



A review of COVID-19's impact on modern medical systems from a health organization management perspective

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Abstract

The novel SARS-CoV-2 (COVID-19) disrupted many facets of the healthcare industry throughout the pandemic and has likely permanently altered modern healthcare delivery. It has been shown that existing healthcare infrastructure influenced national responses to COVID-19, but the current implications and resultant sequelae of the pandemic on the organizational framework of healthcare remains largely unknown. This paper aims to review how aspects of contemporary medical systems – the physical environment of care delivery, global healthcare supply chains, workforce structures, information and communication systems, scientific collaboration, as well as policy frameworks – evolved in the initial response to the COVID-19 pandemic.

Keywords COVID-19 · Coronavirus · Pandemic · Healthcare · Infrastructure · Medical systems

1 The physical environment of healthcare delivery

A major component of modern healthcare systems that witnessed transformation during COVID-19 was the physical context – i.e., built environment – in which care was delivered. The increasing inpatient load led many facilities to redesign existing care spaces to accommodate the increased intensive care volume. Saint John's Episcopal Hospital (SJEH) of Queens, among countless other facilities, successfully converted a Post-Anesthesia Care Unit (PACU) into what was referred to as a “COVID-19 PACU ICU” [1]. In similar fashion, New York-Presbyterian Hospital/Columbia University Irving Medical Center (NYP-Columbia)

converted 23 ORs into a temporary ICU capable of holding 82 patient beds. Anesthesia machines were modified to assist in mechanical ventilation, expanding critical care capacity further. Despite caring for a large number of critically-ill COVID patients in the “ORICU”, this metropolitan hospital recorded similar survival rates that were comparable to others reported at the time [2]. These modifications, among countless others, highlight the importance of team-based medicine and infrastructural flexibility in medical systems.

To illustrate exactly *how* such timely innovation occurred during a pandemic, a group of healthcare professionals from various New York medical facilities created a stepwise process for efficient OR to ICU conversion, summarized in Fig. 1 [3]. These logistical considerations can help medical facilities timely adapt to situations requiring increased critical care capacity in the future.

Other renovation strategies illustrate how even the oldest healthcare establishments in the United States adapted in response to COVID-19. To modify facility features in response to the pandemic, Chief of Hepatology Dr. John Bucuvalas of Mt. Sinai Hospital in New York City employed the help of Model of Architecture Serving Society (MASS) design group, a nonprofit architecture organization with extensive experience in regions of the globe where infectious disease poses major design threats [4]. Cameras secured to the bodies of healthcare staff allowed the design team to visualize the hospital layout and outline recommendations for redesign. Transparent plastic sheeting was utilized as

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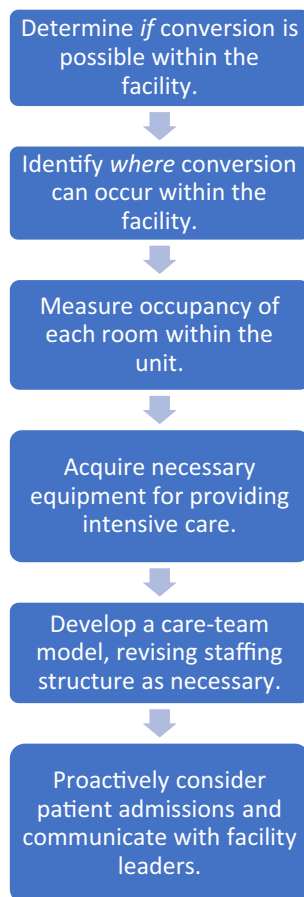


Fig. 1 Steps to Timely Adapt Infrastructure for Critical Care [3]

see-through walls that allowed staff to monitor COVID-19 patients without entering infectious units. To address ventilation challenges, high-efficiency particulate air (HEPA) filtration machines were added to over 250 existing patient rooms, converting them into negative pressure isolation rooms that prevented the spread of infectious airborne particles when doors were opened. Patient rooms, floors, and doorways were painted or taped in a color-coded fashion to provide quick visual cues to staff about risk zones and sterile zones.

