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

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

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Preface

Since the early 1990s, researchers involved in the Disease Control Priorities (DCP) effort have been evaluating options to decrease disease burden in low- and middle-income countries. This working paper was developed to support the Fourth Edition of this effort. It is posted to solicit comments and feedback, and ultimately will be revised and published as part of the DCP4 series.

DCP4 will be published by the World Bank. The overall DCP4 effort is being led by Series Lead Editor Ole F. Norheim, Director of the Bergen Centre for Ethics and Priority Setting in Health, University of Bergen. Core funding is provided by the Norwegian Agency for Development Cooperation and the Norwegian Research Council.

More information on the project is available at: https://www.uib.no/en/bceps/156731/fourth-edition-disease-control-priorities-dcp-4.

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

Abstract

Iran has expanded its primary health care (PHC) network, yielding notable enhancements in health indicators. The core health services portfolio now encompasses PHC, diagnostic and speciality treatment services, and inpatient care. Challenges posed by sanctions and the COVID-19 pandemic have imposed strains on Iran's healthcare system. In response, Iran has undertaken revisions to both service packages, aiming for enhanced efficiency and equity and substantial investments in augmenting its human resources capacity. Nevertheless, the systematic incorporation of service package prioritization within Iran's health system has remained elusive, resulting in an unsustainable framework. To establish a lasting institutional foundation for these service packages, Iran must dismantle institutional obstacles and establish platforms for stakeholder engagement. Such measures will facilitate the prioritization of services, fostering improved efficiency within the health system.

Main Messages

1. While prevention is critical to success during pandemics, supportive care and targeted treatments save lives. Acute care during a pandemic involves: (a) centralized governance for supply chain management, supplemental financing, and coordination of clinical protocols; (b) locally-responsive adaptive capacity such as rapid procurement of physical infrastructure and resources through novel construction or repurposing and workforce (re)deployment; and (c) community engagement within local public health context to address unique needs.

2. Investment in LMICs must be prioritized towards a cost-effective essential package of emergency, critical, and surgical care interventions at the level of district hospitals which reinforce essential interventions of the universal health coverage compendium. A fundamental cornerstone of these interventions is oxygen.

3. Avoid disruptions in routine healthcare in accordance with models of healthcare resilience. Prepare to treat the pandemic in addition to chronic burden of disease.

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1.0 Introduction

The Clinical Challenge of COVID-19

The treatment of patients with COVID-19 posed numerous challenges for healthcare 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 surpassed 118,000 in 114 countries and claimed 4,291 lives, prompting the WHO Director General to declare a global pandemic.(WHO, WHO, WHO-DG) The spread of the virus outpaced emergency, critical, and surgical care capacity (ECSC) to anticipate and prepare for impact in real-time; precipitating an unprecedented crisis in the care of patients.(Guan et al, Huang et al, Wang et al, Zhou et al, Grasseli et al, Wu et al) 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.(Kayambankadzanja et al, Graham et al) The World Health Organization (WHO) estimates that healthcare systems were disrupted so severely by the pandemic that 8 million lives were lost indirectly due to diversion of resources away from essential (non-COVID) health services.(Knutson et al, WHO-TAG, CED, Wolf et al) As patients flooded hospitals, pandemic surges revealed weaknesses in the architecture of healthcare systems; pushing them beyond their breaking points and exacerbating existing health inequities.(El Bcheraoui et al, Siow et al) As the international community reflects on COVID-19, policymakers are eager to apply the lessons learned.(WHO-PRET)

Clinical Interventions and Systems-Level Strategy

Clinical targets are often underemphasized in discussions of pandemic preparedness.(WHA58.5, WHA74.7, WHA75.7) While 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. From a policy standpoint, prevention cannot be presented as an alternative to treatment, since 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. As the medical community adapted to successive waves of COVID variants, innovation was forced upon healthcare institutions, prompting rapid implementation in clinical care and health policy to keep up with demand for clinical services.(Haldane et al) Consider the case of India. In May 2021, India was reporting more than 400,000 new cases of COVID daily. Oxygen and 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.(Kuppali et al, LC-India) 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)

Goals and Objectives of the Current Chapter

The current chapter aims to define pandemic preparedness for acute care systems, with an emphasis on emergency, critical care, and surgical care services, to optimize the treatment of patients. In three sections this chapter discusses: (Section1) treatment narratives from five countries; (Section 2) an essential package of emergency, critical, and surgical interventions; and (Section 3) management strategies for District Hospitals in LMICs. This effort builds on the previous edition of the Disease Control Priorities, Third Edition (DCP3) where chapters on 'pandemics', 'emergency care', and 'essential surgery' outlined synergistic frameworks for implementation.(Madhav et al, Reynolds et al, Mock et al) With the unifying global experience of COVID-19 in recent memory, this chapter incorporates updated strategies through the collection of novel treatment narratives in diverse settings and also identifies a suite of essential emergency, critical care, and surgical care (ECSC) interventions for priority investment in LMICs. This package of essential pandemic interventions is cross-referenced with essential interventions of the Universal Health Coverage Compendium to accentuate the complementarity between pandemic preparedness and health systems strengthening in line with the goal of maintaining non-COVID care modalities during future pandemics.

This chapter Does NOT Cover

This chapter also dovetails with various other chapters from the current Disease Control Priorities, Fourth Edition (DCP4) which focus on non-clinical domains of the COVID-19 pandemic. These other chapters cover topics as broad as prevention, detection, biosecurity, early outbreak control, transmission reduction, immunization, financial protection, community engagement, research and development priorities, and historical lessons from past pandemics. The authors also acknowledge the ongoing Lancet Commission on Medical Oxygen Security, which will describe global oxygen need and strategies for service coverage in more detail. For these reasons, various topics salient to population health will not be covered in the current chapter despite their obvious overlap with clinical care, such as: social distancing, vaccine policy, lab testing, social determinants, community engagement, and travel quarantines, amongst others. This narrow focus on healthcare allows a more granular lens on the healthcare delivery system included in resilience frameworks.(Haldane et al, Kruk et al)

2.0 Review of Treatment Narratives in Five Countries

During surges healthcare providers and administrators adopted novel strategies across various domains and in diverse clinical settings.(Haldane et al, Siow et al, Kuppalli et al) These areas included staffing, communications, physical space, governance, financing, supply chain management, care of at-risk populations, and post-acute case management.(HHS) To better appreciate variations in COVID-19 response globally and gather qualitative information regarding adaptations in clinical care, we performed a semi-structured survey of healthcare providers from five countries to better understand the challenges and opportunities they faced in each of the aforementioned domains of patient care (see Appendix 2.4A for a description of our data collection instrument). These providers were senior individuals who had expertise in policy and management and could serve as "key informants" for their countries. We engaged experts from five countries (Brazil, China, Kenya, Mozambique, and Nepal) that represent a variety of healthcare contexts and geographies across low- and middle-income (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. Concise summaries of strategies and interventions are included for each country below in Table 2.4.1. For more detail, see Appendix 2.4B.

