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Priorities for Acute Care Systems during Pandemics: Lessons from COVID-19

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ABSTRACT

Health care systems across the world struggled to treat patients during the COVID-19 (coronavirus) pandemic. Treatment narratives from low- and middle-income countries (LMICs) demonstrate that effective emergency, critical, and operative care during a pandemic involves the following: centralized governance, supplemental financing, locally adaptive capacity in physical resources, supply chain management, interfacility triage, workforce deployment, and community engagement within existing public health frameworks. The comprehensive review in this chapter also identifies an essential package of cost-effective clinical interventions for priority investment at district-level hospitals in LMICs that harmonizes with essential care from the Universal Health Coverage Compendium. The scarcity of oxygen during the pandemic reinforced the need for a core package of clinical services with the dual purpose of health systems strengthening and pandemic preparedness. Resilient health care systems should prepare to treat patients affected by future pandemics while avoiding disruptions in routine nonpandemic care.

INTRODUCTION

The treatment of patients with COVID-19 (coronavirus) posed numerous challenges for health care systems around the world. On December 31, 2019, China's World Health Organization (WHO) Country Office received notification of the first case of a novel coronavirus. Seventy days later, global cases of this novel coronavirus had surpassed 118,000 in 114 countries and claimed 4,291 lives, prompting the WHO Director General to declare a global pandemic.[1] The spread of the virus outpaced emergency, critical, and surgical care (ECSC) capacity to anticipate and prepare for impact in real time, precipitating an unprecedented crisis in the care of patients (Grasselli, Pesenti, and Ceccone 2020; Guan et al. 2020; Huang et al. 2020; Wang, Hu, et al. 2020; Wu et al. 2020; Zhou et al. 2020). For example, as local supplies of oxygen were depleted, deficiencies in global supply chains led to critical shortages with far-reaching effects on patient care (Graham, Kamuntu, et al. 2022; Kayambankadzanja et al. 2021). As patients flooded hospitals, pandemic surges revealed weaknesses in the architecture of health care systems, pushing them beyond their breaking points and exacerbating existing health inequities (El Bcheraoui et al. 2020; Siow et al. 2020) As the international community reflects on COVID-19, policy makers are eager to apply the lessons learned.[2]

Clinical Interventions and Systems-Level Strategy

Clinical interventions are often underemphasized in discussions of pandemic preparedness (WHA 2005, 2021, 2022). Whereas public health agencies have a duty to control the spread of pathogens, clinicians and the systems they work in have a duty to provide care to those who are suffering. As the medical community adapted to successive waves of COVID-19 variants, innovation was forced upon health care institutions to keep up with demand for clinical services (Haldane et al. 2021). From a policy standpoint, prevention cannot be presented as an alternative to treatment, because individuals who are ill will inevitably seek medical care. The important consideration is how to balance investments in health systems against preparedness and prevention efforts, and what the priorities should be for health system investment in the context of limited resources and a need to maximize value for money.

Gaps in the Literature

WHO now reports that the pandemic caused such severe disruptions to health care systems that more lives were lost indirectly because of the diversion of resources away from non-COVID-19 health services than because of the pandemic itself (COVID-19 Excess Mortality Collaborators 2022; Knutson et al. 2022; WHO 2022a; Woolf et al. 2020). In retrospect, this finding calls into question the knee-jerk reaction of prioritizing pandemic care at the expense of routine (nonpandemic) health care. During pandemic surges, many health care facilities canceled routine care such as screening, elective surgeries, and follow-up for noncommunicable diseases.

A critical gap in the literature (and in practice) is evident between the competing demands of clinical care during pandemic surges and clinical care for quotidian health needs (WHO 2020c, 2020e, 2021a). This chapter addresses that gap as a fundamental premise by embedding recommendations for cost-effective pandemic preparedness into the framework for overall health systems strengthening from the Universal Health Coverage (UHC) Compendium. In doing so, it aims to reconcile the false dichotomy between pandemic preparedness and systems strengthening and promote a package of essential services that carry the dual purpose of developing resilient health care systems capable of adapting to surges without suspending routine health care (Haldane et al. 2021).

Goals and Objectives of This Chapter

This chapter aims to define pandemic preparedness for acute care systems, with an emphasis on emergency, critical, and operative services, to optimize the treatment of patients. In three sections this chapter discusses (1) treatment narratives from five countries; (2) an essential cost-effective package of emergency, critical, and surgical interventions (ECSC); and (3) management strategies for district hospitals in low- and middle-income countries (LMICs). This effort builds on the previous edition of *Disease Control Priorities, third edition* (*DCP3*) in which chapters on pandemics, emergency care, and essential surgery outlined synergistic frameworks for implementation (Madhav et al. 2017; Mock et al. 2015; Reynolds et al. 2017). Although this chapter draws on lessons from COVID-19, it also recognizes the possibility that future pandemics may have different characteristics. Issues of transmissibility, physical manifestations of disease, mortality rates, and host-pathogen interaction may vary significantly with the next pandemic. This chapter's recommendations are sufficiently broad to cover the possibility that a nonrespiratory pandemic occurs in the future.

This chapter also lends special focus to the importance of strengthening underdeveloped health care systems in LMICs. It is true that the COVID-19 pandemic created challenges in high-income countries as well, but the profound disparities in health care workforce, physical infrastructure, and quality of care create especially brittle circumstances in LMICs. In 2016, WHO's Global Strategy on Human Resources for Health Workforce 2030 highlighted a shortage of 18 million health workers, and recent updates via National Health Workforce Accounts show slow progress—with 47 LMICs bearing two-thirds of the global workforce shortage (Boniol et al. 2022; WHO 2013, 2016). The *Lancet* Commission on High Quality Health Systems reports that patients in LMICs are less likely to receive appropriate care in general: mothers and children receive less than half of recommended clinical actions during a typical visit, and less than half of suspected tuberculosis cases are correctly managed (Kruk et al. 2015). The *Lancet* Commission on Medical Oxygen Security reports that in LMICs only 30 percent of people in need of medical oxygen receive it (Graham et al. 2025).

The pandemic also exacerbated existing backlogs for elective surgery in a context where 70 percent of the world's population already lacked access to safe surgery before the pandemic began (Alkire et al. 2015; Jain, Dai, and Myers 2020; Klazura et al. 2022; Park et al. 2022). Longstanding disparities in health care infrastructures are further exacerbated during pandemics when vaccine access lags in LMICs. Two years into the pandemic, disparities in vaccinated individuals between countries ranged from 0 to 95 percent, with LMICs consistently falling behind the COVID-19 Vaccines Global Access targets (McIntyre et al. 2022; PLOS Medicine Editors 2022; Privor-Dumm et al. 2023). The achievement of global health equity will require dedicated attention to strengthening health care systems in LMICs.

