and a 20-bed Oncology Organ Transplant unit, which existed in a different building. The Department also provided coverage to boarding patients in the 15-bed Resuscitation Area in the Emergency Department (ED). The ICUs were operated as closed units with 24 -h, 7-day onsite coverage by board-certified critical care intensivists on a 24/7 basis [3]. Normally, 6 medical teams covered the units during the day with each team consisting of one intensivist consultant, one registrar/fellow and 1–3 residents. The nurse-to-patient ratio in all the ICUs was mostly 1:1, except for Unit F. One certified respiratory therapist covered a maximum of six ventilated patients. Additionally, the department had a rapid response team, which covered the hospital wards and was activated according to predefined criteria and was covered by a separate team that consisted of one physician, one nurse and one respiratory therapist [4]. The Institutional Review Board of the Ministry of National Guard Health Affairs approved the study.

The institution had an established Infectious Disease Epidemic Plan (IDEP) to outline the response to infectious disease surges. This plan had previously guided the hospital and critical care response during a MERS outbreak in 2015, the details of which have already been published. In this outbreak, there was a surge of 130 MERS cases, 63 patients requiring ICU admission to 3 MERS-designated ICUs with a peak daily census of 27 patients [5,6]. Subsequent to this outbreak, several hospital-wide changes were implemented. Triaging of patients presenting to the ED was changed such that a check point before ED entry was built and mandated screening for febrile acute respiratory illness. Patients with positive screening were directed to a respiratory illness clinic, which was separated from the main hospital and included 18 negative pressure rooms. Additionally, several airborne isolation rooms were created in the ED. At the onset of COVID-19 pandemic, the IDEP was reviewed and revised accordingly. Table 1 describes selected elements in this plan. According to the IDEP, one unit (Unit A) was designated as the primary receiving unit for COVID1-19 patients, because of its geographical location being away from main hospital traffic and because its 8 rooms were negative-pressure airborne infection isolation rooms (AIIR). Unit B had 4 negative-pressure rooms and was designated as the second unit to receive patients.

Data collection and analysis

For this study, we noted the number of patients admitted to the adult ICUs with suspected or confirmed COVID-19 between March 1 and July 31, 2020. We also collected quantitative data on the available critical care equipment and PPE supplies and qualitatively assessed our own observations on the ICU response during the COVID-19 outbreak using interviews and open discussions. We presented continuous data as mean with standard deviation and categorical variables as frequency with percentage.

Results

During the study period (March 1 to July 31, 2020), 822 patients were admitted to the adult noncardiac ICUs and had test for SARS-CoV-2 by RT-PCR. The first case admitted to Unit A was on March 8, 2020, to Unit B on May 18, 2020, to Unit F on May 23, 2020 and to Unit E on June 7, 2020. COVID-19 was confirmed in 313 (38.1%) patients with 39 patients having previous negative SARS-COV-2 PCR on 1 or 2 occasions. The mean age of COVID-19 patients was 60.1 ± 15.2 years with the majority (75.1%) being males. As demonstrated in Fig. 1A, the number of cases started to increase in the third week of May 2020. The highest number of suspected and confirmed patients admitted on a single day was 26 (June 4, 2020). The highest daily census of COVID-19 patients in the ICU was 125. The overall mortality rate of patients admitted to the ICU with COVID-19 was 47.0%.

Table 1
Selected elements of the Infectious Disease Epidemic Plan for emerging infectious diseases, including COVID-19, at King Abdulaziz Medical City-Riyadh.