Future hospital architecture considerations include modifying traditional entry patterns to minimize transmission of infectious disease; Fig. 2 illustrates an example of proposed patient flow, with arrows representing foot traffic patterns. Upon facility entry, patients form a line along social distancing floor markers, ultimately proceeding past a no-contact thermal scanner before being permitted to enter subsequent facility spaces based on individual assessment needs [5].

An international cohort study involving patients undergoing elective surgery for various types of cancer across 55 countries found that postoperative pulmonary complication rates as well as postoperative SARS-CoV-2 infection rates were lower in patients who underwent surgery within COVID-19-free surgical pathways [6]. These results suggest that hospitals can avoid preventable harm to admitted patients during future disease outbreaks by investing in dedicated infection-free surgical pathways. Furthermore, flexibility should be a top priority in the redesign of inpatient facilities to allow for rapid compartmentalization of patients, such as illustrated by the implementation of respiratory isolation

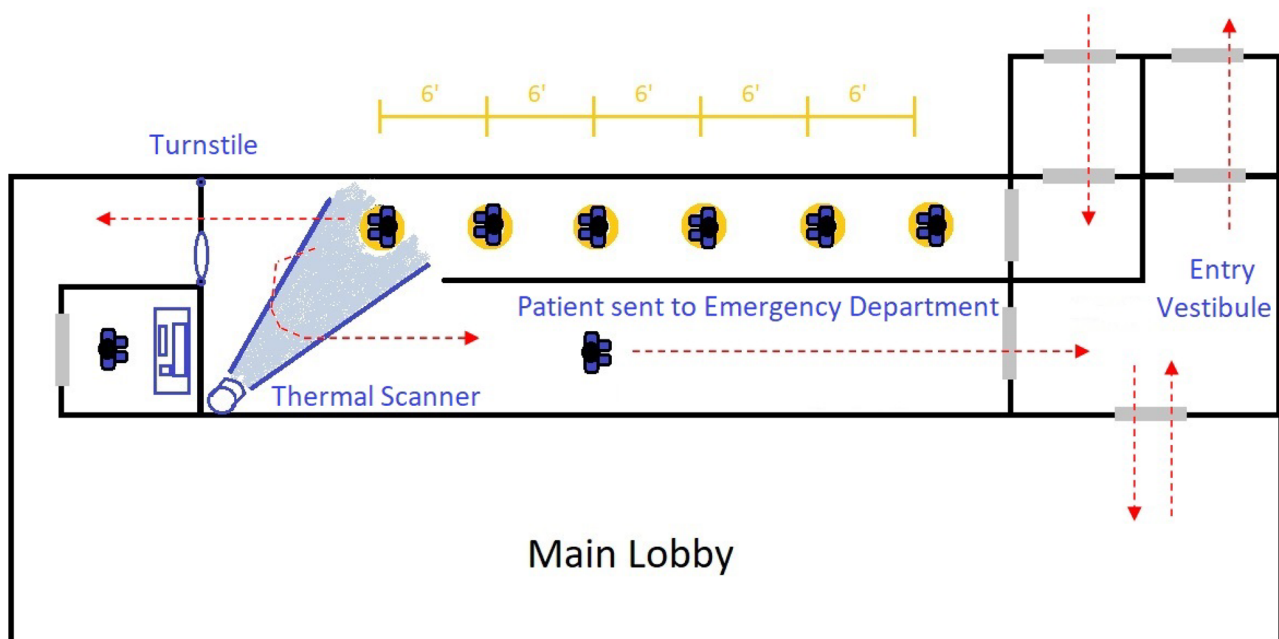


Fig. 2 Layout of socially distanced entrance with foot traffic patterns and no-contact screening [5]

units (RIUs) among various teaching hospitals in the United States as well as the patient segregation system employed by KK Women's and Children's Hospital in Singapore [7, 8]. One Florida facility currently under development is adopting this approach, engineering a 42-bed surgical unit that can be converted into separate isolation rooms in the case of a contagion crisis [9].