Not Covered in This Chapter

This chapter also dovetails with various other chapters from *Disease Control Priorities, fourth edition* (*DCP4*), which focus on nonclinical domains of the COVID-19 pandemic. Those other chapters cover topics as broad as prevention, detection, biosecurity, early outbreak control, transmission reduction, immunization, financial protection, community engagement, research and development priorities (including pathogen-directed treatments), and historical lessons from past pandemics. The recent *Lancet* Commission on Medical Oxygen Security describes global oxygen need and strategies for service coverage in more detail. Consequently, this chapter does not cover various topics salient to population health despite their obvious overlap with clinical care, such as social distancing, vaccine policy, lab testing, social determinants, community engagement, and travel quarantines. This chapter's narrow focus on health care allows a more granular lens on the health care delivery system included in resilience frameworks (Haldane et al. 2017; Haldane et al. 2021; Kruk et al. 2015).

REVIEW OF TREATMENT NARRATIVES IN FIVE COUNTRIES

During surges, health care providers and administrators adopted novel strategies across various domains and in diverse clinical settings (Haldane et al. 2021; Kuppalli et al. 2021; Siow et al. 2020). Consider the case of India. In May 2021, India reported more than 400,000 new cases of COVID-19 daily. Oxygen and personal protective equipment (PPE) supplies were rapidly exhausted. Early lessons from overwhelmed hospitals underscored the importance of supply chain management to accommodate clinical needs, equitable training and deployment of medical providers, links between primary care infrastructure and referral hospitals, and real-time data collection to predict clinical demand (Kuppalli et al. 2021; *The Lancet* COVID-19 Commission India Task Force 2021). As the global volume of infections rose, the grim prospect of learning in real time to manage patients became an urgent reality (Siow et al. 2020).

A semistructured survey of health care providers from five countries was performed to better appreciate variations in COVID-19 response globally and gather qualitative information regarding adaptations in clinical care. It aims to better understand the challenges and opportunities providers faced in domains pertinent to patient care, such as staffing, communications, physical space, governance, financing, supply chain management, care of at-risk populations, and post-acute case management (ASPR TRACIE 2020; refer to annex 12A for a description of the data collection instrument). Surveyed providers were senior individuals who had expertise in policy and management and could serve as "key informants" for their unique settings. The survey engaged experts from five countries (Brazil, China, Kenya, Mozambique, and Nepal), covering a variety of health care contexts and geographies across LMIC settings. Providers were encouraged to consider transitions into and out of pandemic surges and responses implemented across all domains of clinical care, from acute to intensive care and from initial triage to recovery.

Highlights from Health Care Intervention Narratives during the COVID-19 Pandemic

The following paragraphs present concise summaries of the strategies and interventions for each country (designated as a low-income or a middle-income country). For more detailed responses from the survey respondents, refer to annex 12B.

Brazil (Middle-Income Country)

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Local governing bodies and individual hospital systems primarily led the COVID-19 response in Brazil. The Ministry of Health assisted with designation of COVID-19-specific facilities and dissemination of protocols for patient care. State and local health secretaries supported intersystem coordination; however, individual hospitals determined acceptance and transfer criteria for COVID-19 patients, supply chain management, and implementation of strategies such as telehealth to permit continuation of routine health services. Of note, telehealth was not previously permitted, but university health systems developed protocols to implement and then expand the reach of clinical services through telehealth visits. This approach, largely guided by individual hospital interest, presented challenges with uniformity of COVID-19-related care, variability in staffing, access to critical supplies (such as PPE), and inconsistencies with interhospital coordination, which ultimately required greater involvement from the Ministry of Health as subsequent pandemic surges exacerbated these issues. During surges, elective surgeries were canceled in several cities where bed shortages required conversion of operating theaters to intensive care unit (ICU) beds. After surges, existing long-term care facilities without dedicated programs managed patients with long COVID. Staff burnout became an issue during subsequent surges, and task-sharing protocols were key, including transitions between clinical, administrative, and clerical roles.

China (Middle-Income Country)

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The first outbreak of COVID-19 in Wuhan, China, resulted in severe shortages of hospital resources and medical staff, requiring widespread recruitment and dispatch of national medical teams from other parts of the country. The National Health Commission in China drew from prior experience with the SARS-1 pandemic in 2003 and annual influenza outbreaks to rapidly redesignate and expand existing infrastructure. Fever Clinics served the dual purpose of triage and isolation of sick individuals from main hospital campuses. Large-scale public venues were converted temporarily to health care facilities (Fangcang shelter hospitals) for individuals with mild to moderate disease in regions affected by the SARS-CoV-2 virus (Chen et al. 2020). All patients with severe disease were transferred to designated hospitals, and a "dynamic zero" policy allowed continuation of routine medical care in facilities unaffected by COVID-19. Following the initial pandemic surge, widespread screening and contact tracing kept case volumes at a manageable level, which enabled widespread vaccination before native infection. Laboratory testing was initially performed centrally and then expanded peripherally to boost local capacity for testing. This systematic approach based on prior pandemic experience enabled rapid expansion of testing and treatment facilities, early containment of outbreaks, and advanced approaches to studying the virus, its variants, and its long-term effects amid surges.

Kenya (Middle-Income Country)

By ***Patrick Amoth***, MMEd, EBS, Director General of Health, Ministry of Health, Republic of Kenya

Kenya adopted a largely centralized approach to patient care and management during COVID-19. A national task force was created to oversee health care implementation and policy. Financing from the World Bank through the COVID-19 Health Emergency Response Project supported the national task force in disseminating guidelines and providing training for health care workers. This central planning established COVID-19 facilities in each county, expanded critical care units, reassigned staffing between sites, managed supply chains, and more. Individual hospital needs were communicated through designation of key contact personnel, who provided regular updates on staff and patient care metrics to inform regional and national surveillance strategies. High-risk groups—including pregnant women, immunocompromised individuals, and the elderly—received priority immunization. This top-down approach resulted in a largely uniform pandemic response throughout Kenya with little disruption to essential nonpandemic care.