Phase	Trigger to activate	ICUs assigned	Elective surgery	Other hospital functions
Phase I	0–5 cases of suspected or confirmed infectious disease (i.e., COVID-19) in the hospital	• Confirmed COVID-19 cases requiring intubation will be assigned a negative-pressure room and cohorted in one ICU (Unit A). • Confirmed cases that have been diagnosed with COVID-19 in any ICU other than Unit A, shall be transferred to Unit A as soon as possible.	All elective surgery cases run normally.	All services run without interruptions except for certain precautions for COVID-19 patients.
Phase II	6–30 cases of suspected or confirmed infectious disease (i.e., COVID-19) in the hospital	All COVID-19 patients will be cohorted in one unit (Unit A). If the number of patients exceeds its capacity, then other units are identified to receive the additional cases (Unit B, followed by Unit F then Unit E).	All elective surgery cases are cancelled to free more ICU beds.	• Outpatient in-person clinic visits are limited to urgent visits only with shift to virtual outpatient care. • Hemodialysis patients are served with no interruptions.
Phase III	>30 cases of suspected or confirmed infectious disease (i.e, COVID-19) in the hospital	If the number of patients exceeds the capacity of Unit A, then other units are identified to receive the additional cases (Unit B, followed by Unit F then Unit E).	• All elective surgery cases are cancelled to free more ICU beds. • All elective cardiac surgery cases are cancelled.	• Outpatient in-person clinic visits are limited to urgent visits only with shift to virtual outpatient care. • Hemodialysis patients are served with no interruptions.

COVID-19: coronavirus disease 2019, ICU: intensive care unit.

Activation of Phase III of the Infectious disease epidemic plan

The institution's leadership established a command center, chaired by the Executive Director of Medical Services, that met regularly to assess the outbreak situation at national level and in the hospital and made plans accordingly and in line with the institution's IDEP. Table 1 describes selected elements of the IDEP. Phase III of the IDEP was activated on May 21, 2020.

Infection control

Screening for febrile illness at ICU gates

All people were screened for respiratory illness at hospital and ICU gates. Those with acute respiratory illness or fever were not allowed to enter. A record of all persons entering the ICU was maintained.

Screening and isolation of patients

An Acute Respiratory Illness ARI screening tool was created by the institution, which gave points to clinical and demographic features, including fever, cough, dyspnea and area of residence, and was implemented in the Emergency Department. Patients with a score $\geq$4 were directed to be evaluated using droplet precautions. If COVID-19 was clinically suspected, patients had RT-PCR for SARS-CoV-2 and droplet isolation was continued. Airborne isolation was implemented for suspected critically ill patients and when performing aerosol generation procedures.

For patients who had COVID-19, isolation was discontinued initially when two consecutive RT-PCR $\geq$ 24 h apart were negative after resolution of symptoms as per the national guidelines [7]. This practice was abandoned later as the value of viral clearance by RT-PCR was questioned [8]. Patients who recovered from critical illness were kept under droplet isolation for at least 21 days. Isolation was extended in patients who remained severely ill beyond 21 days [8].

Isolation rooms

At baseline, the number of negative pressure ICU rooms was 14 in three units. Clinical engineering assessed these ICU rooms to ensure their functionality. Initially, there were 10 portable HEPA filters for the ICUs. As the number of COVID-19 cases increased, the number of portable HEPA filters for the ICUs was increased to 60.

ICU surge capacity

Increasing the capacity of available ICUs

The initial number of ICU beds dedicated to COVID-19 patients was 58. As the number of patients increased, the bed capacity was internally increased to 71 beds (+39.7%), by cohorting 2 patients/room in selected rooms (Fig. 1B). Unit C and the Oncology Organ Transplant unit only received clean patients due to their physical locations. Additionally, the Pediatric Cardiac ICU (12 beds) was used for clean ICU cases with cardiac intensivist coverage.

Transforming general wards to ICUs and high dependency units

Two wards, each able to accommodate 20 patients, were selected. Portable ICU monitors and cameras were installed in the rooms for monitoring. These wards were covered primarily by the Anesthesia team with support from the Pulmonary/Internal Medicine Department. They received COVID-19 patients after initial management in the any of the four COVID-19 ICUs. Another 15-bed ward was used as a stepdown to care for patients requiring non-invasive ventilation or high-flow nasal cannula. According to the IDEP plan, operating rooms and endoscopy suites were the places to care for COVID-19 patients next. These areas were not needed in the study period.

