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REVIEW ARTICLE

Intensive care challenges for the next pandemic

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ABSTRACT

Experience during the COVID-19 pandemic has highlighted the need for crisis preparedness, particularly in intensive care units (ICUs). Addressing key challenges is vital for improving readiness and response, as well as ensuring better protection for vulnerable populations.

Our review focuses on the recent literature examining the challenges in acute care settings during the pandemic. We aimed to identify lessons that could improve our ability to handle similar situations.

Studies have highlighted the critical role of intensive care, responsiveness, and preparedness. The key challenges identified include a shortage of trained personnel to meet high demand without compromising care quality or overburdening healthcare workers. Resource scarcity during the pandemic emphasizes the importance of reasonable resource allocation to ensure sufficient care provision.

Additionally, addressing post-ICU syndrome and early rehabilitation is crucial, as ICU treatment can lead to long-term physical, psychological, and cognitive issues that can affect patients' quality of life. Finally, fostering a culture of data sharing and research collaboration is essential for knowledge exchange and improving crisis management across healthcare centers.

Keywords: pandemic, intensive care medicine, ICU. Staff, PICS.

Introduction

The COVID-19 pandemic has presented a unique and worldwide challenge to healthcare systems. Since its emergence in 2020, we have experienced an exceptional strain on healthcare resources, comparable to the Spanish flu pandemic of 1918¹. In response to this unprecedented health crisis, governments have enacted extraordinary measures and policies to address the challenges of optimizing available resources².

Hospitals have been inundated with an unprecedented surge in critically ill patients in need of Intensive Care Unit (ICU) beds. New facilities were established, and various response strategies were implemented, resulting in significant variability in hospital and healthcare staff's capacity to cope.

The need for a more agile and adaptable healthcare system, particularly in intensive care, has become a prominent focus of public discussions³. This growing demand has led to expanding healthcare service capacity, bringing unparalleled visibility to our specialty, and inspiring an unmatched collective response^{3,4}. However, it quickly became evident that there was a lack of preparedness to address systemic and global health crises, and reactive responses were insufficient as an effective strategy^{5,6}.

Preparation for future scenarios, such as potential pandemics, armed conflicts, natural disasters, and similar events, is paramount. Intensivists must distill valuable lessons from their experiences, adapt their practices based on observed changes, and reassess strategies that may adversely affect patients, families, and healthcare personnel.

This narrative review, grounded in a critical analysis of the current literature, seeks to encapsulate the evidence of the most pertinent challenges arising during the pandemic. It focuses on crucial aspects such as ICU staffing, available resources, post-intensive care syndrome (PICS) prevention, and research to identify necessary measures to strengthen our capacity and prepare effectively for similar situations in the future.

1. ICU STAFF

Healthcare workers are critical in responding to health crises and providing specialized care to those in need. However, they are also vulnerable and could experience negative consequences, such as burnout and mental health issues, owing to excessive workloads and inadequate staffing resources⁷. The COVID-19 pandemic has emphasized the importance of addressing the needs of ICU staff during emergencies, as the crisis has exceeded existing plans. It has highlighted the importance of evaluating healthcare policies, particularly in providing competent and sufficient staff to meet emergency demands^{7,8}. Addressing these issues could significantly affect various other aspects, which will be discussed further.

The COVID-19 pandemic has also resulted in significant disparities in technical competencies and adherence to international best-practice guidelines among healthcare professionals, resulting in suboptimal clinical outcomes⁹⁻¹¹. These disparities can be attributed to a lack of institutional structures and staffing skills, which has hindered the implementation of effective and equitable response activities¹². The pandemic response was uneven due to deficiencies in central leadership and coordination, politicization of activities, and

variations in regional response capacity¹². These challenges highlight the pre-existing structural inadequacies and insufficient prioritization of public health in healthcare system-strengthening initiatives^{4,13-15}.

Personnel management is a critical aspect of ICU bed operations as it depends on the availability of adequately trained personnel. A response plan must be developed to ensure that specialized care is delivered and to prevent work-related stress. Staff training and recruitment are essential for facilitating the implementation of tasks, reducing administrative burdens, fostering collaboration, and optimizing the delivery of care capacity⁷. This approach alleviates the tension and creates a healthy work environment.

Many nations, regardless of their level of socioeconomic development, often grapple with a scarcity of specialized personnel, such as ICU staff^{11,16}. Implementing strategies focusing on training and education to develop essential competencies to respond to emergencies effectively is crucial^{17,18}. During the pandemic, it became clear that addressing the fundamental aspects of knowledge and skill development, providing ongoing education to maintain trained and competent personnel, and utilizing real or simulated clinical environments are essential^{18,19}. However, it is important to tailor these strategies to specific local needs^{19,20} and to evaluate the knowledge and skills of healthcare teams for at least 18 months after training²⁰. Develop proposals to improve clinical practice and encourage collaboration between professionals to positively impact participants' motivation in these programs and adapt to the moment's requirements, as demonstrated during the pandemic^{18,19,21,22}.