Mozambique (Low-Income Country)

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The Ministry of Health directed the COVID-19 response in Mozambique. Historically, Maputo City served as a centralized destination for all specialty care and maintained this role throughout most of the pandemic. Initially, smaller hospitals designated isolation units for triage of patients to a single, primary referral center in Maputo City (Maputo Central Hospital) that managed all COVID-19 cases. Isolation units were supplied with oxygen tanks and PPE, and this response adequately met early case needs. Because of the relatively low early case volume, anticipatory planning was not undertaken to guide expansion for subsequent surges. As case volume increased exponentially with new variants (especially the Delta variant), units across other facilities were retrofitted and staff were reassigned to care for COVID-19 patients. Facilities included isolation and triage units within tents in order to accommodate 10-fold increases in capacity. A designated COVID-19 treatment facility (such as a hospital) was identified in a major city within each of 11 provinces, where patients ultimately underwent complex care, including an independent pharmacy exclusively for COVID-19 patients. All testing for COVID-19 was performed in a single lab with three- to five-day turnaround of results. Notably, the supply of oxygen cylinders, ventilators, blood gas analyzers, radiography equipment, and PPE was depleted. With the lack of available staff and resources, all non-COVID-19 care and elective surgeries were halted during subsequent surges. Expanding isolation units and staffing required rapid mobilization of finances, including trainees and foreign assistance from the Cuba Cooperation. Recovery from each surge was enhanced by telehealth visits whereby providers could triage patients without exposing them to risks of infection from travel to facilities.

Nepal (Low-Income Country)

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Nepal's COVID-19 response evolved as case volume increased. The national governing body activated committees with key players to coordinate the initial response mechanism in a centralized, top-down manner. Clinical guidelines were prepared nationally with support from the WHO Country Office. Provinces established isolation and testing centers in response to increasing case numbers, managed medications, and oversaw supply chains while local governments managed isolation centers and provided services. For purposes of the pandemic, hospitals were designated as "primary" for COVID-19 treatment or "secondary" for non-COVID-19 care. Hospitals rapidly implemented innovations, including retrofitting for negative-pressure air ventilation systems and color-coded isolation levels to differentiate patients at increased risk of transmission. In some provinces, public spaces (such as vacant factories) were converted to COVID-19 treatment hospitals with acute and intensive care capacity. Testing was expanded early from one central site to public and private labs in all provinces to accelerate case finding. Scarcity of oxygen led to a centralized approach for designated domestic supply. This as-needed approach presented initial challenges because of the lack of existing mechanisms to accommodate large-scale funding and resource diversion, yet the flexibility inherent in this strategy ultimately expedited the response to and containment of future surges through swift innovation.

Lessons Learned

Multiple themes emerged from the collective responses to this semistructured survey in Brazil, China, Kenya, Mozambique, and Nepal. The following subsections briefly summarize the key messages in the categories of general strategies, supply chain management, and essential (nonpandemic) patient care.

General Strategies

Initial pandemic responses coordinated at the national level were most rapidly adopted and efficient. Most countries in the preceding case narratives from the countries surveyed assumed a top-down approach, with national governing bodies overseeing the development and dissemination of guidelines and regional or local bodies responsible for implementation and monitoring of outcomes. Countries that adopted a centralized approach reported a more efficient response to COVID-19 and rapid containment of outbreaks. Early designation of isolation and testing centers was performed, either through creation of COVID-19 units or distinct facilities, with varying complexity that appeared to correlate with the size of outbreak in each country. Telehealth options, where implemented, accelerated triage, reduced risk of transmission to patients and providers, and expedited recovery of essential nonpandemic care after surges. In each setting, real-time data from clinical sites were transmitted back to national command centers for active decision-making and coordination. No sites conducted active trials for novel pathogen-directed treatments.

Supply Chain Management

Responding countries universally experienced supply chain deficiencies. Consumable supplies depleted by surges included PPE, lab testing materials, oxygen, medicines, radiography equipment, and airway support equipment. Innovative maneuvers to maintain adequate supplies at the point of care included cancellation of elective services (for example, surgical care in Mozambique) to repurpose physical resources outside of their original clinical setting; novel sterilization approaches (for example, use of ultraviolet ray in Nepal) for reuse of consumables; novel internal financing mechanisms (for example, through local and national governmental budgets in Mozambique and Nepal); and external support through multinational financers (for example, the World Bank's COVID-19 Health Emergency Response Project program in Kenya) to offset programmatic costs.

Some innovations require greater investment and were not within reach during the pandemic. For example, despite the desire to develop oxygen plants in Nepal, lack of human resources with technical expertise impeded progress. Stockpiling supplies was generally not performed before the first wave, but it was of some utility in planning for subsequent surges. However, utility of stockpiling was limited by multiple uncertainties, such as variation in transmissibility of COVID-19 variants, effectiveness of vaccine campaigns to reduce hospitalizations for severe illness, and fluctuation in budgets restricting discretionary spending. In all settings from this series, supply chain issues were accompanied by hospital overcrowding, staff shortages, and suspension of nonpandemic care during surges.

Essential (Nonpandemic) Patient Care

High-risk populations received prioritization for pandemic-related care and vaccination in some contexts, but not for routine health care during surges. Essential, non-COVID-19 care was largely deferred during peak surges among surveyed countries but reintroduced later in parallel to—and likely permitted by—improvements in supply chain, workforce, and overall resource management. Strategies to systematically improve priority investments for essential health care can improve patient outcomes in future pandemics. Post-acute care was a low-priority focus during active surges, and few countries adopted a systematic approach to the study and management of COVID-19-related conditions, which remains an issue to this day. By developing strategic health plans for future pandemics, countries can more rapidly implement isolation, testing, and treatment strategies while preserving resources to maintain core functions and support research during outbreaks.

The COVID-19 pandemic challenged health systems worldwide and exposed limitations across both high- and low-performing systems. Standardized anticipatory planning, including supply chain redundancy and stockpiles, facilitates rapid expansion of clinical services and overall health system resilience, especially if based on prior pandemic experience. The paucity of oxygen, in particular, demonstrated the need to bolster public-private partnerships to improve local production of supplies in addition to fostering international collaboration to facilitate rapid procurement and transportation of oxygen during surges. Health system management initially benefits from a top-down approach with built-in flexibility for local emergencies. Emergency financing mechanisms can be deployed to ensure facilities and providers maintain operations. Policies and investments should align across the continuum of care, including post-acute care. National strategies for testing, containment, treatment, and investigation of disease outbreaks are needed alongside strategies that permit continuation of essential health care services.