Increasing the equipment for respiratory support

The available critical care and non-invasive ventilators as well as high flow nasal cannulas were enlisted. The initial inventory showed the availability of 197 ICU ventilators, 44 non-invasive ventilators, 50 chronic ventilators, 18 high frequency oscillators and 14 high-flow nasal cannula machines. During the outbreak period, 53

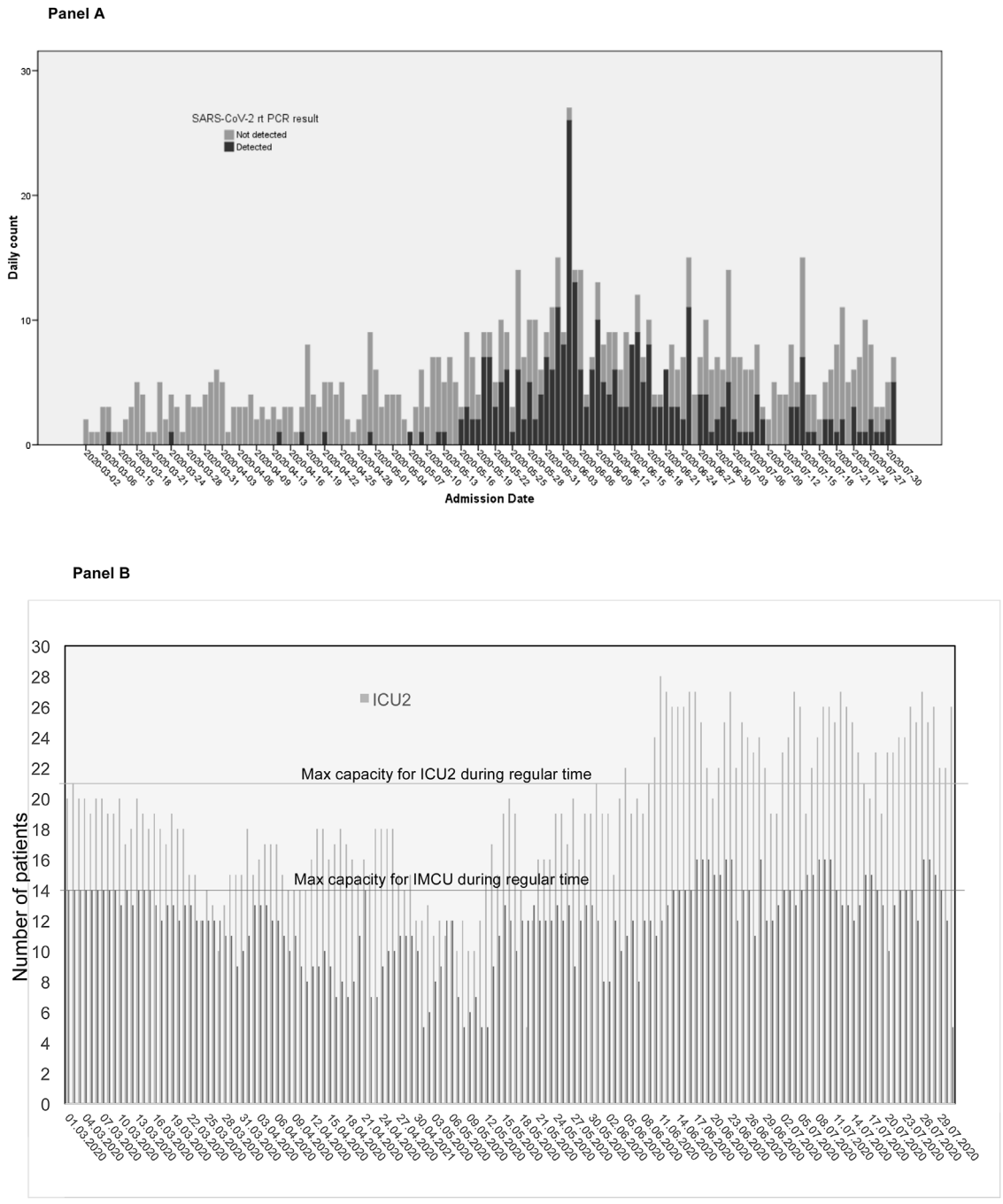

Fig. 1. Number of daily admissions with suspected and confirmed cases of COVID-19 to the adult intensive care units between March 1 and July 31, 2020 (Panel A). The highest number of daily admissions happened on June 4, 2020. The census of admitted patients in two units, Unit B and Unit E (Panel B). Cohorting of two COVIDD-19 patients in selected rooms started in June 2020.

new ICU ventilators, 90 helmets for non-invasive ventilation and 47 high-flow nasal cannula machines were supplied and used. We did not have to use non-ICU ventilators for the acute care of COVID-19 patients.