Table 2.4.1. Highlights from healthcare intervention narratives during the COVID-19 pandemic, by country (designated as low-income (LIC) or middle-income country (MIC)).

Brazil Perspective (MIC)

Gabriel Assis Lopes do Carmo, MD PhD[1]
[1]Serviço de Cardiologia e Cirurgia Cardiovascular, Faculdade de Medicina da Universidade Federal de Minas Gerais, Belo Horizonte, Brasil

The COVID-19 response in Brazil was primarily led by local governing bodies and individual hospital systems. The Ministry of Health assisted with designation of COVID-specific facilities and dissemination of protocols for patient care, however individual hospitals determined acceptance and transfer criteria for COVID patients, supply chain management, and implementation of strategies such as telehealth to permit continuation of routine health services. This approach, largely guided by individual hospital interest, presented challenges with uniformity of COVID-related care, variability in staffing and access to critical supplies, and inconsistencies with inter-hospital coordination, which ultimately required greater involvement from Ministry of Health as subsequent pandemic surges exacerbated these issues.

China Perspective (MIC)

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[1]Vice President and Director, Department of Pulmonary and Critical Care Medicine, China-Japan Friendship Hospital, National Clinical Research Center for Respiratory Diseases, Clinical Center for Pulmonary Infections, Capital Medical University, Beijing, China
[2]Department of Pulmonary and Critical Care Medicine, China-Japan Friendship Hospital, Beijing, China

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 triage facilities, isolation centers, and large-scale care facilities (Fangcang shelter hospitals)[1] in regions affected by the SARS-CoV-2 virus. Following the initial pandemic surge, widespread screening and contact tracing kept case volumes at a manageable level which enabled widespread vaccination prior to native infection. 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 long-term effects amidst surges.

Kenya Perspective (MIC)

Patrick Amoth, MMEd EBS[1]
[1]Director General of Health, Ministry of Health, Republic of Kenya

Kenya adopted a largely centralized approach to patient care during COVID-19, with designation of a national task force to oversee dissemination of patient care guidelines, establishment of COVID facilities, expansion of critical care units, staffing reassignment between sites, supply chain management, and more. Individual hospital needs were represented through designation of key contact personnel, who provided regular updates on staff and patient care metrics to inform regional and national surveillance strategies. This top-down approach resulted in a largely uniform pandemic response throughout Kenya.

Mozambique Perspective (LIC)

Lucia Chambal, MsC MD[1]; Matchecane Cossa MD[2]
[1]Infectious Disease Specialist, Medicine Department, Maputo Central Hospital, Maputo, Mozambique
[2]Director of National Surgery Program, Ministry of Health, Mozambique; Department of Surgery, University Eduardo Mondlane, Thoracic Surgery, Surgical Department, Maputo Central Hospital, Maputo, Mozambique

The COVID-19 response in Mozambique was directed by the Ministry of Health in response to increasing case volume. Historically, Maputo City serves as a centralized destination for specialty care and maintained this role throughout the pandemic. Initially, individual hospitals designated isolation units for triage of patients toward a single, primary referral center in Maputo City that managed all COVID cases and this response adequately met early case needs. Due to a relatively low early case volume, anticipatory planning was not undertaken to guide expansion for subsequent surges. As case volume increased exponentially with new variants, units across facilities were retrofitted and staff were reassigned to care for COVID patients. Notably, the supply of oxygen cylinders was depleted. As a result, all non-COVID care and elective surgeries were halted during surges due to lack of available staff and resources, and rapid mobilization of finances was required to expand isolation units and staffing.

Nepal Perspective (LIC)

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[2]Department of Community Medicine, Kathmandu University School of Medical Sciences, Dhulikhel, Nepal

Nepal's COVID 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: 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 example, scarcity of oxygen led to a centralized approach for designated domestic supply. This as-needed approach presented initial challenges due to lack of existing mechanisms to accommodate large-scale funding and resource diversion, yet the flexibility inherent to this strategy ultimately expedited the response to and containment of future surges through swift innovation.

Lessons Learned: General Strategies

Initial pandemic responses coordinated at the national level were most rapidly adopted and efficient. Most countries in this case series 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 and rapid containment of outbreaks. Early designation of isolation and testing centers was performed, either through creation of COVID units or distinct facilities, with varying complexity that appeared to correlate with the size of outbreak in each country.

Lessons Learned: Supply Chain Management

Supply chain deficiencies were universally experienced by responding countries, with innovative approaches adopted following initial surges. Supply chain issues were accompanied by hospital overcrowding and staff shortages as primary challenges during subsequent surges. Lack of funding strategies for pandemic-related patient care resulted in significant delays and subsequent budget deficits. Where available, accessible supplemental funding can support swift staffing changes by deploying incentives, minimizing supply chain issues, reducing burden on healthcare workers, and mitigating long-lasting financial impacts of future pandemics.

Lessons Learned: Essential Patient Care

High-risk populations received prioritization for pandemic-related care and vaccination in some contexts, but not for routine healthcare during surges. Essential, non-COVID care was largely deferred during initial surges among surveyed countries but reintroduced with later surges 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-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.

Summary of Lessons Learned

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 partnership 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 must align across the continuum of care, including post-acute care. National strategies for testing, containment, treatment, and investigation of disease outbreaks are needed in parallel to strategies that permit continuation of essential health care services.

3.0 Essential Package of Clinical Interventions during Epidemics/Pandemics

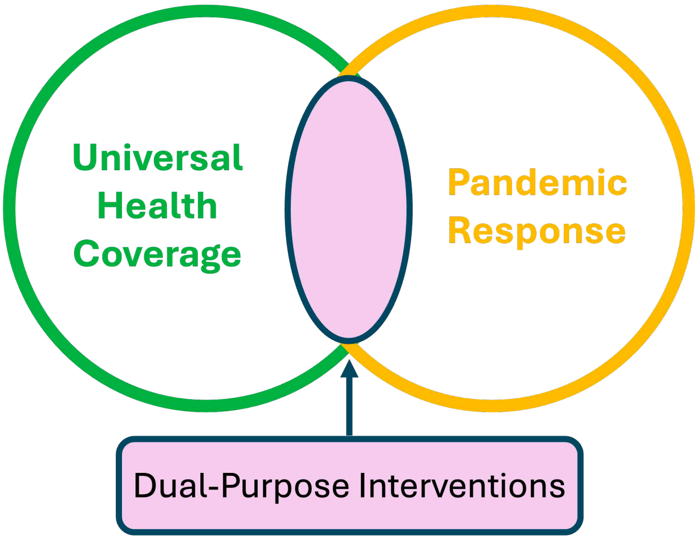
Background

The COVID-19 pandemic provides a unique opportunity to review clinical interventions that underpin the successful treatment of patients during pandemics. The DCP3 previously highlighted essential clinical interventions for emergency, critical, and surgical care to support the achievement of universal health coverage.(Madhav et al, Reynolds et al, Mock et al) However, without a focus on the unique challenges inherent to pandemic response these recommendations may not be implementable during surges. Additionally, countless clinical guidelines have become available in the scientific and gray literature regarding the clinical treatment of patients with COVID-19 and how to offset overcrowding of facilities with expertise in critical care. Momentum around these issues is evident in the World Health Assembly passing Resolution 76/2 in 2023 calling for ‘integrated emergency, critical, and operative care for universal health coverage and protection from health emergencies,’ acknowledging that “COVID-19 revealed pervasive gaps in capacity of emergency, critical, and operative care services that resulted in significant avoidable mortality and morbidity globally.”(WHA76/2)