ESSENTIAL PACKAGE OF CLINICAL INTERVENTIONS DURING EPIDEMICS AND PANDEMICS

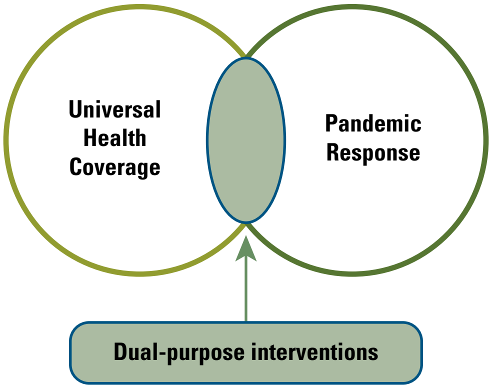
The COVID-19 pandemic provides a unique opportunity to review clinical interventions that underpin the successful treatment of patients during pandemics and harmonize them with the goals of health systems strengthening (WHO 2020c, 2021a). *DCP3* highlighted essential clinical interventions for ECSC to support the achievement of UHC (Madhav et al. 2017; Mock et al. 2015; Reynolds et al. 2017). Without a focus on the unique challenges inherent to pandemic response, however, these recommendations may not be implementable during surges. Although WHO has also published numerous guidelines for clinical management of COVID-19 (WHO 2020d, 2020g, 2022b, 2023), distinct guidelines and interventions for pandemic preparedness and UHC may promote a false dichotomy between preparing for the next pandemic and more general strengthening of health systems. In reality the two goals overlap significantly because UHC and health security are complementary goals (WHO 2020c, 2021a). Passage by the World Health Assembly of Resolution 76/2 in 2023 shows the momentum around these issues. That resolutions calls for "integrated emergency, critical, and operative care for universal health coverage and protection from health emergencies," and acknowledges that "COVID-19 revealed pervasive gaps in capacity of emergency, critical, and operative care services that resulted in significant avoidable mortality and morbidity globally"(WHA 2023, 1).

Methodology

This chapter presents a concise framework for strategic investments in ECSC systems to improve outcomes during epidemics and pandemics while simultaneously strengthening routine care delivery. Building on the previous section of treatment narratives, this essential package of services was designed around feasibility and cost-effectiveness, with special consideration given for management of surge conditions in LMICs where deficiencies in staffing, supplies, and infrastructure are known to exist. The methodology was designed to promote the resiliency of health care systems as capable of absorbing shock and adapting to dynamic situations during future pandemics while concurrently maintaining critical core (nonpandemic) functions (Kruk et al. 2015; Nuzzo et al. 2019; United Nations 2017; WHO 2020c, 2021a).

First, a list of ECSC interventions for pandemics was created from a structured review of novel scientific research (such as Pubmed), gray literature, and guidance documents from DCP3 and WHO. Publicly available resources from WHO address operational considerations for case management of COVID-19 in a health facility, severe acute respiratory infections treatment centers, clinical care for severe acute respiratory infection, and clinical management of COVID-19 (WHO 2020d, 2020g, 2022b, 2023). Of note, the literature review encountered significant attention to pathogen-directed treatments such as chloroquine, remdesivir, favipiravir, nirmatrelvir/ritonavir, convalescent serum, and others in the scientific literature. However, regardless of their efficacy in treating COVID-19, it is not possible to confirm any single treatment's utility in future pandemics so these specific interventions were underemphasized. This approach was also consistent with identifying dual-purpose interventions that were common to pandemic preparedness and more general health systems strengthening according to the conceptual model in figure 12.1.

Figure 12.1 Conceptual Model Highlighting Dual-Purpose Interventions at the Intersection of Pandemic Preparedness and Universal Health Coverage



Source: Original figure created for this publication.

Second, this list of ECSC interventions for pandemics was vetted with international experts according to the criteria of cost-effectiveness and feasibility from available scientific literature (table 12.1). An important aspect of identifying what interventions are "essential" for treatment of patients during pandemics is determining how much health they generate for a given amount of money spent. The DCP project has always taken the position that cost-effectiveness analysis is a critical tool that becomes even more important in times and places where resources are especially scarce. A structured literature review identified economic evaluations related to treatments for pandemic infections, with a focus on viral respiratory pathogens (such as COVID-19 and influenza) and viral hemorrhagic fevers (such as Ebola). Table 12.1 provides highlights from the original studies identified. Six systematic reviews of cost-effectiveness in ECSC interventions outside of the context of a pandemic also contributed to the understanding of cost-effectiveness for ECSC: two manuscripts for emergency and critical care bundles (Vandepitte et al. 2021; Wilcox et al. 2019) and four for surgical interventions (Chao et al. 2014; Grimes et al. 2014; Ifeanyichi et al. 2024; Saxton et al. 2016).

Third, this list of essential ECSC interventions was cross-referenced with the UHC Compendium (annex 12C). Each intervention was labeled broadly as diagnostic, therapeutic, or population or systems level. Therapeutic categories were also subdivided into groups of procedures, respiratory support, and cardiac support, with those groups subsequently organized according to the broad function of disease management—diagnosis/triage, core management of critical illness, management of complications of critical illness, and systems-level interventions (refer to table 12.2 later in the chapter). Interventions were then assigned to domains of the health care system according to the WHO Building Blocks framework (WHO 2010). These domains initially included all spaces where patients underwent treatment for COVID-19 (such as home, ambulatory clinic, emergency department, hospital ward, and ICU), and were subsequently collapsed into discrete clinical categories of primary health center, first-level (district) hospital, second- or third-level hospital, and postdischarge.

Table 12.1 Highlights from Literature Review to Identify Economic Evaluations Related to Acute Care Services for Pandemic Infections