Bed management

Executive daily rounds were conducted to identify patients for transfer to another ICU (COVID-19 ruled out or improved) or ward. Daily meetings attended by different disciplines were also conducted at noon time daily to facilitate transfers and communication between the different teams, augment bed capacity and address related issues. At least 10 beds were made available in the four COVID-19 ICUs for new admissions on a daily basis.

Personal protective equipment

The Infection Prevention and Control Department and Nursing Services assessed the adequacy of PPE supply in the hospital in February 2020. Universal application of face masks in all clinical areas was requested in April 2020 as per the national guidelines [9]. In February and March 2020, N95 mask fit-testing and refit-testing was performed for ICU staff. Eleven out of 82 physicians (13.4%) and 35 out of 62 RTs (56.5%) failed fit-testing. Thirty-five complete powered air-purifying respirators were already available

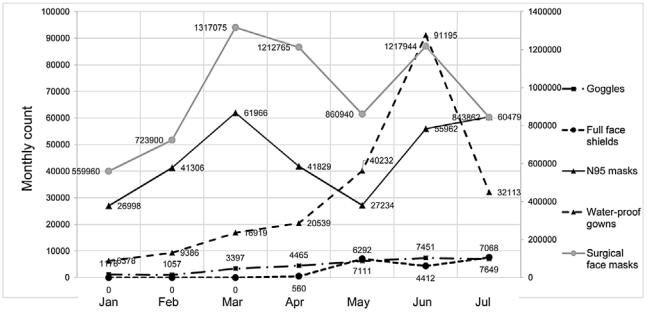

Fig. 2. The monthly consumption of different personal protective equipment (goggles, face shields, N95 face masks, water-proof gowns, surgical face masks) from January 1 to July 31, 2020. The secondary axis is for the counts of the surgical face masks.

in the ICUs since the MERS outbreak in 2015. For the COVID pandemic, 50 additional hoods were made available for healthcare workers (HCWs) who failed the N95 respirator fit-test or preferred to use this modality. Up to two powered air-purifying respirators were available to each COVID ICU. Expecting shortages, extended use or reuse of N95 masks was implemented following the CDC and national guidelines [9]. Water-resistant gowns were applied while providing patient care. Fig. 2 describes the monthly consumption of PPE from January 1 to July 31, 2020 and demonstrates multiple fold increase in PPE consumption. This was associated with an increase in the consumption of alcohol-based hand rub (70% ethyl alcohol) from approximately 5000 500-ml bottles per month in January and February 2020 to more than 20,000 bottles per month from March to July 2020.

Training

A competency testing on infection prevention and control and donning and doffing PPEs, a program called Right Care Right Now, was required on hiring and every two years since 2015. This was reinforced in March 2020. Simulation-based training was done for ICU physicians, nurses and respiratory therapists. Topics addressed included airway management, intubation and intrahospital transport [10]. 110 nurses selected from units that had monitoring systems and provided moderate sedation were trained on critical care nursing as part of a 4-week up-skilling program; 87 of them covered COVID and non-COVID patients in the different ICUs using tiered staffing model.

Staffing

A modified rota for physicians was implemented such that there were “clean” and COVID teams during the daytime shifts. The rota allowed stand-by coverage. HCWs with increased risk of complications from COVID-19 were assigned to low-risk areas (clean team). Each medical team covered 16–20 confirmed/suspected COVID patients. The nurse-to-patient ratio for COVID-19 patents was mostly 1:1 for the acute ICUs. The RT-to-patient ratio for COVID-19 patents was 1:6. The wards transformed into ICUs were staffed using a team/task nursing model of care with experienced ICU nurses working with 2 up-skilled nurses and managing clusters of 4–6 patients.