In addition, the COVID-19 pandemic has profoundly affected the emotional well-being of healthcare workers¹¹. The uncertainty of the pandemic, shortage of personal protective equipment, ethical triage decisions, fear of contracting the virus, and concerns about transmitting it to family members have all contributed to emotional stress among healthcare workers. The National Report on Physician Burnout and Suicide reported an incidence of burnout of 44% among ICU physicians²³, which has been exacerbated by additional physical and psychological demands and poor job recognition caused by the pandemic. Nursing teams have also reported high levels of anxiety and physical discomfort, leading to negative effects on the quality of care and patient safety²⁴. Therefore, ICU professionals must address these issues as they are as important as theoretical knowledge. The ongoing pandemic has underscored the urgent need to address existing gender inequalities. Women comprise a significant proportion of the healthcare and social workforce, accounting for approximately 70%^{4,17}. During health crises, women are more likely to experience disruptions in their daily routines, workplace dynamics, and frontline professional activities due to the association of gender with caregiving roles, which may be exacerbated by prolonged school closures²⁵. To bring about change, it is imperative to improve the conditions and implement measures that ensure women are well-represented among health leaders, such as implementing quotas²⁶.

Furthermore, all workers must be guaranteed parental and family leave to support work-life balance and maintain the attractiveness of critical care as a labor field²⁷.

2. RESOURCE MANAGEMENT

The functioning of healthcare institutions is highly complex. This complexity arises from numerous and persistent interactions between individuals and entities such as caregivers, patients, infrastructure, and equipment involved in multiple clinical processes²⁸.

It is crucial to note that during the pandemic, critical care was provided to patients in a healthcare context characterized by resource scarcity, limited availability of supplies and care, and high demand for these resources^{7,16,29}. Despite numerous initiatives to enhance the system's capacity, the unprecedented increase in demand for care required implementing a crisis resource management policy involving rationing criteria²⁹. As a result, clinical decisions regarding distributing and prioritizing scarce resources were made³⁰.

Decision-making during the pandemic was particularly challenging for clinical staff under immense care burdens and faced significant uncertainties. These decisions had a significant emotional impact as they presented difficult ethical dilemmas³¹. Therefore, it is crucial to develop protocols and clinical action guidelines that can guide the decision-making process regarding the distribution of clinical resources in the face of new crises³⁰. These frameworks should be based on ethical principles such as equity, solidarity, distributive justice, and cost and opportunity to maximize collective welfare.

Similarly, the probability of survival and quality of life after discharge are considered based on each patient's condition³². It is vital to emphasize that decisions regarding the principle of justice should be transparent,

public, and accessible to all stakeholders to ensure equitable treatment and foster public trust in healthcare institutions and their personnel³³. It is also imperative to carefully consider and establish ethical foundations that will guide palliative care as a fundamental component of care for patients deemed suitable for non-intensive care or those who have undergone the triage process³⁴.

The need to increase the number of ICU beds has been evident since the onset of the pandemic. To address this issue, various approaches were adopted during the first wave of the pandemic. Although these approaches are practical, they present multiple challenges that compromise the quality and safety of care. Therefore, there is a need for pre-planned and structured scalable ICU capacity based on regional realities. It is difficult to extrapolate a single model to all centers because the main requirement is flexibility. Flexible approaches can provide significantly scalable ICU capacity without consuming large amounts of resources during non-pandemic periods. It is also essential to assess the availability of equipment, supplies, and drugs, which may be grossly inadequate during increased demand. Many centers are concerned about the availability of ventilators without considering the importance of oxygen supply, which is essential for ICU patients. In addition to ventilators, COVID-19 has threatened the supply of dialysis machines, intravenous infusion pumps, supplies, and drugs. In the future, it will be necessary to maintain an updated inventory of current supplies and project potential gaps in the event of a sudden increase in demand, as well as to improve the drug supply chain and adopt a

conservative approach to prescribing and using alternative drug classes when possible⁵. The responsibility of government entities in countries that have successfully managed the pandemic must be emphasized. Implementing territorial contingency plans and resource optimization was crucial in managing the health crisis. To ensure better preparedness for future health crises, it is essential to incorporate lessons learned, such as having an emergency plan that considers the distribution of patients based on geographical areas, the possibility of referral to other centers when necessary,³² and the centralization of the coordination and management of beds to enable network operation. Additionally, it is essential to expand the critical bed capacity through alternative strategies, such as bed conversion, along with protocols that guide the admission and discharge criteria of ICUs, as well as the prioritization and grouping of patients with infectious conditions in specific areas to protect health personnel³⁵.