Author	Intervention	Cost-effectiveness data	Comments
Kairu et al. 2021	(1) EC (2) EC + ACC (3) Status quo	(1) EC-cost/DALY averted (US$, % GDP per capita): 719.61, 0.35 (2) EC + ACC-cost/DALY averted (US$, % GDP per capita): 1,711.52, 0.822 (3) Status quo-cost/DALY averted (US$, % GDP per capita): 225.11, 0.11 ICER cost/DALY averted (Status quo-EC) (US$, % GDP per capita): –23.16, –0.01 ICER cost/DALY averted (EC + ACC – EC) (US$, % GDP per capita): 1,378.21, 0.66	EC = essential care for COVID-19 managed on hospital wards, including supplemental oxygen and IV fluids, according to WHO Living guidance for clinical management of COVID-19 (2021) ACC = advanced critical care for critical COVID-19 patients typically provided in ICUs, such as mechanical ventilation, ARDS, thromboembolism, shock management Location: Kenya, 2021 GDP per capita = US$2,081.80
Beshah et al. 2023	(1) Noninvasive management (2) Invasive management	(1) Noninvasive ACER cost/DALY averted (US$, % GDP per capita): 1,991, 2.15 (2) Invasive ACER cost/DALY averted (US$, % GDP per capita): 3,998, 4.32 ICER cost/DALY averted (invasive–noninvasive): 4,948, 5.35	Noninvasive management-oxygen without intubation Invasive management-intubation Location: Ethiopia, 2021 GDP per capita = US$925.0
Cleary et al. 2021	(1) GW (2) GW + ICU	ICER cost/DALY averted (GW + ICU – GW) (R, US$, % GDP per capita): 73,091, 3,835.12, 0.54	GW = general wards management only GW + ICU = general wards + ICU management Location: South Africa, 2021 GDP per capita = US$7,055.04
Risko et al. 2020	(1) Constrained PPE supply/ status quo (2) Investment in PPE	ICER cost/case averted (PPE investment – constrained PPE) (US$): 59 ICER cost/death averted (PPE investment – constrained PPE) (US$): 4,309	Modeling study, locations considered: LMICs aggregate, East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia, Sub-Saharan Africa
Kazungu et al. 2021	(1) Inadequate supply of PPE (2) Adequate/full PPE utilization	ICER cost/case averted (full PPE – inadequate PPE) (US$, % GDP per capita): 51, 0.024 ICER cost/death averted (full PPE – inadequate PPE) (US$, % GDP per capita): 3,716, 1.78	Location Kenya, 2021 GDP per capita = US$2,081.80
Sheinson et al. 2021	(1) Treatment (no oxygen support; oxygen support without ventilation; oxygen support with ventilation) (2) Best supportive care	ICER cost/QALY, payer perspective (treatment – supportive care) (US$, % GDP per capita): 22,933, 0.33 ICER cost/QALY, societal perspective (treatment – supportive care) (US$, % GDP per capita): 8,028, 0.11	Hospitalized patients with COVID-19 Location: United States, 2021 GDP per capita = US$70,248.63
Gandjour 2021	(1) Maintain current ICU bed capacity (no change) (2) Expand ICU bed capacity	MCER of last bed added to existing ICU capacity, cost/life year gained (euro, US$, % GDP per capita): 21,958, 23,558.85, 0.46	Hospitalized patients with COVID-19 Location: Germany, 2021 GDP per capita = US$51,203.55

Sources: As cited in the table.

Note: ACER = average cost-effectiveness ratio; ARDS = acute respiratory distress syndrome; DALY = disability-adjusted life year; GDP = gross domestic product; ICER = incremental cost-effectiveness ratio; ICU = intensive care unit; IV = intravenous; LMICs = low- and middle-income countries; MCER = marginal cost-effectiveness ratio; PPE = personal protective equipment; QALY = quality-adjusted life year; R = South African rand; WHO = World Health Organization.

Economic Evaluation of Essential ECSC during Pandemics

As the intervention under consideration becomes more complex and resource-intensive and uses higher-priced commodities or more skilled labor, it tends to become less cost-effective. For example, two studies that looked at investment in PPE supply both found that these investments would be very cost-effective, because they would prevent many infections and deaths associated with health care; these findings would apply across a range of LMIC contexts (Guinness et al. 2023; Kazungu et al. 2021; Risko et al. 2020). A South African study looking at ICU plus general ward management of persons with COVID-19, compared to general ward management alone, concluded that the latter was cost-effective, albeit in the context of a relatively mature health care system (Cleary et al. 2021). However, although neither noninvasive management nor invasive management of COVID-19 was found to be cost-effective in an Ethiopian context, similarly intensive interventions were found to be cost-effective in Kenya, underscoring that local context, cost drivers, and epidemiology greatly influence the overall value for money in this kind of care (Beshah et al. 2023; Kairu et al. 2021; Kazibwe et al. 2022; Memirie et al. 2022). The seemingly contradictory findings underscore the role that local budgets and implicit cost-effectiveness thresholds can have on cost-effectiveness analysis.

The study from Kenya provides a few additional insights into the spectrum of cost-effectiveness findings (Kairu et al. 2021). That study looked separately at "essential care" (including supplemental oxygen and intravenous fluids) and "advanced critical care" (including invasive management of respiratory failure and shock) as compared to a status quo scenario. Essential care was more cost-effective (that is, cost-saving) than the status quo; when advanced critical care was added to essential care, the combined strategy would be cost-effective compared to the status quo, at local willingness-to-pay thresholds.

Triangulating the findings from these studies leads to the conclusion that basic supportive care in a non-ICU setting is likely to be cost-effective (compared to doing nothing) in many or nearly all countries; however, advanced ICU-level services may or may not be cost-effective, depending on the local health system context and specific intervention components. Finally, regardless of the specific pandemic interventions offered, all countries can and should invest in maintaining basic hospital infection control procedures, oxygen infrastructure, anesthesia capacity, and adequate supplies of PPE to reduce harm to patients (with or without pandemic infection) and health workers.

A Novel Framework for Essential ECSC during Pandemics

All clinical interventions were grouped to emphasize their place within the system of interrelated health care settings. Clinical interventions can be broadly classified as follows: those that should be available in all settings, those that are core to the function of a strong first-level (district) hospital under nonpandemic conditions, those that should be available selectively in the district hospital during pandemic surge conditions, and those that are better reserved for second- or third-level hospitals because they are either not feasible or not cost-effective (table 12.2). These groupings allow for a concise overview of the salient care in the areas of diagnosis, triage, stabilization, basic and advanced treatment, and rehabilitation. This chapter emphasizes capacity in the district hospital.

The district hospital should be a hub where each community can access safe acute care services. The backbone of clinical care at the district hospital is a healthy, flexible workforce of competent providers who are protected with PPE and trained in basic life support and advanced cardiac life support. Core functionalities at the district hospital level include clinical monitoring, detection of physiologic deterioration, and triage to the appropriate level of care. These functionalities typically will require basic diagnostic studies such as imaging, laboratories, electrocardiogram, and pathology and basic supportive care such as electrolyte repletion, insulin, and anticoagulation. Once admitted to a district hospital, patients should have available to them additional support for acute respiratory failure and shock, including supplemental oxygen, suction, noninvasive ventilatory support, intravenous fluids, antimicrobials, blood product transfusion, and epinephrine. At select district hospitals, advanced care should also be available during pandemic surges to provide timely access in the event of rapid clinical decompensation and to prevent overcrowding in secondary or tertiary facilities. Advanced care for respiratory failure and shock includes mechanical ventilation, central catheters for vasopressive and inotropic medications, and surgical procedures such as surgical airway and gastrostomy tubes and associated anesthesia. In a context of severe or critical illness, management of complications is imperative to treat associated pain with analgesia or sedation, distress with anxiolytics, and basic surgical procedures such as laparotomy, thoracostomy tube, amputation, and wound care or coverage. After treatment and in preparation for discharging a patient from the district hospital, rehabilitation services such as physical therapy and occupational therapy will facilitate transfer to post-acute care. These cost-effective interventions at the district hospital level will allow for treatment of patients during acute pandemic surges and nonpandemic essential care.