Clinical management

Standardization of care across all critical care units

A medical management protocol was built in the hospital information system. It covered guidelines on intubation, fluid resuscitation, management of ARDS including steroid therapy, standing instructions for nursing staff focussing on safe medication administration and treatment goals and for respiratory therapists focussing on lung protective approach. The protocol was updated based on the published evidence. Additionally, a focussed COVID-19 documentation guideline was created to reduce nursing documentation requirements in the electronic medical record.

Specific antiviral therapy

Antiviral therapies specific for SARS-CoV-2 were given as per the Saudi Ministry of Health guidelines [7]. Their prescription was restricted to the Infectious Disease service.

Respiratory care

The early use of high-flow nasal oxygen and noninvasive ventilation, via face mask interfaces as well as the newly introduced helmet, was expanded in patients with acute hypoxemic respiratory failure due to COVID-19, which followed international trends and evidence from observational studies [11]. Awake prone positioning was encouraged. Intubated patients with severe ARDS/severe hypoxia had prone positioning based on a departmental protocol.

Renal replacement therapy

The ICU and Nephrology teams decided that CVVHD to be the best modality to provide continuous renal replacement therapy. Conventional dialysis was also tried in patients who were on low-moderate doses of vasopressors. The departmental heparinization protocol for continuous renal replacement therapy was modified such that higher doses were given to patients to avoid filter clotting.

Addressing the goals of care

The institution had developed a model to address the goals of care for hospitalized patients with focus on choices of treatments to be given rather than on treatments not to be given [12]. During COVID pandemic, physicians were encouraged to address the goals of care for patients who were deteriorating and had multi-organ failure before the development of cardiac arrest. During IDEP phase 3, limitation of treatment was implemented when agreed on by three physicians with informing the family.

Cardiac arrest

The institution developed guidelines on advanced cardiac life support for COVID-19 patients in cardiac arrest, including arrests in the prone position. These guidelines aimed at maximizing staff safety, such that cardiopulmonary resuscitation would be commenced only after donning full PPE.

Intrahospital transport

Intrahospital transport was organized to avoid intrahospital spread. Nonintubated patients wore face masks. Imaging studies, such as computed tomography, for COVID-19 patients were done at the end of the day-shift to avoid mixing with other patients. At the start of the pandemic, isolation transport units (ISOPODs) were used for the intrahospital transport of COVID-19 patients. This process caused delay, was a risk in itself, and was thought to be unnecessary; hence was abandoned.

Reduction and management of staff exposure

Reducing the number of unnecessary HCW-patient encounters was thought to reduce staff exposure and risk of acquiring COVID. Medications pumps were put outside the rooms by using longer tubings. Whenever feasible, the user interface of the ventilator was

also placed outside the rooms, which allowed adjustment of the ventilator settings with less HCW exposure.

Communication with families

Regular visits were not allowed. Informed consents were obtained from patients/next of kin on presentation to the ED. If not done, telephonic informed consents were obtained. Families were updated on a daily basis by phone or videoconference

Staff management

During the outbreak, multiple staff issues were encountered. These included increased workload due to implementation of strict infection control measures and severe COVID-19 management, uncertainty over PPE effectiveness especially with its extended use or reuse, anxiety over acquiring COVID-19 and its lethality, and concerns for the well-being of their immediate family. Our institution provided fresh meals to frontline staff, dedicated a hotline and a clinic to support their psychologic welfare, and presented appreciation letters to frontline HCWs.

Discussion

In this report, we described how our Intensive Care Department responded to a COVID-19 outbreak in Riyadh, Saudi Arabia. The COVID-19 pandemic posed multiple challenges to the ICUs worldwide, including the ICUs of our institution. The response addressed multiple issues including ICU surge capacity, changes in the ICU workflow, communication among HCWs, supply of equipment and PPEs and staffing.

Maintaining ICU surge capacity is key to the success of critical care services to care for high numbers of patients during a pandemic or disaster [13]. It should be based on a coordinated system approach that may involve national/local and institutional plans to redistribute resources and prioritize healthcare delivery [14]. Our institution had an IDEP plan and experienced a MERS CoV outbreak in 2015 [5,6]. The need for ICU beds was less in 2015, but the previous overall experience brought up resilience to the institution in dealing with similar situations, including the current COVID-19 pandemic.