2 Supply chain disturbances

Global supply chain networks represent another component of medical systems that experienced strain and subsequent evolution in response to the pandemic. Pre-existing resource inequities among care facilities across the globe were exacerbated by unexpected demand surges induced by the pandemic; even the wealthiest countries were not exempt from resource scarcity [10]. In a national survey of academic medical centers within the United States in April 2020, half of all correspondents reported PPE stockpiles of two weeks or less [7]. Notably, the availability of crucial hospital resources, such as ICU beds, was found to be significantly associated with mortality rates in a given region within the United States during the initial months of the pandemic; it was estimated that one additional ICU bed per COVID case reduced a hospital's incidence rate of death by 20% [11]. According to a survey conducted by McKinsey & Company in 2020, some of the most commonly reported barriers limiting the early COVID-era surgical capacity were inpatient bed availability and COVID-19 testing capacity [12].

Other supply disruptions emerged as the pandemic strained resources necessary for appropriate handling of the deceased. After reaching morgue capacity, bodies of deceased COVID-19 patients in a Detroit medical facility were stored in empty hospital rooms [13]. Due to a lack of burial resources in Ecuador, cardboard coffins were distributed to help meet demands [14]. Importantly, it has been shown that mismanagement of mass fatality situations can have deleterious consequences on community resilience as a whole [15]. In the context of the COVID-19 pandemic, Entress et al. proposed several recommendations for nations to consider. Suggested is the immediate, universal development and adoption of mass fatality management (MFM) plans – which provide safe, alternative ways for families to grieve – as well as the stockpiling of MFM resources via increased production by the private sector [16]. For governments without existing MFM plans, organizations such as the Centers for Disease Control and Prevention (CDC) offer guidelines and templates for national, state, and local governments to employ in the development process [17].

The COVID-19 pandemic highlighted various weaknesses in the international healthcare supply chain via simultaneous output disruption along with heightened consumer demand

[18]. Transitioning towards heavier reliance on insourcing was the strategy that allowed 3 M, a multinational conglomerate company, to meet the N95 mask demand surge in the early stages of the pandemic. The company's ability to double its global production of masks in only two months stemmed largely from its sourcing of raw materials for their masks in close proximity to their manufacturing plants and consumer populations that they serve [19].

Another major healthcare supply chain management response that emerged during the pandemic was increased reliance on public–private partnerships to promote national relief efforts. Various organizations employed this strategy, establishing funds that supported federal efforts in strengthening national health capacities in response to the COVID-19 crisis [20]. Collapsing supply chains ignited a shift towards heavier reliance of national health programs on the private sector in the United States. Over the course of the pandemic, healthcare systems increasingly relied on private enterprise to meet emergency demands, remedy disruptions in supply networks, and bolster effective health resource distribution and development. As cases in the United States spiked in cities like New York, initial partnerships were reactive and philanthropic [21]. After the United States Congress passed their liability waiver on March 18, 2020, 3 M was able to adapt their respirators – initially designed for industrial use – into masks for medical use [22].

Other early adaptations to public–private partnerships included building and disseminating diagnostic test kits. On February 4, 2020, the United States Food and Drug Administration (FDA) authorized using the CDC's polymerase chain reaction (PCR) assay, thus enabling CDC-qualified laboratories to perform unprecedented levels of diagnostic testing [23]. In a report published on July 1, 2020, the United States Health and Human Services extended partnerships with national pharmacy and grocery retail chains to include community-based testing, which expanded COVID-19 testing sites to more than 600 locations [24]. In Ireland, public–private partnerships were exploited to increase access to urgent surgical care via private hospitals' leasing as part of the government's response of increasing bed capacity during SAR-CoV-2 surges [25]. Another notable partnership emerged with Operation Warp Speed (OWS). Key federal health organizations – e.g. the National Institutes of Health (NIH), CDC, FDA, and Biomedical Advanced Research and Development Authority (BARDA) – worked with major private pharmaceutical companies and invested an unprecedented \$10 billion to aid in COVID-19 vaccine development [26].