Multiple components of clinical care pertinent to pandemic preparedness and UHC are recommended only for higher-level facilities. These components include interventions that are not feasible or not cost-effective at the district level and that require significant investment for acquisition, maintenance, and use. Advanced diagnostic studies in this category are computed tomography (CT) scans and magnetic resonance imaging (MRI) studies, among others. Advanced interventions for organ failure include renal replacement therapy for acute kidney failure and extracorporeal membrane oxygenation for complete respiratory collapse. When available, these services may play a role in select patients' care but should be considered only after first meeting the core functions for district hospitals.

Table 12.2 Essential ECSC Interventions Relevant to Pandemics Mapped to the UHC Compendium for Implementation at First-Level (District) Hospitals

	Primary health center	First-level hospital	Second- or third-level hospital	After discharge
Diagnosis/ triage		**Basic life support**		
	surge	**Advanced cardiac life support**		
	surge	**Monitoring, identification, and triage of patients with clinical deterioration**		
		Basic supportive care of patients requiring hospitalization and management of complications of inpatient hospitalization (for example, electrolyte repletion, insulin, and anticoagulation)		
		Basic diagnostic studies including laboratory, pathology, and imaging studies (for example, POC to tier 2 labs, X-ray, ultrasound, and EKG)		
			Advanced diagnostic studies (laboratory, pathology, and imaging studies including tier 3 labs, CT, and MRI)	
Core management of critical illness	surge	**Basic support for acute respiratory failure** with supplemental oxygen, suction, and noninvasive ventilatory support as needed		
		Basic management of shock according to etiology with basic hemodynamic support (for example, IV fluids, blood product transfusions, norepinephrine) and basic interventions (for example, antibiotics, IM epinephrine)		
		surge	**Advanced management of shock** with hemodynamic support and etiology-specific interventions (for example, central catheters, multiple pressors, thrombolytics, and inotropy)	
		surge	**Advanced support for acute respiratory failure** with advanced ventilatory support as needed (for example, mechanical ventilation for ARDS, surgical airway, and gastrostomy tubes)	
Management of complications of critical illness		**Management of pain, distress, and other symptoms** (for example, sedation, analgesia, and agitation management)		
		Basic surgical procedures and associated anesthesia (for example, thoracostomy tube, laparotomy, amputation, and wound care/coverage)		
			Specialized interventions for organ failure (for example, renal replacement therapy for acute kidney failure and extracorporeal membrane oxygenation, including central catheters/cannulations)	
		Rehabilitation services to address complications of severe illness and assist with recovery to baseline (for example, PT, OT, SLP, and discharge options)		
Systems-level interventions	**Flexible workforce** that can be repurposed to meet surge capacity			
	Supply chain reforms to ensure surge capacity for key commodities			
	Ensure adequate supply of **PPE** in surges			

Sources: Albutt et al. 2020; Aljishi et al. 2022; Bertini et al. 2022; Biswas 2015; Budinger and Mutlu 2014; Chen et al. 2020; Chmielewska et al. 2021; Festic et al. 2017; Inglis, Ayebale, and Schultz 2019; Kassirian, Taneja, and Mehta 2020; Maximous et al. 2021; Mohapatra and Mohan 2020; Palazzuoli, Beltrami, and McCullough 2023; Perez et al. 2023; Santana, Fontana, and Pitta 2021; Schell et al. 2021; Sheth et al. 2020; Thomas, Abdulateef, and Godard 2022; von Zweck et al. 2023; Watkins et al. 2018; Wong et al. 2020; Zahedi et al. 2023; Zainab, Gooch, and Tuazon 2023. Refer also to World Health Organization, "WHO Compendium: Health Interventions for Universal Health Coverage," (accessed June 20, 2023), https://www.who.int/universal-health-coverage/compendium.

Note: ARDS = acute respiratory distress syndrome; CT = computed tomography; ECSC = emergency, critical, and surgical care; EKG = electrocardiogram; IM = intramuscular; IV = intravenous; MRI = magnetic resonance imaging; OT = occupational therapy; POC = point of care; PPE = personal protective equipment; PT = physical therapy; SLP = speech language pathology; UHC = Universal Health Coverage.

IMPLEMENTATION AND MANAGEMENT IN DISTRICT-LEVEL HEALTH CARE SYSTEMS

Global agencies have taken steps to translate lessons learned from COVID-19 into pragmatic policy for the future—for example, WHO's Preparedness and Resilience for Emerging Threats initiative and the World Bank's Health Emergency Preparedness and Response Umbrella Program.[3] Many of these (and other) programs aim to provide special assistance to LMICs, where strain from the pandemic exacerbated chronic deficiencies in care capacity, resulting in significant mortality.[4] The following subsections synthesize care packaging and management strategies from these and other initiatives with a focus on value and efficiency for health care facilities in LMICs. Management strategies are summarized according to the building blocks framework of health care delivery, which has been applied to models of health care resiliency during the pandemic (Haldane et al. 2021).

Adaptations in Infrastructure: Physical Space

Pandemic surges often require rapid adaptation in local health care infrastructure. Narratives from earlier in the chapter are consistent with the literature that it is critical to secure adequate physical space for clinical care of patients with COVID-19. Future pandemics may require building new facilities, altering existing facilities, or repurposing secular structures for clinical care. In LMICs, it may not be possible to perform construction in every geographic district, but facilities in central locations can be designated as hot spots exclusively for pandemic care and others can be reserved for routine (nonpandemic) health care (ASPR TRACIE 2020; Haldane et al. 2021; Siow et al. 2020). Historically, this approach reinforces the role of pandemic emergency facilities developed by WHO for the Ebola epidemic (Kruk et al. 2015).

Health Workforce

In most settings, health care workers had a high risk for infection, creating absences of key personnel during surges when care was needed most (Bandyopadhyay et al. 2020; WHO 2020a). Successful strategies to ensure coverage of essential services in LMICs include aggressive implementation of PPE, realignment of duty hours to accommodate staff illness, support to avoid burnout, and incentivized reallocation. Staffing shortages in district hospitals may be addressed by emphasizing key clinical competencies over concrete titles. Educational tools now exist to assess competency and learn skills for a broad spectrum of health care activities, from clinical tasks (such as vaccination, acute stabilization, infection control, charting, and ventilator management) to health care management (such as provider well-being and infodemic strategy) (AHA 2020; CDC 2021; WHO 2021b).[5] During surges, medical and paramedical staff may cover functions outside their job description in order to avoid gaps in key capacities of the health care facility. Accomplishing continuity requires coordinating rapid dissemination of educational modules between medical and nursing societies, facility managers, local and regional centers for disease control, and ministry of health leadership.