There were many changes in the ICU workflow during the COVID-19 outbreak. The main goals of these changes were the efficient care of patients with severe COVID-19 and other ICU patients and staff protection taking into consideration equipment shortage due to decreased supply and increased consumption. Expanding the ICU workforce by up-skilling selected nurses and deploying physicians who have critical care skills, such as an airway team, which was led by an anesthesiologist, was necessary in our institution. This has been utilized by hospitals world-wide to face the pandemic [14]. Restructuring the multidisciplinary rounds and changing the communication patterns between HCWs and families, using web-based videoconferencing and phone calls, were also needed. These are crucial to keep the ICU workflow in line with the usual care practices as much as possible and maintain patient-centered standards of care [14]. The use of advanced digital technologies and artificial intelligence will likely be an integral part of healthcare in the future [14,15].

HCWs are at risk of infection. In Italy, 20% of responding HCWs acquired the infection and represented 10% of COVID cases [16,17]. This may lead to transmitting the infection to their colleagues and patients which may amplify the epidemic and further strain the hospital. Hence, staff protection and prevention of COVID transmission among HCWs was very important. We performed training on donning and diffing PPE and performed on-going monitoring or PPE practices and practiced extended use and ruse of PPE due to supply shortage. Facemasks were applied universally in clinical areas. A meta-analysis of four randomized controlled trials that compared medical masks with N95 respirators found that the use of medical masks did not increase laboratory-confirmed viral (including coronaviruses) respiratory infection (odds ratio 1.06; 95% confidence inetrval 0.90-1.25; I^2 = 0%; low certainty in the evidence) or clinical respiratory illness (odds ratio 1.49; 95% confidence interval: 0.98-2.28; I^2 = 78%; very low certainty in the evidence) among HCWs [18]. Only one trial evaluated coronaviruses separately and found no difference between the two groups (p = 0.49) [18]. National or regional strategic reserves of critical care equipment, pharmaceuticals and PPE with effective supply chain and efficient utilization protocols are needed [14].

The staff wellbeing should be a focus of hospital managers. [14]. A cross-sectional study in China found that a considerable proportion of HCWs reported experiencing symptoms of depression, anxiety, insomnia, and distress, especially women, nurses, those in Wuhan, and front-line HCWs directly engaged in the care of patients with suspected or confirmed COVID-19 [19]. Another survey of HCWs in the United Kingdom found that the main reasons for higher anxiety scores during the COVID-19 pandemic compared to the preceding period were concerns about exposure to SARS-CoV-2 and lack of PPE [20]. In a systematic review (13 studies, 33,062 participants), insomnia was prevalent in 38.9% of HCWs during the COVID-19 pandemic, anxiety in 23.2% and depression in 22.8% [21]. Female HCWs and nurses exhibited higher rates of affective symptoms compared with male and medical staff [21]. Mental health can be supported through drop-in sessions with psychologists/psychiatrists, leadership communication with front liners, empowerment of staff [22]. These interventions may protect against adverse mental health outcomes [23]. Our institution provided different forms of psychologic and other forms of support to the staff.

In conclusion, the COVID-19 pandemic stressed our ICU to unprecedented limits. Its successful management required preplanning for surge capacity and transforming regular wards into ICUs. Prompt bed allocation and timely patient flow were needed to maintain open beds for new patients. Increasing PPE supplies as well as practicing conservative use were also crucial for HCWs to safely manage patients. Other changes in ICU workflow were needed to maintain patient care and staff safety.

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Competing interests

None declared.

Ethical approval

Not required.

Authors' contribution

HMD: study conception and design, data acquisition, data analysis and interpretation, drafting and revising the manuscript critically for important intellectual content.

AD, AM, VB, BN, JA, HH, NT, HJ, AH, MKH, MZ, SBS, MMS, AS: data acquisition and interpretation, revising the manuscript critically for important intellectual content.

YMA: study conception and design, data acquisition, data interpretation, revising the manuscript critically for important intellectual content.

All authors approved the final version of the manuscript.

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