Finally, the cooperation and leadership of academies and scientific societies are vital for establishing technical guidelines and standards. The work carried out under government funding helped overcome the healthcare crisis and construct a solution by transferring knowledge from various disciplinary areas, significantly contributing to research and innovation^{36,37}. This confirms academies' public commitment to society, allowing opportunities to foster and promote collaborative pathways with state agencies. It is essential to establish a model that addresses these needs and is not subject to the priorities of different authorities, thereby making access more flexible.

3. POST-ICU SYNDROME AND EARLY REHABILITATION

ICU survivors experience prolonged physical deterioration, cognitive impairment, and psychological distress, commonly referred to as post-intensive care syndrome (PICS) and affects not only the long-term outcomes of patients but also the mental health of patients' and their families³⁸. The 2019 coronavirus pandemic presented an additional challenge: many patients with COVID-19 required intensive care, and a significant number survived³⁹⁻⁴¹. The question then arose: What happens to patients with COVID-19 once they are discharged from the ICU? Given the interventions and treatments to which critically ill patients with COVID-19 were exposed, prolonged mechanical ventilation with exposure to increased sedation and limited physiotherapy during and after hospitalization, the risk of disease transmission, and the limitations of social support (restricted visitation)^{42,43}, it is reasonable to assume that the incidence of PICS would increase dramatically worldwide, along with the associated health and economic challenges.

As the pandemic evolved, the scientific community noticed that many patients did not recover their previous vital state, and several deficiencies were observed in patients who became ill with COVID-19 beyond the acute phase, known as Long COVID⁴⁴ when symptoms persisted for more than 12 weeks. Long COVID mainly includes fatigue and muscle weakness, sleep disturbances, anxiety, and depression, among others^{42,43}. A study in France on survivors of severe COVID-19 showed that at four months post-hospital discharge, 23% and 18% presented anxiety

and depression, respectively, and 28% presented muscle weakness compatible with ICU-related neuropathy⁴⁵. In the New York cohort of survivors, 87%, 20%, and 49% of patients with prolonged stay presented with physical, cognitive, and psychological deficits one month after post-hospital discharge⁴⁶. In another study, the 6-minute walk test was evaluated three months after post-ICU discharge, finding that 48% of survivors on mechanical ventilation had an altered test⁴⁷. A multicenter study on patients with severe COVID-19 supported by extracorporeal membrane oxygenation (ECMO) showed that at six months post-ECMO, 13% presented cognitive alterations, 24% had returned to work full-time, and 13% had part-time work⁴⁸. Patients with risk factors for PICS must be continuously evaluated in the ICU for physical, psychological, and cognitive alterations to determine the need for physical, occupational, psychological, and other therapies. Therefore, prevention of PICS at an early stage is a significant challenge. For this, daily assessment of pain, analgesic use, correct choice of sedatives, release of mechanical ventilation, delirium, mobility, nutrition, sleep, and family participation in care are essential. PICS prevention actions executed in the acute phase of critical illness can be crucial for the rehabilitation of survivors, with the goal of not only preventing impairment but also providing the opportunity to return to their original lives. The following are some points to consider.

Analgesia, Sedation and Delirium Prevention

Analgesic and sedative management plays a crucial role in relieving pain and anxiety and allows patient comfort. Considering the patient's critical pathology and environment,

the appropriate choice of sedatives can prevent short-, medium-, and long-term problems, such as delirium and cognitive alterations. Evaluation of sedation levels is essential; over-sedation in the acute stage of critical illness is frequent and exposes the patient to complications. Likewise, daily delirium assessment using validated scales and prevention and environmental and pharmacological treatment following clinical guidelines are suggested in cases where it occurs. Immobilization, sleep interruption, and restricted visits may increase the risk of delirium and PICS. The creation of protocols for delirium prevention, considering daily assessment and treatment of pain and delirium, treatment of agitation, daily assessment of weaning from the mechanical ventilator, early mobilization, sleep protection, and incorporation of the family in care can promote early rehabilitation of critically ill patients, prevent PICS, and improve long-term quality of life^{49,50}.