Methodology

The current chapter presents a concise framework for strategic investments in ECSC systems to improve outcomes during epidemics/pandemics while simultaneously strengthening routine care delivery.(Table 2.4.2) Building on the previous section of treatment narratives, multiple criteria were developed to design this essential package of services. First, a list of ECSC interventions was extracted from a structured review of novel scientific research (i.e. Pubmed), gray literature, and guidance documents from the WHO and DCP3. Second, this list was vetted with international experts to define a set of essential ‘dual-purpose’ ECSC services of high priority on the basis of cost-effectiveness, feasibility, and health impact.(Figure1.1) Special consideration was 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 healthcare systems as capable of absorbing shock and adapting to dynamic situations with the ‘dual purpose’ of concurrently maintaining critical core (non-COVID) functions.(Kruk et al, UN-CEB, Nuzzo et al)

Figure 1.1. Conceptual model highlighting 'dual-purpose' interventions at the intersection between pandemic preparedness and universal health coveragae.



Findings: A Novel Framework for ECSC During Pandemics

Initial review of the literature led to a comprehensive list of discrete ECSC services that were mapped to the UHC and assigned to domains of the healthcare system according to the WHO Building Blocks framework (Appendix 2.4C).(WHO) These clinical services were later consolidated into concise thematic domains relevant to emergency, critical, and surgical care (i.e. basic and advanced diagnostic studies, basic supportive care, management of shock and respiratory failure, and basic surgical procedures). These were subsequently organized according to the broad function of disease management (i.e. diagnosis/triage, core management of critical illness, management of complications of critical illness, and systems-level interventions).

Economic evaluation of 'essential ECSC' During Pandemics

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 position of the DCP project has always been that cost-effectiveness analysis is a critical tool that becomes even more important in times and places where resources are especially scarce. We performed a structured literature review to identify economic evaluations related to treatments for pandemic infections, with a focus on viral respiratory pathogens (e.g., COVID-19, influenza) and viral hemorrhagic fevers (e.g., Ebola). Table 2.4.2 provides highlights from the five studies we identified.

Table 2.4.2. 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	1) EC 2) EC + ACC 3) Status quo	EC-Cost/DALY averted (USD, GDP per capita): 719.61, 0.35 EC+ ACC- Cost/DALY averted (USD, GDP per capita): 1711.52, 0.822 Status quo- Cost/DALY averted (USD, GDP per capita): 225.11, 0.11 ICER cost/DALY averted (Status quo-EC) (USD, GDP per capita): -23.16, -0.01 ICER cost/DALY averted (EC + ACC - EC) (USD, GDP per capita): 1378.21, 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 managment 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 2081.80 USD
Beshah et al	1) Noninvasive management 2) Invasive management	Non-invasive-ACER cost/DALY averted (USD, GDP per capita): 1991, 2.15 Invasive-ACER cost/DALY averted (USD, GDP per capita): 3998, 4.32 ICER cost/DALY averted (invasive-noninvasive): 4948, 5.35	Noninvasive management-oxygen without intubation Invasive management-intubation Location: Ethiopia, 2021 GDP per capita 925.08 USD
Cleary et al	1) GW 2) GW + ICU	ICER cost/DALY averted (GW + ICU-GW) (ZAR, USD, GDP per capita): 73091, 3835.12, 0.54	GW= general wards management only GW + ICU= general wards + ICU management Location: South Africa, 2021 GDP per capita 7055.04 USD
Risko et al	1) Constrained PPE supply/status quo 2) Investment in PPE	ICER cost/case averted (PPE investment - constrained PPE) (USD): 59 ICER cost/death averted (PPE investment - constrained PPE) (USD): 4309	Modeling study, locations considered: LMIC aggregate, East Asia & Pacific, Europe & Central Asia, Latin America & Caribbean, Middle East & North Africa, South Asia, Sub-Saharan Africa
Kazungu et al	1) Inadequate supply of PPE 2) Adequate/full PPE utilization	ICER cost/case averted (full PPE-inadequate PPE) (USD, GDP per capita): 51, 0.024 ICER cost/death averted (full PPE-inadequate PPE) (USD, GDP per capita): 3716, 1.78	Location Kenya, 2021 GDP per capita 2081.80 USD
Vandepitte et al, Systematic Review			
Sheinson et al	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) (USD, GDP per capita): 22933, 0.33 ICER cost/QALY, societal perspective (treatment-supportive care) (USD, GDP per capita): 8028, 0.11	Hospitalized patients with COVID-19 Location: United States, 2021 GDP per capita 70248.63 USD
Gandjour et al	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, USD, GDP per capita): 21958, 23558.85, 0.46	Hospitalized patients with COVID-19 Location: Germany, 2021 GDP per capita 51203.55 USD
Wilcox et al, Systematic Review			

There is a trend from more to less cost-effective as the intervention under consideration becomes more complex and resource-intensive and uses higher-priced commodities and/or more skilled labor. For example, two studies that looked at investment in personal protective equipment (PPE) supply both found that these investments would be very cost-effective, as they would prevent many healthcare-associated infections and deaths; these findings would be applicable across a range of LMIC contexts.(Risko et al, Kazungu et al) A South African study looking at intensive care unit 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 healthcare system.(Cleary et al) However, while neither non-invasive management nor invasive management of COVID-19 were 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, Kairu et al)

The study from Kenya provides a few additional insights into the spectrum of cost-effectiveness findings. They 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 than the status quo (i.e., it was cost-saving); 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, we conclude 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 basic hospital infection control procedures, oxygen infrastructure, and maintain adequate supplies of PPE to reduce harm to patients (with or without pandemic infection) and health workers.

Table 2.4.3. Essential ECSC interventions from the Universal Health Coverage Compendium relevant to pandemics.