3 Staffing structure & workforce alterations

Yet another aspect of medical systems that the pandemic significantly altered was staffing frameworks. Hospitals were forced to significantly increase their patient-to-nurse

ratios due to hospital crowding and lack of resources. Investigating hospital staffing and quality of care in New York and Illinois, Lasater et al. found that most hospitals in both states were understaffed despite both states having a larger than the average number of nurses, 18.7 per 1000 population and 16.7 per 1000 population, respectively [27]. The extent of nurse understaffing was highlighted as the virus surged within the United States, which experienced an overall increase in patient-to-nurse ratios from an average of 3.3 to 9.7 in adult medical-surgical units. Safety-net hospitals across New York City, including Interfaith Medical Center in Brooklyn and New York-Presbyterian's satellite in Queens, were forced to quadruple their patient-to-nurse ratios in ICUs, which typically have standard ratios of only two patients per nurse [28]. Likewise, relaxation of state guidelines in December 2020 led many facilities across California to temporarily operate with new patient-to-nurse ratios to meet the heightened demand for care: 3:1 for ICU, 6:1 for emergency room, and 7:1 for medical-surgical units [29].

Increased reliance on contingent staffing arose out of necessity to help overwhelmed healthcare systems meet the increased demand for intensive critical care during the pandemic. The increasingly prominent role of travelling nurses and critical care physicians highlighted the value of a flexible workforce in a time of global health crisis. As different regions of the United States experienced transient surges in cases over the course of the pandemic, the demand for travel ICU nurses in that region correspondingly peaked [30]. In an October 2020 report, the British Medical Association (BMA) urged healthcare facilities to further maximize the use of retired doctors who were available to return to work to achieve necessary healthcare workforce expansion. Notably, despite 28,000 retired doctors in the United Kingdom making themselves available for work in the early stages of the pandemic, only a small fraction were ultimately deployed [31].

Shifting workforce dynamics reflect other ways in which healthcare facilities adapted to personnel shortages during the pandemic. Many medical schools – including those of Harvard, University of Massachusetts, and Boston University – gave fourth year students the opportunity to graduate early so that they could assist hospitals in patient care during the pandemic [32]. On the contrary, other adaptations, such as the implementation of RIUs to treat non-ICU COVID-19 cases in teaching hospitals across the United States, involved heavier utilization of attending physicians, lessened usage of residents, and no incorporation of students [7]. Among this network of 72 academic medical centers, most reported reduced frequency of in-room encounters across provider types collectively compared with pre-pandemic times.

Shifting workforce dynamics surfaced in other regions of the globe. In Ireland, general practitioner (GP) face-to-face consultations significantly decreased, telemedicine consultations significantly rose, and non-COVID-19-related consultations substantially dropped for certain patient cohorts including children under 6 years old and adults over 70 [33]. Moreover, role adaptations between different provider types emerged in response to increased demand for palliative and end-of-life care during the pandemic. A national survey from the United Kingdom found that the increased need to provide family support was more pronounced for nurses compared with GPs and that most nurses had conducted 'more'/'a lot more' face-to-face visits while over a third of GPs had conducted 'less'/'a lot less' face-to-face visits [34].