Early rehabilitation

Due to the high percentage of survivors who present with physical alterations and difficulties in activities of daily living when returning home, early rehabilitation in patients at risk of acquired critical patient weakness is essential⁴⁹. According to the patient, early rehabilitation protocols should include multidisciplinary therapies, respiratory training, mobilization, and occupational and speech therapies. Electrical stimulation therapy is an option for patients undergoing deep sedation and neuromuscular blockade⁵¹.

Family Involvement

Family visits were restricted to the ICU and hospitals during the pandemic, which caused a substantial decrease in the interaction

between the patient, family, and the healthcare teams, with significant consequences in the PICS and PICS-F^{52,53}. In-person family participation is suggested whenever possible; it decreases psychological distress and suffering in family members and patients and decreases delirium in critically ill patients. In the event of a new pandemic, restrictions to the family are likely to be present; in these cases, it is recommended to be prepared with remote communication protocols that incorporate training to health teams in communication during crises and the incorporation of technology to avoid harmful effects of this situation in critical patients, their families, and health teams.

Team training

Participation of a multidisciplinary team is crucial for the prevention of PICS. Periodic training of the team for new crises plays a vital role in enhancing the team's capacity for coordination and reorganization as well as efficient and effective resource allocation. For this, it is essential to have "a priori" to identify and work on potentialities and barriers in the team and educate and communicate. Periodic training is suggested by considering the rotation of the health teams⁵⁰.

Outpatient rehabilitation and follow-up

Follow-up clinics for critically ill patients can reduce the use of PICS⁵⁴. These follow-up clinics should be multidisciplinary in addressing the range of needs that survivors may present and coordinating with primary care services to reintegrate patients into the community and their daily lives. The follow-up team should consider the patient's condition, severity, stage of the disease, and other factors associated with the life course, as well as the family and social environment. Based

on this information, an individualized plan should be developed with medium- and short-term therapeutic objectives⁵⁵.

4. CHALLENGES IN RESEARCH

Research is crucial in improving healthcare and patient care, especially during the COVID-19 pandemic when new research approaches and strategies have been developed⁵⁶. These innovations have been essential for overcoming the challenges posed by the pandemic, with clinical research playing a central role in their resolution⁵⁷. Although conducting research during a pandemic is exceptionally difficult, it is still necessary to rethink conventional practices to sustain scientific progress under adverse circumstances⁵⁶. Future research should consider these unique challenges and adapt them to accelerate research that can help contain the spread and support optimal care.

Development of methodological flexibility

Conducting traditional clinical trials during the pandemic has been challenging because of the need for methodological flexibility without compromising scientific rigor and ethics. Researchers have turned to early analytical techniques such as interim analysis and adaptive trial designs, which allow modifications to the trial protocol based on preliminary data⁵⁸. These methodologies are valuable when time is critical, as demonstrated by the World Health Organization (WHO) Solidarity Trial, which evaluated multiple treatments in various contexts. Additionally, innovative designs such as adaptive sequential designs, adaptive response randomization, historical and dynamic borrowing, and multilevel trials with various arms have been crucial for quickly identifying effective interventions⁵⁹.

Clinical studies have been adapted to better serve COVID-19 patients by adjusting the inclusion and exclusion criteria, enhancing safety measures, and exploring novel therapeutic methods⁶⁰. Researchers have taken special precautions to safeguard the healthcare workers' well-being in these studies by providing emotional and psychological support⁶¹. Rigorous review processes have been implemented to maintain ethical and scientific standards, and transparency in communicating results has been promoted⁶². These efforts have allowed significant progress in intensive care knowledge during this pandemic.

Scientific rigor and ethics

The review process for new research study submissions should be expedited while maintaining the scientific and ethical standards of research⁶³. Each study must promote knowledge, improve health, and sustain methodological rigor, ensuring that the benefits outweigh any possible harm to the communities and the people involved⁶¹. Additionally, it is crucial to guarantee informed consent, the safety of participants, methodological validity to answer the scientific question and conduct a thorough review of all studies submitted for publication⁶³. It is recommended that the need for data transparency and peer review be balanced with the benefits of accelerating the knowledge of study results during a rapidly developing pandemic.

Formation of national and international networks

The COVID-19 pandemic has underscored the significance of global cooperation in research as researchers have joined forces to share data, knowledge, and resources,

leading to more rapid and effective responses to crises. This highlights a proactive and socially conscious scientific and academic community capable of promptly coordinating efforts⁶⁴. Even under tremendous pressure, clinical and translational research organizations and networks are vital for advancing therapeutic innovation. Healthcare facilities and institutions such as critical care units provide valuable information on incidence, case presentation, risk factors, infection control, prevention, and resource management, which are indispensable for clinical and public health policy decisions⁶⁵.