<table>
<tr><th></th><th>Primary Health Center</th><th>First Level Hospital</th><th>Second/Third Level Hospital</th><th>Post-Discharge</th></tr>
<tr><td rowspan="6">Diagnosis/Triage</td><td colspan="4">Basic Life Support (BLS)</td></tr>
<tr><td><----- surge</td><td colspan="2">Advanced Cardiac Life Support (ACLS)</td><td></td></tr>
<tr><td><----- surge</td><td colspan="2">Monitoring, identification, and triage of patients with clinical deterioration</td><td></td></tr>
<tr><td></td><td colspan="2">Basic supportive care of patients requiring hospitalization and management of complications of inpatient hospitalization (ex. electrolyte repletion, insulin, anticoagulation)</td><td></td></tr>
<tr><td></td><td colspan="2">Basic diagnostic studies including laboratory, pathology, and imaging studies (ex. POC to tier 2 labs, X-ray, ultrasound, EKG)</td><td></td></tr>
<tr><td></td><td></td><td>Advanced diagnostic studies (laboratory, pathology, and imaging studies including Tier 3 labs, CT, MRI)</td><td></td></tr>
<tr><td rowspan="4">Core Management of Critical Illness</td><td><----- surge</td><td colspan="2">Basic support for acute respiratory failure with supplemental oxygen, suction, and non-invasive ventilatory support as needed</td><td></td></tr>
<tr><td></td><td colspan="2">Basic management of shock according to etiology with basic hemodynamic support (ex. IV fluids, blood product transfusions, norepinephrine) and basic interventions (ex. antibiotics, IM epinephrine)</td><td></td></tr>
<tr><td></td><td><----- surge</td><td>Advanced management of shock with hemodynamic support and etiology-specific interventions (ex. central catheters, multiple pressors, thrombolytics, inotropy)</td><td></td></tr>
<tr><td></td><td><----- surge</td><td>Advanced support for acute respiratory failure with advanced ventilatory support as needed (ex. mechanical ventilation for ARDS, surgical airway, gastrostomy tubes)</td><td></td></tr>
<tr><td rowspan="4">Management of Complications of Critical Illness</td><td></td><td colspan="2">Management of pain, distress, and other symptoms (ex. sedation, analgesia, agitation management)</td><td></td></tr>
<tr><td></td><td colspan="2">Basic surgical procedures (ex. thoracostomy tube, laparotomy, amputation, wound care/coverage)</td><td></td></tr>
<tr><td></td><td></td><td>Specialized interventions for organ failure (ex. renal replacement therapy for acute kidney failure and Extra-Corporeal Membrane Oxygenation, including central catheters/cannulations)</td><td></td></tr>
<tr><td></td><td colspan="3">Rehabilitation services to address complications of severe illness and assist with recovery to baseline (ex. PT, OT, SLP, discharge options)</td></tr>
<tr><td rowspan="3">Systems-Level Interventions</td><td colspan="4">Flexible workforce that can be repurposed to meet surge capacity</td></tr>
<tr><td colspan="4">Supply chain reforms to ensure surge capacity for key commodities</td></tr>
<tr><td colspan="4">Ensure adequate supply of PPE in surges</td></tr>
</table>

*Citations: Thomas et al, Chen et al, Chmielewska et al, Watkins et al, Sheth et al, Albutt et al, Betrini et al, Aljishi et al, Maximous et al, Wong et al, Zahedi et al, Palazzuoli et al, Biswas et al, Schell et al, Zainab et al, Festic et al, Budinger et al, AMCP et al, Mohapatra et al, vonZweck et al, Santana et al, WHO UHC, Inglis et al, Kassirian et al.
**Abbreviations: POC = point of care, EKG = electrocardiogram, CT = computed tomography, MRI = magnetic resonance imaging, ARDS = acute respiratory distress syndrome, IV = intravenous, PT = physical therapy, OT = occupational therapy, SLP = speech language pathology, PPE = personal protective equipment.

4.0 Implementation and Management at the District-level Healthcare Systems

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

Adaptations in Infrastructure: Physical Space

Pandemic surges often require rapid adaptation in local healthcare infrastructure. Narratives from Section 1 were consistent with the literature that it is critical to secure adequate physical space for clinical care of patients with COVID-19. This 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 COVID care while other facilities can be reserved for routine (non-COVID) healthcare.(Siow et al, Haldane et al, HHS) Historically, this underscores the role of pandemic emergency facilities developed by the WHO for the Ebola epidemic.(Kruk et al)

Health Workforce

In most settings, healthcare workers were at high risk for infection, creating absences of key personnel during surges when care was need most.(Bandyopadhyay et al, WHO) Successful strategies to ensure coverage of essential services in LMICs include: aggressive implementation of personalized protective equipment, realignment of duty hours to accommodate staff illness, support to avoid burnout, and incentivized reallocation. Staffing shortages at the District Hospital 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 healthcare activities; from clinical tasks (i.e. vaccination, acute stabilization, infection control, charting, ventilator management, etc) to healthcare management (i.e. provider well-being and infodemic strategy).(OCC, NHS, CDC, Oxford, CSP, AHA, AARC, WHO) During surges, medical and paramedical staff may cover functions outside their stereotypical job description (i.e. medical assistant, surgeon, nurse, anesthesiologist, etc) in order to avoid gaps in key capacities of the healthcare facility. In order to accomplish continuity, rapid dissemination of educational modules must be coordinated between medical and nursing societies, facility managers, local/regional centers for disease control, and Ministry of Health leadership.

Biomedical engineers 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 healthcare team during COVID-19 surges. 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 COVID-19 pandemic is that the mere presence of oxygen does not translate inherently into oxygen availability at the point of care with patients. The expertise expertise of biomedical engineers extends to oxygen-related technologies, such as oxygen delivery devices (i.e. nasal cannula, noninvasive ventilatory support machines, ventilators), oxygen storage devices and 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.

Investments in Essential Interventions at the District Hospital

Investing in core capacities in ECSC at District Hospitals in LMICs will be necessary. Unfortunately, advanced critical care capacity in many LMICs is restricted to centrally-located tertiary centers which become easily overwhelmed during surges. In order to provide rapid, local access at a population level and avoid overcrowding of tertiary facilities countries can explore strategies to decentralize some care to District hospitals.(Table 2.4.2) Ideally, basic management available at the District hospital includes shock and acute respiratory failure include IV fluids, blood product transfusions, norepinephrine, antibiotics, intramuscular epinephrine, supplemental oxygen, suction, and non-invasive ventilatory support. At select District hospitals, elements of advanced critical and surgical care capacities may also be decentralized, such as: ARDS, surgical airway, gastrostomy tubes, central catheters, sedation, analgesia, etc. In order to preserve capacity at the District hospitals themselves, various countries expanded access to supplemental oxygen at home.(Haldane et al) When patients require higher levels of care (i.e. kidney failure, ECMO), urgent referrals and transfer to tertiary centers should be expedited.

