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ORIGINAL ARTICLE

Using a 5p strategic medical stockpile model to build an optimal and resilient supply chain in health emergencies

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ABSTRACT

Background: The healthcare sector witnessed the occurrences and impacts of disruptions on supply chains during the coronavirus disease (COVID-19) pandemic. Consequently, it is essential to strengthen institutional medical supply chain systems by addressing the key attributes of strategic stockpile plan renewal: flexibility, traceability and transparency, perseverance and responsiveness, global independence, and equitable access.

Aim and objective: To establish a resilient supply chain integrated into the emergency management cycle by proposing a sustainable 5P strategic medical stockpile model.

Settings: Online evidence, available literature, and lessons learned during the COVID-19 response in the Emirate of Abu Dhabi.

Methods: This review employed a systematic methodology of identification, selection, assessment, synthesis, and interpretation of data from peer-reviewed articles, review reports, and response frameworks spanning the years 2012–2020. In addition, media reports and announcements were analyzed to determine the implications of COVID-19 on the supply chain from 2020 to 2022. Recommendations are formulated in response to the identified shortcomings revealed during the review process, as well as considering experiences and lessons resulting from responses to address COVID-19 in the Abu Dhabi Health Sector.

Results: Our analysis revealed a deficiency in effective operational protocols for building a robust supply chain. The experience gained from responding to COVID-19 has highlighted deficiencies such as unclear issues with stockpiles, inadequate resources, insufficient planning, the absence of established procedures, and a lack of performance monitoring. The pandemic had a tremendous impact on health systems and medical supply chains worldwide. Our suggested model necessitates aligning responses with national contingency protocols. Accountability may fluctuate during each phase of an emergency, depending on decision-making authority and jurisdictional capabilities.

Conclusion: The proposed 5P model can support policymakers, health regulators, institutions, and professionals in formulating strategies to establish a resilient stockpile system that serves as a medical supply chain buffer when supplies are not instantly accessible.

Keywords: Counterfeit, emergency response, policymakers, resilient supply chain, shortage, strategic medical stockpile.

Introduction

A strategic stockpile is a repository of drugs and medical supplies that are intended for use in a public health crisis. In the initial outbreak of the coronavirus disease (COVID-19) pandemic, a global shortage of personal protective equipment (PPE) including gowns, gloves, surgical masks, and respirators in hospitals caused prevalent panic among policymakers and hospital administrators worldwide. In response to a significant surge in demand for certain items, various countries established special agreements with each other to support

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the supply chain. Illicit and counterfeit pharmaceutical products, encompassing medications, surgical masks, and N95 respirators, inundated the global market as well. Furthermore, the mass media consistently covered shortages in medical supplies and resources, such as insufficient hospital beds, oxygen supplies, and antivirals. These shortages played a role in destabilizing the global medical supply chain. Consequently, the COVID-19 pandemic has renewed attention to the need to develop and sustain a Strategic medical stockpile (SMS). A focused and strategic approach is also needed to execute emergency interventions that can mitigate, prepare, respond, and recover, which are based on a resilient medical supply chain that was established to address any foreseeable future public health threats.

According to the U.S. Department of Health and Human Services [1-4], since a health threat can appear at any moment, a Strategic national stockpile (SNS) forms part of the federal medical response infrastructure that can respond and supplement medical countermeasures that are taken by states, tribal nations, territories, and the largest metropolitan areas during public health emergencies. The supplies, medicines, and devices housed in the stockpile, essential for lifesaving care, serve as a temporary and interim solution when an immediate or sufficient supply may not be accessible.

The SNS is structured to address any public health threat, and its personnel covers a range of specialties, including pharmacy, clinical care, emergency management, medical logistics and operations, quality control, public health, procurement, financial management, information technology, strategic planning, training, policy, and communications. Collaboratively, they ensure the timely dispatch of suitable resources to the correct location. For the purposes of this study, SMS and SNS are used interchangeably.

Literature review

History of medical stockpile

Huang has elaborated stockpile history as after Ebola and acquired immunodeficiency syndrome emerged in the 1970s and 1980s, respectively, the U.S. government perceived an urgent need to strengthen its public health system [5]. In 1999, under the watch of President Bill Clinton, the Department of Health and Human Services introduced the Bioterrorism Preparedness and Response Initiative which aimed to strengthen the country's public health response to biological threats. Subsequently, the national pharmaceutical stockpile was placed under the jurisdiction of the Centers for Disease Control and Prevention (CDC). In its first year of operation, it received Congressional appropriations of US$51 million [6].

Figure 1 Administration for Strategic Preparedness and Response, [7] shows the history of stockpile responses in the US. In several instances, stockpiles played a pivotal role in the country's response to various emergencies.