During the ongoing COVID-19 pandemic, numerous national and international collaborations have emerged. Health systems, universities, and research institutions have collaborated with public-private partnerships. These collaborations have resulted in a more unified approach to pandemic research by efficiently sharing findings and resources. The COVID-19 Tools accelerator is a prime example of these collaborations, bringing together various stakeholders to accelerate the development, production, and equitable distribution of tests, treatments, and vaccines against COVID-19⁶⁶. Moreover, the pandemic has driven open science initiatives in which scientists share research results and data in real-time, promoting immediate access and collaboration without delays associated with publication and patents. This approach has not only accelerated investigation but also fostered a culture of transparency and cooperation that can serve as a model for future crises.

Preparation for Data Collection

Preparing to face crises such as the pandemic requires the implementation of robust data

collection systems. The use of advanced electronic tools, including pre-filled forms and electronic clinical records (EHR), has been demonstrated to be critical in recent studies^{67,68}. National registries have provided valuable information regarding the epidemiology of critically ill COVID-19 patients, allowing the scientific community to collaborate and disseminate the main characteristics of the disease⁶⁹. These tools optimize data capture and systematization, enabling efficient exchange of information between different centers and geographic locations. Additionally, real-time records of high-risk patients, including those with COVID-19⁷⁰ can improve the quality of care. Such studies offer a cost-effective and statistically robust means of generating accurate population estimates⁷¹. The RECOVERY clinical trial is an outstanding instance that highlights the importance of data preparation⁷². In this study, the investigators used existing hospital data networks to recruit and gather patient data swiftly. This strategy enabled the trial to progress expeditiously without extensive data collection, ultimately reducing the time from conception to obtaining valuable results.

Another example is the Dutch Data Warehouse (DDW), a multicenter database of electronic medical records of critically ill COVID-19 patients⁶⁹. However, high data heterogeneity poses a challenge to international collaboration and comparability. In the future, national registries that include essential information on patients with acute respiratory failure in the ICU should be implemented in both high- and low-resource settings⁵. These registries could also include reporting forms for other clinical conditions

and provide real-time access to data. In conclusion, thorough preparation is essential for data collection during crises like pandemics to ensure an effective and evidence-based response to public health challenges.

Incorporating diversity and equity into research

Physiological variables, patient comorbidities, and sociodemographic factors, including race, sex, and socioeconomic status, are crucial determinants of intensive care⁷³. To provide equitable care, it is essential to recognize and thoroughly investigate these factors during ICU treatment. It is necessary to emphasize the need to study devices and interventions in different racial backgrounds; it is not appropriate to assume that interventions are applied uniformly, regardless of race⁷⁴.

Similarly, although women are generally sicker, they are less likely to be admitted to the ICU and have less severe illness^{75,76}. Studies have also indicated that women are less likely to receive life-sustaining therapies and more likely to have treatment limitations⁷⁷. Moreover, it is essential to distinguish between biological distinctions (sex) and personal identities (gender) and to analyze sex separately, particularly when considering minority groups in the ICU⁷³.

The COVID-19 pandemic has highlighted disparities between socioeconomic groups, with lower socioeconomic status associated with higher mortality rates after intensive care admission and more treatment limitations in the ICU population^{78,79}. Research suggests that patients from socioeconomically disadvantaged areas have a higher frequency

of ICU admission and 30-day adjusted mortality⁸⁰. Therefore, it is crucial to incorporate socioeconomic status into research to determine its association with mortality and investigate its possible association with other factors, such as the intensity of treatment in the ICU and other ICU decisions. Moreover, examining clinical results in low-resource settings is essential because findings from high-income countries may not be reliably extrapolated to low- and middle-income countries. It is therefore crucial to investigate these factors⁸¹.

Conclusion:

The COVID-19 pandemic has exerted extraordinary strain on global healthcare systems, especially in ICUs. In response to this unparalleled health crisis, governments worldwide have implemented exceptional measures and have sought to optimize available resources. Hospitals face enormous challenges in meeting the demand for ICU beds, resulting in significant disparities in their responsiveness to these resources. There is a growing consensus regarding the urgency of a more agile, resilient, and prepared healthcare system, particularly in critical care delivery, capable of addressing the deficiencies highlighted as a consensus among stakeholders. This calls for proactive planning and interdisciplinary collaboration between different actors and sectors. Furthermore, it is critical to prioritize the well-being of ICU personnel, develop effective resource management strategies, and implement early preventive measures for PICS. Additionally, research challenges, including equity considerations, must be addressed to build a more robust and

responsive healthcare infrastructure capable of withstanding future crises.

Conflict of Interest Declaration:

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interests in the subject matter or materials discussed in this manuscript.

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