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. Critical supplies include but are not limited to: essential medicines, vaccines, PPE, oxygen, pulse oximetry, and ventilators. Some countries with previous epidemic/pandemic experience maintained stockpiles of critical supplies; but many experienced severe shortages.(Kuppali et al) The global experience with medical oxygen is instructive of the need to coordinate supply chains for emergency situations characterized by soaring demand.(Kitutu et al) It was recently included in the WHOs list of essential medicines, but appeared in the anesthesia section, which underestimates its utility during pandemics. Oxygen plays a foundational role in the treatment of COVID-19 across various stages of disease pathology, across various healthcare settings, and even in patient’s homes. However, ensuring a consistent supply is available for patient care throughout all levels of a healthcare system is challenging when considering the various methods of oxygen production (liquid oxygen, pressure swing adsorption, oxygen concentrators) and matching it to demand. In addition to production, the transportation, storage, and delivery of oxygen require specialized equipment (i.e. cylinders, pipes) and experienced biomedical engineers to implement protocols safely. Globally, the supply chain of oxygen was dependent on limited manufacturing capacity in select countries; underscoring the need for fair market regulation, financial risk protection against catastrophic expenditures for patients, and to boost public-private collaboration for local production. These and other issues are discussed in the Lancet Commission on Medical Oxygen Security as a cautionary tale for future public health emergencies.(Kitutu et al)

The Need to Maintain non-COVID Care During Pandemic Surges

The blanket policy of suspending non-COVID clinical care during surges came under question throughout the pandemic.(Siow et al, Haldane et al) During initial surges many healthcare systems preserved critical resources by cancelling clinical services not directly related to COVID-19, including essential diagnostic and therapeutic interventions.(See Appendix 2.4B) This strategy resulted in significant deficiencies in essential care.(BMJ, Caldeira et al) For example, patients seeking care for cancer experienced restricted access to screening (ie mammogram, colonoscopy) and vital medications (including cycles of chemotherapy).(Jazieh et al, Puricelli et al, Le-Bihan et al) Cancellations of elective surgery also led to significant delays, adding an estimated 28 million surgeries to already-existing backlogs.(Park et al, Klazura et al, Jain et al, Wang et al, Soreide et al, Rubenstein et al, COVIDSurg) The WHO estimates that healthcare systems were disrupted so severely by the pandemic that 8 million excess lives were lost indirectly due to diversion of resources away from essential health services.(Knutson et al, WHO-TAG, CEM, Wolf et al) For these reasons, 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, Legido-Quigley et al, Legido-Quigley et al) Strategies for LMICs include investment in District-level capacity to deliver essential interventions from Table 2.4.2 which support pandemic response and universal health coverage.

Fair Rationing in Pandemic Surges

Bedside clinicians in LMICs are often faced with 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) Principles from medical ethics can be used in tandem with cost-effectiveness evidence to ensure these decisions are made fairly. Emanuel and colleagues laid out several recommendations for fair rationing during pandemic surges, which we summarize here.(Emanuel et al)

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

Finally, all patients who need a particular nonspecific intervention (e.g., mechanical ventilation) should be treated equally: there is no reason to prioritize these interventions for infected persons as compared to persons with other conditions (in the example above: acute asthma, intraoperative respiratory support). This last recommendation is especially salient for healthcare systems that postpone non-emergent care for non-COVID-19 conditions and experienced excess mortality from delayed care and budget deficits from cancelled elective procedures (for example).

5.0 Final Recommendations

The COVID-19 pandemic levied a devastating impact on healthcare systems worldwide. Healthcare facilities were crippled under the dual strain of providing routine essential care in addition to managing episodic pandemic surges. 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 emergency, critical, and surgical care interventions which promote preparedness for surges while simultaneously bolstering capacity to achieve universal health coverage. 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 provide a cautionary tale of the need to develop resiliency in healthcare systems.

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Appendices

Appendix 2.4A. Domains of health care included in semi-structured questionnaire, defined.

Domain	Brief Description
Clinical Site Selection	*Discuss any designation for a particular facility as a "COVID facility" or unit as a "COVID unit", including criteria for designation, timing, epidemiology, resources, retrofitting, expertise, etc.*
Communications	*Describe intra-facility, interfacility, and external communication channels that were created (between healthcare systems, facilities, staff, providers, patients, media, general populations, etc.)*
Coordination of Care / Governance	*Describe intrasystem coordination (across sites) or intersystem coordination (across regions/systems), including patient evaluations, transfer/acceptance criteria, etc., and any emergency operations, task forces, or incident command systems implemented*
Equipment and Supplies	*Discuss changes to supply chain management, rationing, utilization of supplies or equipment (oxygen, personal protective equipment, vaccines, ventilators, medications, etc.). Which equipment and supplies were readily available, and which were not?*
Financing	*Describe any emergency or catastrophic funding mechanisms implemented to support healthcare delivery during pandemic surges. What financial challenges were faced by your healthcare facility or system, and what was the response (effective or not)?*
Maintaining Core Functions	*Describe how core components of patient care were maintained, and which modifications were required (such as utilization of telehealth, reassigning clinical space or facilities to COVID-19 treatment or triage areas, deferred operative cases or clinic visits, etc.)*
Post-Acute Case Management	*Describe case management beyond the acute hospitalization including transition to long-term facilities and/or challenges with disposition from hospital, management of "long-COVID", etc.*
Special Patient Populations	*Describe special considerations taken for certain at-risk patient populations (children, elderly, immunocompromised, pregnant, etc.)*
Staff	*Discuss task-sharing, recruitment, training, and transfers among staff members at various levels of care (administrative, clerical, clinical, etc.), and any efforts to prevent provider burnout*

Appendix 2.4B. Detailed responses to semi-structured questionnaire on domains of patient care during COVID-19, by country.

Domain	Brazil	China	Kenya	Mozambique	Nepal
Clinical Site Selection	The Ministry of Health oversaw creation of COVID-specific facilities and hospital units, with support from individual hospitals and local administrators guided by local interests.	Drawing from the prior SARS-1 pandemic in 2013, China has maintained Fever Clinics as screening and isolation centers for seasonal influenza outbreaks. These centers, isolated from main hospital campuses to reduce risk of transmission, were rapidly designated as primary triage sites for suspected COVID cases based on commonly reported symptoms. Early in the pandemic, China adopted a novel strategy to permit rapid expansion of treatment facilities through development of Fangcang shelter hospitals, which were large-scale public venues temporarily converted to healthcare facilities to serve as isolation and treatment centers for patients with mild to moderate illness. All patients requiring higher level of care were admitted to designated hospitals. This initial response permitted rapid control of COVID cases with the initial pandemic surge. Initially, laboratory testing was performed at a central facility and later on, laboratory personnel were dispatched to various regions to strengthen the local capacity for nucleic acid amplification testing.	At the direction of the national governing body, COVID facilities were established within each county. In response to surges, critical care units were expanded and staff were reassigned from other sites or units to fill gaps at designated COVID facilities.	Upon declaration of the pandemic, the Ministry of Health designated a single hospital in Maputo City as the primary referral hospital for all COVID patients in the province. All other health facilities in the province designated a single isolation unit with assigned staff and retrofitted units with oxygen cylinders for symptomatic patients awaiting results of laboratory testing prior to transfer to this central hospital. Maputo Central Hospital remained the country's main referral hospital for non-COVID cases. With initial surges, this system adequately met case needs (n=16). In early 2021 with the emergence of the Delta variant, increased travel resulted in the first major surge in Mozambique and required conversion of multiple hospital units and hired tents to expand isolation unit availability 10-fold. Non-COVID patients in these converted units were distributed to other departments. A designated COVID treatment facility was identified in a major city within each of the 11 provinces. Patient triage transitioned from isolation units within hospitals to physically separated triage units near designated COVID treatment facilities. All COVID tests for the country were performed at a single laboratory and patients remained in isolation units during the 3-5 day turnaround for results.	Immediately designated a primary hospital as an isolation center for case management, and secondary hospitals for ongoing non-COVID related care. Clinical management guidelines were prepared at the national level with support of WHO, Nepal. As case numbers increased, additional public and private hospitals were designated as isolation centers to accommodate surges. Within hospitals, a color-coding system was implemented to differentiate isolation levels based on risk of transmission. In some provinces, secular facilities (e.g. vacant factory spaces) were converted to COVID treatment hospitals capable of acute and intensive care. Existing emergency and intensive care units were retrofitted to include negative pressure systems. Additional COVID care centers were created exclusively for intensive care-level infected patients. Testing facilities were expanded from a single, central laboratory to include public and private laboratories in all provinces to expedite early diagnosis by the second pandemic surge.