The numerous changes to staffing structure during the early stages of the pandemic had significant downstream consequences, with problems arising in various aspects of healthcare both directly and indirectly. Understaffing induced financial strain on healthcare systems in terms of higher staffing expenses because of heavy competition in staff wages; this problem was particularly evident for rural hospitals compared to their urban counterparts [35]. Paid incentives and bonuses were increasingly deployed by hospitals to attract health workers and hospitals increasingly hired workers from outside their regions. In a report released by consulting firm Kaufman Hall in 2021, nearly 90% of responding U.S. health systems reported having increased base salaries for healthcare personnel [36]. Various 2020 key performance indicators of U.S. Hospitals and Health Systems experienced volatility because of such workforce adaptations. Total Expense per Adjusted Discharge and Labor Expense per Adjusted Discharge rose by approximately 14% nationwide; this occurred simultaneously with a 6% decline in gross outpatient revenue and a 4.9% fall in operating margins [37].

Aside from the financial impact of staffing remodeling, understaffing during the early pandemic also invited room for error, with heightened risk for accidents and adverse patient health outcomes. A study from July 2021 explored how understaffing influenced "near misses" – events that could potentially result in accidents and injuries in the hospital setting – and found that personnel understaffing led to heavier reliance on safety workarounds, which resulted in near misses when cognitive failures, another result of understaffing, were high [38]. Another research group conducted a survey involving nurses from 254 hospitals in New York and Illinois between December 2019 through February 2020 and found that understaffed units were associated with unfavorable patient safety ratings, poor quality of care, sub-optimal infection prevention, missed treatments and procedures, missed patient surveillance, missed administration of medication on time, and loss of important patient information

during handoffs [39]. Overall, these findings indicate that staffing alterations due to COVID-19 had numerous impacts on the quality of healthcare provided in the inpatient setting.

Geographic disparities also became evident amidst COVID-induced staffing alterations. One example can be seen with the comparison of rural versus urban nursing home establishments. Though rurality itself was not associated with COVID-19 infections or related deaths, a study involving the early pandemic period revealed that there was a higher degree of volatility in staffing shortages in rural nursing homes compared to their urban counterparts [40]. While rural nursing homes experienced a higher proportion of staffing shortages until mid-November 2020, staffing shortages in urban nursing homes were relatively stable over the same period, despite fluctuations in COVID-19 case volume. These results implicate that regional factors during the pandemic significantly influenced how problematic staffing shortages were for a given healthcare establishment.

Financial burdens, adverse patient health outcomes, and regional disparities in care are only a few among numerous other lasting consequences of COVID-19 on staffing structure. Looking forward, strategic workforce management will be crucial to mitigate the long-term consequences of a shaken healthcare workforce.

4 Information & communication systems

The coronavirus outbreak highlighted the critical role of information and communication systems within modern healthcare systems. On March 6, 2020, Medicare services were expanded to cover telemedicine visits for the duration of the COVID-19 public health emergency [41]. A rapid rise in telehealth usage was seen across a wide range of medical specialties, coinciding with governmental expansion efforts at this time. Records from a New York healthcare system revealed a 1,529% increase in the number of telemedicine urgent care visits in just 15 days during March 2020, echoed by a comparable rise in virtual ambulatory care visits [42].

Temesgen et al. predicted long-term changes likely to occur in modern healthcare following the pandemic, including increased employment of telemedicine, and subsequently, increased humanitarian outreach to underserved populations [43]. To continue such increased reliance on telehealth, global health systems will need to address various challenges impeding its universal usage. According to a 2019 survey, 94% of health system executives in the United States reported that factors such as the Health Insurance Portability and Accountability Act (HIPAA) and other patient privacy regulations restricted the adoption of digital strategies in their systems [44]. In addition to oversight challenges, reimbursement methods likely also need modification for telemedicine's universal adoption to be

successful. Fortunately, previous state-level policy changes that expanded Medicaid telemedicine coverage resulted in increased telemedicine utilization [45]. While addressing these issues will take time coordination across the entire healthcare and legal landscape, telehealth's evolution and mass adoption throughout COVID-19 will likely prove advantageous to modern medical systems.