Biomedical engineers and technicians are often overlooked in the landscape of critical hospital personnel. These technicians of biomedical devices and supplies proved to be an essential component of the health care team during COVID-19 surges, because they oversee the procurement, maintenance, handling, repair, safety, and preparation of key resources, including but not limited to medical oxygen. A critical lesson from the pandemic is that the mere presence of oxygen in a hospital does not translate inherently into oxygen availability at the point of care with patients (Graham et al. 2025). The expertise of biomedical engineers extends to oxygen-related technologies, such as oxygen delivery devices (for example, nasal cannula, noninvasive ventilatory support machines, and ventilators), oxygen storage devices and safety protocols, oxygen concentrators, and pulse oximetry. Given the obvious need to deliver oxygen across multiple platforms and settings, biomedical engineers are essential members of the pandemic treatment team. In fact, biomedical engineers play key roles in numerous hospital processes—such as sterile processing of biomedical instruments, maintenance of hospital technology, and blood banks—highlighting the importance of such personnel whether or not future pandemics are linked to respiratory collapse.

Investments in Essential ECSC Interventions at the District Hospital Level

Despite the necessity of investing in core ECSC capacities in district hospitals in LMICs, advanced critical care capacity in many of those countries is restricted to centrally located tertiary centers that become easily overwhelmed during surges. In order to provide rapid, local access at the population level and avoid overcrowding of tertiary facilities, countries can explore strategies to decentralize some care to district hospitals (table 12.2). Ideally, basic management available at the district hospital level includes treatment of shock and acute respiratory failure with intravenous fluids, blood product transfusions, norepinephrine, antibiotics, intramuscular epinephrine, supplemental oxygen, suction, and noninvasive ventilatory support, including anesthesia. In select district hospitals, elements of advanced critical and surgical care capacities—such as acute respiratory distress syndrome, surgical airway, gastrostomy tubes, central catheters, sedation, anesthesia, and analgesia—may also be decentralized. To preserve capacity at the district hospitals themselves, various countries expanded access to supplemental oxygen at home (Haldane et al. 2021; WHO 2020b). When patients require higher levels of care (such as for kidney failure or to undergo extracorporeal membrane oxygenation), urgent referrals and transfer to tertiary centers should be expedited. Of note, pathogen-directed treatments (such as antivirals) may be implementable across multiple levels of care but should be rigorously studied in real time within acute care settings with necessary regulatory oversite for appropriate allocation of resources but sufficient flexibility and adaptability for surge conditions.

Management of Supply Chains

During pandemic surges, scarcity of medical technologies and supplies undermines the successful treatment of patients, calling attention to supply chain coordination at local, national, and international levels (Best and Williams 2021; Bhaskar et al. 2020; Dai et al. 2021; Miller et al. 2021; Patel et al. 2017). Critical supplies include, but are not limited to, essential medicines, vaccines, PPE, oxygen, pulse oximetry, and ventilators (Cohen and van der Meulen Rodgers 2020). As the pandemic unfolded, the world clearly did not have sufficient supplies for the demands placed on health care systems in high- and low-income settings alike (Kuppalli et al. 2021; Rowen and Laffey 2020; Sharma et al. 2020).

Strategies in supply chain management rest on the pillars of preparedness and responsiveness (Bryce et al. 2020; Day 2014; Hohenstein et al. 2015). *Preparedness* strategy occurs before a shock hits the health system and has a long-term view of solutions. These solutions may include stockpiling resources, increasing domestic production, and supporting innovations in the supply of relevant goods (Plans-Rubió 2020). *Responsiveness* strategy occurs after the crisis strikes and has a short-term view of real-time solutions. These solutions may include emergency procurement through purchase of supplies from the global market of goods or loans of supplies between facilities within a country (Adelman 2020). From a policy and health systems management perspective, countries often engage in both preparedness and responsiveness strategies simultaneously between pandemic surges (Handfield et al. 2020; Jiang, Rigobon, and Rigobon 2022).

Despite the availability of modeling exercises from systems dynamics and game theory approaches, dialing in the appropriate procurement of supplies remains a challenge in pandemic preparedness (Abedrabboh et al. 2021; FalagaraSigala et al. 2022; Gotz, Auping, and Hinrichs-Krapels 2024). For example, in considering stockpiles of PPE, anticipatory procurement can undoubtedly be cost-effective and stockpiling reduces acute deficiencies in supplies when demand increases during peak surge conditions (Dow, Lee, and Lucia 2020; Folkers 2019). Advance stockpiling, however, increases the likelihood that some supplies may expire on the shelf or go unused if the next surge is delayed or never comes. Experts in supply chain management recommend consideration of such uncertainties and discourage overreliance on a single strategy. Other uncertainties include global disruptions in transportation networks, production times, and delivery times; competition for scarce goods; variable pricing; and export restrictions. Most of these factors are outside the control of policy makers and health care administrators, but efforts should be taken to at least reduce the effect of these uncertainties on procurement of critical supplies.

The global experience with medical oxygen highlights the need to coordinate supply chains for emergency situations characterized by soaring demand (Graham, Bakare, et al. 2022; Graham, Kamuntu, et al. 2022; Graham et al. 2025; Kitutu et al. 2022). WHO's recent list of essential medicines included medical oxygen, but in the anesthesia section, which shows an underestimation of oxygen's utility during pandemics. Oxygen plays a foundational role in the treatment of COVID-19 across various stages of disease pathology, across various health care settings, and even in patients' homes. Ensuring availability of a consistent supply for patient care throughout all levels of a health care system, however, presents challenges when considering the various methods of oxygen production (liquid oxygen, pressure swing adsorption, and oxygen concentrators) and matching supply to demand. In addition to production, the transportation, storage, and delivery of oxygen require specialized equipment (such as cylinders and pipes) and experienced biomedical engineers to implement protocols safely. Globally, the supply chain of oxygen depended on limited manufacturing capacity in select countries, underscoring the need for fair market regulation, financial risk protection against catastrophic expenditures for patients, and boosting public-private collaboration for local production. The *Lancet* Commission on Medical Oxygen Security discusses these and other issues as a cautionary tale for future public health emergencies. (Graham et al. 2025; Kitutu et al. 2022).