Coordination of Care / Governance	Individual hospitals were primarily responsible for overseeing core functions with support from local government. Specifically, acceptance and patient transfer criteria was defined by local health agencies and required adaptation from hospital to hospital. Intersystem coordination was supported by State and Local Health Secretaries.	During the initial COVID outbreak in Wuhan, hospitals experienced severe shortages of resources and medical staff, particularly those with critical care expertise. National medical teams with necessary expertise were rallied from around the country and dispatched to Wuhan. With subsequent surges, a similar approach was taken to accommodate increasing case volume across different regions.	A COVID-19 national task force was established for case management with responsibility for developing and updating guidelines and training healthcare workers. County health directors oversaw coordination of treatment centers.	Care coordination in Mozambique presents a unique challenge as patients self-triage and present either to the nearest facility according to convenience or travel further to Maputo Central Hospital to seek higher level of care. Hospitals adopted a reflexive approach as cases arrived and admitted all patients awaiting transfer to the primary referral hospital. Individual provinces and Maputo City held regular coordination meetings with key players, and the Ministry of Health also provided platforms to facilitate coordination across provinces, facilities, and providers seeking both clinical and material support.	Federal and provincial governing bodies oversaw development of health care policies and guidelines, while local governing bodies oversaw implementation of guidelines. Early in the pandemic, the federal government activated national committees with key players to coordinate the initial response mechanism in a centralized, top-down manner. Provinces established isolation and testing centers, managed medications, and other essential services. Local governments managed isolation centers and provided services with minimal deviation. Incident command system was developed and modified according to evolving needs during pandemic surges.

Equipment and Supplies	Supply chain issues were prevalent during the initial COVID surge due to lack of regulation at the national or local level. To mitigate early challenges, hospitals worked in partnership with one another to lend critical supplies and equipment. As critical PPE and medications became unavailable, Ministry of Health and local agencies stepped in to implement supply chain management guidelines.		Supply chain management was coordinated at the national level as an arm of the COVID-19 national taskforce.	Initially, COVID numbers remained relatively low and available equipment (PPE, oxygen tanks, etc.) were sufficient. With the arrival of the 2021 Delta variant, the massive surge in case volume resulted in a sudden deficit in oxygen cylinders, ventilators, blood gas analyzers, radiography equipment, PPE, and more. The Ministry of Health sponsored purchase of additional oxygen cylinders and supplies to retrofit isolation beds.	Incident command system performed daily reviews of supply chain, with coordination from designated individuals at the government and facility levels. During supply chain interruptions, novel sterilization approaches (UV ray) and alternative materials were used to permit recycling of PPE. Where possible, hospitals produced their own PPE to ameliorate shortages. Supply chain issues (PPE, essential equipment) were prevalent during initial surge. With subsequent surges, a COVID relief fund was allocated from national and provincial budgets to maintain necessary resources. Simultaneously, PPE and essential equipment was stockpiled after the initial surge. In the second surge, oxygen availability was compromised and required development of oxygen plants in designated spaces yet lack of necessary human resources impeded these efforts.
Post-Acute Case Management	Post-acute care facilities were not created in most cities. Patients with "Long COVID" were managed in existing long-term care facilities with sparse and isolated efforts to implement dedicated programs to care for this subset of patients.	A patient cohort for initial COVID survivors with matched community controls was established and followed for 3 years to present. These patients completed symptom questionnaires, imaging (chest computed tomography), and pulmonary function testing to generate long-term follow-up data on post-COVID conditions.	Hospital-based care was adopted for mild and moderate cases of COVID, as well as management of patients with "Long COVID" who were the discharged to home after post-acute management.		After the second COVID surge, guidelines were developed in collaboration with international organizations for the treatment of "Long COVID". A transdisciplinary team was established to apply guidelines locally and develop training modules. Post-COVID clinics were established but remain inefficient due to lack of human resources and registries to effectively identify and monitor cases.

Special Patient Populations			High-risk groups such as pregnant women, immunocompromised, and elderly received priority immunization status.	Most patients hospitalized with COVID carried comorbidities such as diabetes, hypertension, COPD, asthma, and HIV/AIDS. Due to the unique medical needs of these populations, specialized staff from all units were reassigned to COVID treatment units and an independent pharmacy was designated for COVID patients.	At-risk populations such as pregnant women, immunocompromised, and those with chronic diseases received priority COVID care based on case severity. Similarly, these groups received priority access to vaccination. However, these populations also experienced significant delays in routine care due to fear of contracting COVID. As a result, there was an increase in number of home deliveries, neonatal deaths, and immunization drop-out rate among children. During the second wave, improved access to telemedicine services resulted in fewer delays in care for these special populations.
Maintaining Core Functions	Telehealth care, previously not permitted in the country, was implemented at several institutions to provide routine health services. During peak surges, elective surgeries were deferred in several cities, particularly were ICU bed shortages required conversion of operating theatres. However, where possible, core functions were maintained in parallel to COVID care.	From the initial pandemic surge, a "dynamic-zero" policy was adopted to permit continuation of routine medical care in regions unaffected by COVID-19. Large-scale nucleic acid amplification testing was carried out to screen for new cases and extensive contact tracing followed to identify potential new cases. As a result of these strategies, the number of confirmed COVID cases remained low prior to December 2022 and a majority of citizens were able to obtain full vaccination with booster(s) prior to natural infection.	At the national level, the Ministry of Health developed guidelines specific to continuity of essential health services to mitigate disruption of critical, non-COVID health services.	During COVID surges, the majority of planned, non-COVID care (excluding existing inpatient cases) was deferred. All elective surgery was cancelled and emergent or oncologic surgeries were handled on a case-by-case basis at the discretion of the operating surgeon. Two phenomena were noted, including a reluctance of patients to seek care due to fear of contracting the virus, and a deficiency of providers due to reassignment to COVID treatment centers or personal illness. To support resumption of non-COVID care, telehealth visits were implemented and allowed providers to triage in person visits on an as-needed basis. Patients with chronic conditions on stable home medication regimens were able to bypass routine physician visits and access prescriptions directly or received several months' supply of medications at once.	Due to designation of hospitals as isolation centers and prioritization of COVID care, routine services such as outpatient and elective care, including surgeries, were placed on hold. Routine care was managed by hospitals and emergency departments where necessary. This led to significant financial implications for private sectors. With subsequent surges, comprehensive services were provided in parallel to COVID-specific services at the outpatient and inpatient level, including resumption of elective surgery.