Another integral role of information and communication systems made apparent by COVID-19 was the vitality of effective global health surveillance and warning systems in monitoring emerging public health threats and providing timely notifications and directives to the public. Prior to COVID-19, such systems had been established, such as the Global Public Health Intelligence Network [46]. However, there is still a need for more effective and integrated communication systems, supported by the global spread of SARS-CoV-2 despite timely warning efforts by existing health information systems in December 2019 [47]. In a 2020 publication by the Journal of Medical Internet Research, it is suggested that a main flaw of existing global health surveillance systems is that their notification recipient pool is relatively narrow, limited to a small circle of government and health officials [48]. To solve this issue, Sakib et al. proposed a national-level pandemic notification system aimed at informing not only leading officials, but the public at large. This notification system would involve hierarchical threat levels, each with their own easily interpreted – i.e., tailored to the surrounding linguistic context – logo and set of guidelines.

5 Scientific globalism & vaccine revolution

While countries restricted mobility by reducing travel and closing borders to curb the spread of SARS-CoV-2, the scientific community advanced global collaboration to achieve the common goal of managing and finding a timely solution to the pandemic. Scientific globalism is described by its mission to advance knowledge and open science, while scientific nationalism focuses on economic competitiveness [49]. A new emphasis on scientific globalism emerged from this crisis out of clinical necessity, subsequently improving multilateralism and collaboration among nations and ultimately catalyzing the development of a SARS-CoV-2 vaccine.

Early in the pandemic, publishers and scientific societies signed a commitment to ensure the World Health Organization (WHO) had rapid access to emergent scientific publishing, and several major academic publishers opened access to over 32,000 COVID-19 related articles [50–52]. Additionally, the pandemic era's increase in open access scientific publications aided lower-income countries on the “periphery” of scientific discovery [53, 54]. Alongside the enhanced scientific cooperation witnessed during the pandemic,

international humanitarian efforts leveraged strengths to augment the global response to the SARS-CoV-2 outbreak. The landmark Access to COVID-19 Tools combined academic resources from the Africa CDC and the WHO with humanitarian foundations to make 120 million rapid test kits available [55]. Leveraging international partnerships has been done prior to COVID-19, most notably the United States partnerships between academic medical institutions and nongovernmental organizations after the 2010 Haiti earthquake [56]. However, international partnerships early in the SARS-CoV-2 pandemic offered a unique approach using the logistical infrastructure of humanitarian organizations alongside academic institutions' scientific expertise to deliver a timely, coordinated global response to a major infectious disease outbreak [57].

By the time the WHO declared COVID-19 a pandemic on March 11, 2020, at least 37 different entities across the globe had begun COVID-19 vaccine development [58, 59]. Unlike other vaccine development processes in the United States that typically involve three phases of clinical trials in sequence, the three phases of clinical trials overlapped to expedite the COVID-19 vaccine development process [60]. By July 2nd, 2020, over 150 vaccine candidates had been developed, though the majority of which were still in preliminary stages [61]. In December 2020, less than a year after entering clinical trials, the Pfizer-BioNTech and Moderna COVID-19 vaccines were authorized for emergency use by the U.S. Food and Drug Administration [62, 63]. According to a timeline provided by the American Journal of Managed Care, on February 1st, 2021, the number of American citizens vaccinated with at least one dose surpassed the number of citizens that had tested positive for SARS-CoV-2 since January 20, 2020 [64]. Such rapid development and deployment of a vaccine that was found to be highly efficacious as well as safe left substantial implications for modern medicine, the scientific community, and the global population at large. Exactly how such a vaccine came to be warrants further attention.

Following the discovery and publication of the SARS-CoV-2 genome, vaccine development efforts largely shifted towards a focus on a specific protein encoded by this viral genome – the spike surface glycoprotein. While traditional vaccines may have offered long-term immunogenicity as well, the ribonucleic acid (RNA) platform gathered increasing attention because of its relative safety, efficacy, lower production costs, and quicker development time compared to more conventional alternatives, such as live-attenuated and subunit vaccines [65]. In point, the particular manufacturing capabilities of the RNA-based COVID-19 vaccine eventually culminated in the entry of Moderna's vaccine candidate, mRNA-1273, into phase 3 clinical trials on July 27th, 2020, and alternative vaccine candidates followed suite [66].