Principles of successful supply chain management are most effective when considered as a package of interventions that are highly contextualized and systematically deployed to optimize coordination between suppliers and the health system (FalagaraSigala et al. 2022; Gotz, Auping, and Hinrichs-Krapels 2024; van Hoek 2020). First steps for stockpiling include maintaining a national database of available supplies, a crisis plan to calculate additional needs, and storing raw materials for future manufacturing. Other cost-effective tactics include dedicating storage space for PPE and combining with strategies, such as social distancing, to prolong the time between surges (Abedrabboh et al. 2021). In anticipation of the need to urgently purchase goods from the global market, a diversified supplier network can reduce reliance on single-site production and any regional or global transportation disruptions. No one-size-fits-all approach to supply chain management exists; however, by selectively adopting these measures, countries can mitigate the effects of pandemic crises.

The Need to Maintain Nonpandemic Care during Pandemic Surges

The blanket policy of suspending non-COVID-19 clinical care during surges came into question throughout the pandemic (Haldane et al. 2021; Siow et al. 2020; WHO 2020c, 2021a). During initial surges many health care systems preserved critical resources by canceling clinical services not directly related to COVID-19, including essential diagnostic and therapeutic interventions (refer to annex 12B). This strategy resulted in significant deficiencies in essential care (Caldeira et al. 2020; Schell et al. 2021). For example, patients seeking care for cancer experienced restricted access to screening, such as mammograms and colonoscopies, and vital medications, including cycles of chemotherapy (Jazieh et al. 2020; Le Bihan-Bengamin et al. 2023; Puricelli Perin et al. 2021). Cancellations of elective surgery also led to significant delays, adding an estimated 28 million surgeries to existing backlogs (COVIDSurg Collaborative 2020; Jain, Dai, and Myers 2020; Klazura et al. 2022; Park et al. 2022; Rubenstein et al. 2022; Søreide et al. 2020; Wang, Vahid, et al. 2020). WHO estimates that the pandemic disrupted health care systems so severely that 8 million excess lives were lost indirectly because of diversion of resources away from essential health services (COVID-19 Excess Mortality Collaborators 2022; Knutson et al. 2022; WHO 2022a; Woolf et al. 2020). Consequently, health system resilience literature focuses not only on absorbing shocks during health emergencies but also on maintaining continuity of high-quality care (Haldane et al. 2021; Legido-Quigley and Asgari 2018; Legido-Quigley et al. 2020). Strategies for LMICs include investing in district-level capacity to deliver essential ECSC interventions (from table 12.2) that support both pandemic response and UHC.

Fair Rationing in Pandemic Surges

Bedside clinicians in LMICs often face rationing decisions when resources for interventions are scarce. As we learned during the COVID-19 pandemic, surges exacerbate resource scarcity and require especially difficult decisions (WHO 2020f). The following principles from medical ethics can be used in tandem with cost-effectiveness evidence to ensure these decisions are made fairly. Emanuel et al. (2020) lay out several recommendations for fair rationing during pandemic surges, summarized here. Because it is possible to conceive of clinical scenarios in which the application of ethical principles fails to identify a clear choice, the process of implementing these principles should be transparent, consistent, and preferably not at bedside in order for the decision-making process to maintain its face validity with the public. Although maximizing health benefits aligns generally with the goals of utilitarianism, policy makers and administrators should adapt these principles to local values before implementing them.

First, the principle of maximizing health benefits is paramount and aligns with the goal of health economic evaluation (for example, to identify interventions with the greatest value for money). Thus, interventions that offer the greatest chance of saving lives or generating healthy life years (that is, providing treatments to those persons who have the most to gain from them) should have priority. Second, frontline health workers and caregivers should—in the event they fall ill—be given priority for interventions. Third, when multiple patients with similar prognoses require a scarce intervention, that intervention should be allocated on a random selection–based (lottery) system, rather than on a first-come, first-served basis. Fourth, people who participate in pandemic-related research studies should receive priority because of their assumption of additional risk. Fifth, the principles for rationing differ by intervention. For preventive interventions like vaccines, higher-risk groups (such as the elderly) should be prioritized because they have the most to gain from not being infected in the first place; by contrast, for curative interventions like ventilators, those with the best prognosis (such as younger individuals with no comorbidities) should be prioritized.

Finally, all patients who need a particular nonspecific intervention (such as mechanical ventilation) should be treated equally: there is no reason to prioritize these interventions for infected persons as compared to persons with other conditions (for example, acute asthma exacerbation or intraoperative respiratory support). This last recommendation is especially salient for health care systems that postponed nonemergent care for non-COVID-19 conditions and experienced excess mortality from delayed care and budget deficits because of, for example, canceled elective procedures.

Final Recommendations

The COVID-19 pandemic levied a devastating impact on health care systems worldwide. The dual strain of providing routine essential care and managing episodic pandemic surges crippled health care facilities. Successful systems-level adaptations to optimize the treatment of patients include centralized governance, supply chain management (including stockpiling critical resources), interfacility triage, workforce (re)deployment, repurposing physical infrastructure, and community engagement. Urgent investment is necessary in LMICs to support an essential package of ECSC interventions that promote preparedness for surges while bolstering capacity to achieve UHC. These interventions, including medical oxygen, are spread across the continuum of clinical care with the goal of optimizing the utility of the district hospital and avoiding clinical backlogs during surges. The clinical experience of caring for patients during the COVID-19 pandemic provides a cautionary tale of the need to develop resiliency in health care systems for future pandemics.

NOTES

1. WHO, "WHO Director-General's Opening Remarks at the Media Briefing on COVID-19—11 March 2020," https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020; refer also to WHO, "WHO COVID-19 Dashboard" (accessed June 20, 2023), https://covid19.who.int/;
2. WHO, "Initiatives: Preparedness and Resilience for Emerging Threats (PRET)" (accessed June 20, 2023), https://www.who.int/initiatives/preparedness-and-resilience-for-emerging-threats#.
3. Refer also to WHO, "Initiatives: Preparedness and Resilience for Emerging Threats (PRET)"; World Bank Group, "Health Emergency and Preparedness Response (HEPR) Umbrella Program" (accessed June 20, 2023), https://www.healthemergencies.org/.
4. WHO, "WHO COVID-19 Dashboard."
5. Refer also to American Association for Respiratory Care (AARC), "AARC University: Adult Critical Care: COVID-19: Lessons Learned" (accessed June 20, 2023), https://www.aarc.org/education/covid-19-lessons-learned/; National Health Service England, "Education and Training Framework" (accessed June 20, 2023), https://www.england.nhs.uk/coronavirus/documents/c0237-education-and-training-framework/; Open Critical Care, "Suggested COVID-19 Trainings" (accessed June 20, 2023), https://opencriticalcare.org/suggested-trainings/; Oxford Policy Management, "Designing a Learning Tool to Assess the Competencies of Public Health Managers" (accessed June 20, 2023), https://www.opml.co.uk/projects/designing-a-learning-tool-to-assess-the-competencies-of-public-health-managers.

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