Health Workforce	Staffing decisions were made at the individual hospital level. Burnout was prevalent. To address the issue of burnout, task sharing was implemented to recruit medical doctors from other specialties to high census areas (where technically suited) or reassign to clerical or administrative roles to support ongoing COVID-related care efforts.		The national government, with support from the COVID-19 Health Emergency Response Project (CHERP), oversaw reassignment of surge staff across counties to maintain key staffing positions.	A team of local clinicians (8), nurses (10), and reassigned auxiliary personnel were assigned to the primary COVID referral hospital during the initial surge. With a rapid increase in case numbers during the 2021 Delta surge, massive expansion in staffing was achieved through mass hiring of general clinicians (58), nurses (108), auxiliary agents (48), drivers (4) and lab technicians (4), as well as seeking expertise from the Cuba Cooperation (3 intensivists, 3 intensive care nurses). Additional, essential staff were serially recruited from all subspecialty units in the hospital, including medical and surgical residents. During this surge, all reassigned personnel ceased non-COVID related care and training.	Significant staffing shortages were experienced at the provincial and local hospital level. At the local level and with local funding incentives (communication allowance, hazard pay), temporary recruitment of healthcare workers was employed to fill gaps in coverage. At the same time, staff in private sectors experienced salary deductions as routine services were halted. Burnout was widespread due to task sharing (posting of medical doctors to COVID units irrespective of expertise, administrators assigned to multiple roles). To minimize exposure and burnout, staff were posted to COVID units on a rotating basis (2-week posts) during subsequent surges.

Communications	A centralized, national agency disseminated protocols related to patient care which were then implemented at the state and local level. Intra-facility communication occurred largely remotely (email, telephone, teleconferencing). University hospitals developed technology to support telehealth initiatives for initial consultation and routine follow-up care.		A designated contact at each COVID facility provided regular updates on hospital admissions, discharges, and deaths to county health directors and disease surveillance coordinators. These data were summarized in county-level line lists, which then informed national case lists.	Initially, triage hospitals reported COVID cases to the primary referral hospital via telephone and arranged transfer via ambulance upon acceptance. Within facilities, daily meetings occurred to review case numbers, new admissions, transfers, discharges, and deaths. These metrics were summarized in daily and weekly reports that were shared with the Ministry of Health. Hospitals closed to visitors and all communication surrounding patient care occurred via twice daily telephone calls from providers.	A national coordination committee was immediately formed and oversaw development of an Incident Command Center and Health Emergency Operation Center. The committee was responsible for activation of isolation centers, defining periods of lockdown, and communicating hospital and facility-level data to the national government and media. Weekly cluster meetings were held between incident command representatives and public, private, and federal health officials to update on current situations, management protocols, case investigation and contact tracing. Poor internet connectivity hindered online reporting of case data. Government-level, daily press briefings were held to support public awareness. Information was made readily available to the public via mobile applications, call centers, hotlines and social media.
Financing	The Ministry of Health, supported by state and local agencies, redistributed budgets to increase the value paid by the Public Health System for COVID-related care. Health insurance companies also incentivized COVID care by increasing the value of reimbursements. Salary incentives were implemented for certain members of the workforce (i.e. trainees) for providing COVID care.		Funding was mobilized and distributed from the national government to county and local governments.		COVID crisis funds were established at the local level with budgets provided by provincial and federal governments via diversion from lower-priority sectors. Funds were distributed by local governments toward COVID management on an as-needed basis. The majority of funding was diverted toward supply chain management during initial surges and occasionally required extreme measures such as reduction in staff salary with delayed and incomplete reimbursement. Supply chain issues arose in part due to delays in budget release and lack of expenditure guidelines.

Appendix 2.4C. Comprehensive normative literature review of healthcare interventions during COVID-19 pandemic.

	At Home	Ambulatory Services	Clinic	Emergency Department	Acute Care Services	ICU	Reference
Diagnostic		**Basic Lab Testing** FLH18, RH3					FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Diagnostic				**Advanced Lab Testing** HC68, FLH18, FLH58			HC68 (Health center pathology services) FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 58 (First-level hospital pathology services)
Diagnostic	**POC Testing**						
Diagnostic		**CT Scan** FLH18, RH3		**CT Scan** FLH18, RH3			FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)

Diagnostic		**Ultrasound/POCUS** FLH18	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock)
Diagnostic		**MRI** FLH18, RH3	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Diagnostic	**X-ray**	**X-ray**	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Diagnostic	**Vital Sign Monitoring**	**Vital Sign Monitoring**	
Diagnostic		**EKG**	
Procedure/ Diagnostic		**Thoracentesis-Diagnostic, Therapeutic** FLH18, RH3	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)

Therapeutic	**Supplemental Oxygen***	**Supplemental Oxygen** FLH 22, FLH 18, FLH 45	FLH22 (Management of acute exacerbations of asthma and COPD using systemic steroids, inhaled beta-agonists, and, if indicated, oral antibiotics and oxygen therapy) FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway) *Herwerden et al
Therapeutic		**PO/IV Electrolyte Supplementation** FLH23, FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway) FLH23 (Medical Management of acute heart failure)
Therapeutic		**IV Fluids** FLH11, FLH 18, FLH 45, RH3	FLH11 (Full supportive care for severe childhood infections with danger signs) FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)

Therapeutic		**IV Corticosteroids** FLH18, RH3		FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Therapeutic			**IV vasopressors*** FLH18, FLH45	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory) Maximous et al.
Therapeutic	**PO diuretics** HC44	**PO/IV diuretics** HC44, FLH23		HC44 (Medical management of heart failure with diuretics, betablockers, ACEi, and mineralocorticoid antagonists) FLH23 (Medical management of acute heart failure)

Therapeutic	**PO antibiotics** FC1, FLH22	**PO/IV antibiotics** HC1, FLH18, FLH22, RH3	HC1 (Early detection and treatment of neonatal pneumonia with oral antibiotics) FLH 22 (Management of acute exacerbations of asthma and COPD using systemic steroids, inhaled beta-agonists, and, if indicated, oral antibiotics and oxygen therapy) FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Therapeutic	**PO analgesics** HC47	**PO/IV analgesics** HC47, HC67	HC47 (Essential palliative care and pain control measures, including oral immediate release morphine and medicines for associated symptoms) HC67 (Expanded palliative care and pain control measures, including prevention and relief of all physical and psychological symptoms of suffering)
Therapeutic		**Thrombolytics**	
Therapeutic		**IV/SubQ anticoagulants**	
Therapeutic		**Blood and blood product transfusion** FLH18	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock)
Therapeutic	**Agitation/anxiety***		*Wong et al
Therapeutic	**Inhaled/Nebulized Beta Agonists/Bronchodilators** HC37, FLH22		HC37 (Low-dose inhaled corticosteroids and bronchodilators for asthma and for selected patients with COPD) FLH 22 (Management of acute exacerbations of asthma and COPD using systemic steroids, inhaled beta-agonists, and, if indicated, oral antibiotics and oxygen therapy)