Such mRNA vaccine technology existed prior to the pandemic, but the creation of the COVID-19 vaccine accelerated its usage in modern medicine. This technology is now being explored in additional disease settings across the globe. Among various other projects currently underway, one team of researchers at the University of Texas MD Anderson Cancer Center is testing the use of mRNA technology as novel treatment for colorectal cancer [67]. This project, among numerous other efforts, highlight how pressures on modern medical systems arising from COVID-19 may permanently alter vaccine technology for the better.

Though the creation of the COVID-19 vaccine represented a tremendous stride forward in the fight against the pandemic, the actual rollout and implementation of global vaccination has not been without backlash. As of January 29, 2022, only 64% of the U.S. population has been fully vaccinated against COVID-19, leaving over a third of the population unvaccinated [68]. Being the interface between science and the people at large, hospital systems have a unique place in the vaccine discussion. Dissemination of accurate medical knowledge and public education on the topic is a crucial responsibility that many healthcare providers continue to take on.

6 Health policy evolution

The pandemic underscored the importance of institutional involvement in public health infrastructure. Public health mandates, relaxed regulations, and policy expansion efforts tackled major challenges induced by the pandemic, such as mitigating the spread of COVID-19, addressing workforce shortages, and providing economic relief to citizens and institutions.

Implementation of behavioral mandates, such as social distancing and quarantine measures, decreased viral transmission in the early months of the pandemic [69]. Curfews, lockdowns, and restrictions on large gatherings were among the most effective government mandates overall [70]. The state-sanctioned lockdown implemented throughout the United States resulted in a lower change in viral reproduction number in the early stages of the pandemic compared to alternative, less substantial measures [70]. Quantitative analysis of the national emergency response in China between December 31st, 2019 and February 19th, 2020 revealed that Wuhan's implementation of social distancing measures, such as closing intracity public transportation and entertainment venues, helped limit the growth of the pandemic in China, avoiding hundreds of thousands of cases of SARS-CoV-2 infection by the 50th day of the pandemic [71].

A country level analysis revealed that lower levels of national preparedness in detecting and reporting COVID-19 cases were a substantial factor associated with higher rates of viral transmission and mortality. The same study showed

that higher COVID-19 caseloads were associated with countries that had longer time to border closure from the first reported case [72]. In the early weeks of the pandemic in China, the sooner a city implemented lockdown measures, the lower case numbers it reported [71]. Compared to countries with more timely and effective national responses to COVID-19 that enabled viral containment – e.g. the United Arab Emirates – other countries such as the United States and the United Kingdom were hit considerably harder by the pandemic [73]. Collectively, these examples suggest that stronger degrees of government intervention promoted more effective viral containment on a national level.

In addition to the implementation of behavioral mandates and lockdown measures aimed at mitigating the spread of SARS-CoV-2, health organizations published proposals and guidelines to address healthcare personnel shortages. In an October 2020 report, the British Medical Association (BMA) stated that medical workforce numbers – especially consultants – must increase in order to overcome backlog from the pandemic [74]. Within the United States, the CDC advised hospitals to cancel all non-essential procedures, address social factors preventing healthcare workers from reporting to work, and request healthcare workers to postpone elective time off work [75]. A publication from the Journal of the American Medical Association (JAMA) proposed relaxed state regulations to increase available nursing staff, like the Nurse Licensure Compact [76]. California previously set an example of legislation aimed to limit the patient-to-nurse ratio, leading to greater workforce sustainability [77]. In response to nursing shortages in Illinois and New York, legislation aimed at mandating safer staffing practices to improve patient care was introduced [78, 79]. House Bill 2604 in Illinois failed to pass, but Assembly Bill A2954 was referred to the Ways and Means Committee on January 8th, 2020 and has since been pending further review. Although these bills demonstrate various efforts taken by state governments to provide workforce relief during COVID-19, state-level guidance was lacking in other respects. For example, only twenty-six states in the United States provided guidance for the allocation of ventilators during critical moments of the coronavirus pandemic [80].

Nearly overnight, the pandemic transformed the needs of society and the role of clinical care in daily life. While reactive efforts, such as changes to long-standing policies, occurred during the pandemic to help healthcare systems across the globe meet the demand surges, there is now an opportunity to permanently transform healthcare policy for the better via proactive efforts. Various policy efforts taken during the pandemic targeted the “sludge” within modern healthcare systems, or policies and protocols that impede timely delivery of actual physical care [81], such as those implemented by Centers for Medicare and Medicaid Services that expedited the care delivery process by increasing

coverage of telemedicine visits during the pandemic [41]. Continuing this overall trend of loosening unnecessary restrictions in the post-COVID era within modern health systems could enhance the global response to future disease outbreaks by increasing the ability of nations to react in a timely manner to emergency public health situations. Continuing to permit verbal orders in hospital settings, eliminating certain signature and documentation requirements for low-risk treatment procedures, and continuing the expansion of telehealth coverage and access are examples of such policy changes to consider [82].

The pandemic highlighted another area where further policy evolution may improve modern healthcare delivery and thus public health outcomes in the context of global health emergencies – enhanced investment in public health infrastructure. Heightened capital allocations would allow further investment in national emergency response programs, such as Emergency Operations Plans required in United States hospitals to help facilities respond and recover from emergencies [83]. According to an annual report from 2020, CDC funding of state and local emergency preparedness decreased by almost 50% between 2002 and 2020, dropping from \$940 million to \$670 million [84]. In light of this, proposed policy changes in the post-COVID era include measures such as expanding federal funding of national health infrastructure and tackling complexities within existing healthcare funding, such as those in the United States [85].

In addition to matters of healthcare funding, there are other areas of global health infrastructure that may experience volatility proceeding the initial SARS-CoV-2 catastrophe. Structural changes to reimbursement models are predicted to occur in the post-COVID era, as well as modifications to physician licensure that may eliminate state borders to practicing medicine in the United States [43]. Following previous infectious disease outbreaks, existing policy frameworks were restructured to strengthen national response efforts, and the results bring optimism for the world following the pandemic. The 2015 Middle East Respiratory Syndrome (MERS) represented a policy failure compared to COVID-19, but its sequela – i.e., the development and implementation of various beneficial policy changes – served as precedent to stop the spread of SAR-CoV-2 in South Korea [86]. Overall, policy developments during the SARS-CoV-2 pandemic will serve as a framework for future pandemics, much like the MERS outbreak of 2015 did for South Korea.

7 Conclusion

A plethora of changes – both direct and indirect – to global medical systems emerged following the SARS-CoV-2 outbreak and many more will likely become apparent in its procession. Infrastructural transformation was evident

down to the physical foundation of healthcare, with architectural redesign of facilities spearheaded by unparalleled innovation. Massive disruptions occurred across global supply chains, but with them came fresh ideas for mitigating resource shortages. Other aspects of modern healthcare infrastructure echoed similar patterns of evolution, such as those illustrated by a migratory workforce, the groundbreaking advancements that capacitated the creation of the COVID-19 vaccine, and unprecedented collaboration displayed across nations, which became united by a single purpose against a common enemy. Despite representing a deeply tragic part of human history, the ingenuity, adaptability, and collaboration demonstrated during COVID-19 highlight the ongoing progression of modern medicine and yield optimism for the future of modern healthcare systems.

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Declarations

Ethics approval All procedures performed in the reviewed studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent Informed consent was obtained from all individual participants included in the studies that are reviewed in this paper.

Competing interests The authors have no relevant financial or non-financial interests to disclose. Bayli Davis, Dr. Bankhead-Kendall, and Dr. Dumas declare that they have no conflicts of interest.

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