Therapeutic	**Insulin* (SubQ, IV)**				*Zahedi et al.
Therapeutic		**IV inotropes*** FLH18, FLH45		**IV inotropes*** FLH18, FLH45	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway) *Maximous et al
Therapeutic		**IV chronotropes** FLH 18, FLH45			FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Therapeutic				**ECMO* (including cannulation)** FLH18	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) *Aljishi et al
Therapeutic	**Oral Antivirals** P9, HC34, FLH18, RH3				P9 (Decentralize stocks of antiviral medications in order to reach at-risk groups and disadvantaged populations) HC34 (Stockpile and consider treating early high-risk patients with antiviral medications according to nationally endorsed guidelines) FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)

Therapeutic		**IV monoclonal antibodies** FLH 18	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock)
Therapeutic	**Temp management (ex. PO antipyretics, ice packs)** FLH18, FLH57, RH3	**Temp management (pharm/non-pharm; ex. PO/IV antipyretics, cooling/warming devices)** FLH18, FLH57, RH3	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH57 (Prevention and relief of refractory suffering and acute pain related to surgery, serious injury, or other serious, complex, or life-limiting health problems) RH3 (Management of refractory febrile illness including etiologic diagnosis at reference microbiological laboratory)
Therapeutic	**Rehabilitation Therapies: Speech Language, Physical, Occupational, Cardio/Pulmonary Rehab Programs** C52, C58, C59, FLH53, FLH55, FLH56		C52 (Cardiac and pulmonary rehabilitation programs) C58 (Training and retraining for disorders of speech, swallowing, communication, and cognition) C59 (Training, retraining, and exercise programs that address musculoskeletal injuries and disorders, including chronic low back and neck pain) FLH 56 (Mobilization activities following acute injury or illness) FLH 55 (Initial assessment, prescription, and provision of individualized interventions for musculoskeletal, cardiopulmonary, neurological, speech and communication, and cognitive deficits, including training in preparation for discharge) FLH 53 (Evaluation and acute management of swallowing dysfunction)
Therapeutic		**Management of ileus, bowel obstruction, GI complications** FLH24, FLH34, FLH44	FLH24 (Management of bowel obstruction) FLH34 (Colostomy) FLH44 (Repair of perforations (for example, peforated peptic ulcer, typhoid ileal perforation)

Therapeutic	**Basic Life Suppport** HC61		HC61 (Resuscitation with basic life support measures)
Therapeutic	**Labor & Delivery in COVID-19 Patients** HC2, HC3, FLH2, FLH4, FLH5, FLH6, FLH7, FLH8		HC2 (Management of miscarriage or incomplete abortion and post abortion care) HC3 (Management of preterm premature rupture of membranes, including administration of antibiotics) FLH2 (Induction of labor post-term) FLH4 (Management of eclampsia with magnesium sulfate, including initial stabilization at health centers) FLH5 (Management of maternal sepsis, including early detection at health centers) **FLH6 (Management of newborn complications, neonatal meningitis,** **and other very serious infections requiring continuous** **supportive care (such as IV fluids and oxygen))** FLH7 (Management of preterm labor with corticosteroids, including early detection at health centers) **FLH8 (Management of labor and delivery in high-risk women,** **including operative delivery (CEmNOC))**
Therapeutic		**Other Urgent/Emergent Surgical Procedures** FLH33, FLH35, FLH40, FLH48, HC59	FLH33 (Burr hole to relieve acute elevated intracranial pressure) FLH35 (Escharotomy or fasciotomy) FLH40 (Management of osteomyelitis, including surgical debridement for refractory cases) FLH48 (Trauma laparotomy) HC59 (Drainage of superficial abscess)
Therapeutic		**Wound Coverage** FLH46	FLH46 (Basic skin grafting) Surgical debridement of wounds Wound coverage
Procedure		**Tube Thoracostomy, Needle Decompression** FLH18, FLH50	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative

			measures for septic shock) FLH 50 (Tube Thoracostomy)
Procedure		**NGT/Enteral Tube Insertion**	
Procedure		**Urinary Catheter Insertion**	
Procedure		**CVC Insertion**	
Procedure		**GI Tube Placement (PEG, G-J)**	
Procedure		**Port Placement**	
Procedure		**Intraosseus Access Placement**	
Procedure/ Respiratory Support		**Surgical Airway** FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Procedure/ Respiratory Support		**Open thoracic surgical procedures for complications of pneumonia (including VATS vs sternotomy)*** FLH18, FLH45	FLH 18 (Evaluation and management of fever in clinically unstable individuals using WHO IMAI guidelines, including empiric parenteral antimicrobials and antimalarials and resuscitative measures for septic shock) FLH 45 (Resuscitation with advanced life support measures, including surgical airway) *reference for Video-assisted thoracic surgery (VATS) vs sternotomy
Respiratory Support		**Invasive Mechanical Ventilation** FLH45, RH4	FLH 45 (Resuscitation with advanced life support measures, including surgical airway) RH4 (Management of acute ventilatory failure due to acute exacerbations of asthma and COPD; in COPD use of bilevel positive airway pressure preferred)

Respiratory Support	**Endotracheal Intubation** FLH45, FLH22, RH4	FLH 45 (Resuscitation with advanced life support measures, including surgical airway) FLH 22 (Management of acute exacerbations of asthma and COPD using systemic steroids, inhaled beta-agonists, and, if indicated, oral antibiotics and oxygen therapy) RH4 (Management of acute ventilatory failure due to acute exacerbations of asthma and COPD; in COPD use of bilevel positive airway pressure preferred)
Respiratory Support	**Proning** FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Respiratory Support	**Basic Airway Management (including bag-valve-mask ventilation)** FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Cardiac Support	**CPR (chest compressions)** FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Cardiac Support	**Defibrillation-AED or otherwise** FLH45	FLH 45 (Resuscitation with advanced life support measures, including surgical airway)
Population/ Systems	**Education for danger signs** HC12, HC30, HC33	HC12 (Detection and treatment of childhood infections with danger signs (IMCI)) HC30 (Evaluation and management of fever in clinically stable individuals using WHO IMAI guidelines, with referral of unstable individuals to first-level hospital care) HC33 (Identify and refer to higher levels of health care patients with signs of progressive illness)
Population/ Systems	**Immunization** P12, HC35	P12 (Ensure influenza vaccine security at national and subnational level) HC35 (Annual flu vaccination and pneumococcal vaccine every five years for individuals with underlying lung disease)

Population/ Systems	**Counseling about handwashing with soap + WASH services** P13, C51		P13 (Mass media messages concerning awareness on handwashing and health effects of household air pollution) C51 (WASH behavior change interventions, such as community-led total sanitation)
Population/ Systems	**Isolation for high risk communicable diseases** P11		P11 (Develop plans and legal standards for curtailing interactions between infected persons and uninfected population and implement and evaluate infection control measures in health facilities
Population/ Systems	**PPE**		