Medical supply shortages and counterfeit products

Analysis of media reports and regulatory announcements has highlighted numerous cases of shortages and counterfeit medical supplies, attributed to the likely consequence of not establishing a resilient supply chain. This deficiency has a significant contribution to affecting the health sector operations, particularly under the strain of the COVID-19 pandemic. Table 1 summarizes the overview of shortages of medical supplies, the introduction of counterfeit product incidents, possible contributing factors, and outcomes during the COVID-19 pandemic.

Existence, importance, and need for SMS worldwide.

The idea of a stockpile is not new, yet its importance, influence, and development may have undergone a revival during the COVID-19 pandemic. In India, Bobdey has explained that certain imperatives will dictate the country's conceptualization of a national stockpile [24]. They include command and control, infrastructure development, initial creation and maintenance of the stockpile, annual inventory check, creation of a national databank for a virtual stockpile, training, and security of the stockpile. In its National Response Framework, the National Emergency, Crisis, and Disaster Management Authority (NCEMA) of the United Arab Emirates has described the requirement and purpose of a strategic stockpile in terms of the securement of supplies that can minimize the impact

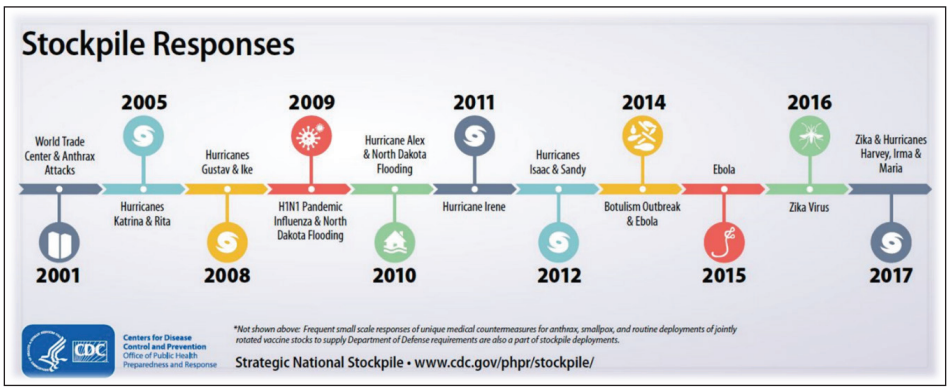

Figure 1. *Stockpile responses in the US between 2001 and 2017 (The image is re-used with consent granted from SNS Operations Center, CDC).*

Table 1. *Summary of counterfeit products and shortages of medications and medical consumables along with potential contributing factors during the COVID-19 pandemic (source: property of the author[s]).*

Year	Overview of the incident, possible contributing factors and outcomes
Proliferation of counterfeit products amidst the COVID-19 pandemic	
March 2020	Globally, approximately 4.4 million units of illicit pharmaceuticals were confiscated, encompassing erectile dysfunction pills, anti-cancer medication, hypnotic and sedative agents, anabolic steroids, analgesics/painkillers, nervous system agents, dermatological agents, and vitamins. A total of over 37,000 unauthorized and counterfeit medical devices were seized, with the majority consisting of surgical masks and self-testing kits (HIV and glucose). In addition, various surgical instruments were among the confiscated items leading to an elevated risk of introducing a product that is ineffective, contaminated, or substandard to the market [8-10].
July 2020	In the Middle East and North Africa, close to 20 million illicit pharmaceutical items, including respiratory masks, face masks, sanitizing products, gloves, thermometers, medical glasses, and more, were removed from the market.
March 2021	Millions of counterfeit N95 surgical respirators, including models such as 1,860, 1,860S, 8,210, 1,870+, 9,205+, and 9,210+, due to heightened demand, panic buying, and hoarding, inundated the market and were subsequently seized [11-12,13].
June 2021	Counterfeit and unauthorized COVID-19 testing kits and surgical masks, jeopardize public safety.
Shortage of medical consumables amidst the COVID-19 pandemic	
March 2020	World Health Organization notified shortages of PPE, attributed to an escalation in demand, panic buying, hoarding, and misuse [14-15].
March 2021	The Suez Canal experienced a 6-day blockade due to the grounding of the Ever given, a 20,000 TEU container ship, which halted all traffic until it could be successfully dislodged resulting in substantial adverse effects on trade between Europe, Asia, and the Middle East [16].
August 2020 – Jan 2022	FDA (Food and Drug Administration) announced categories of devices in the FDA device restricted availability of supply due to a surge in demand, the list includes: • Dialysis-related products • Personal protective equipment • Testing supplies and equipment • Ventilation-related products
May 2021	Medical oxygen shortage in India due to rise in demand coupled with insufficient supply [17].
April 2021	Nebulizers, blood-pressure monitors, digital thermometers, and glucometers shortage announcements from manufacturers and suppliers resulted from the rise in demand coupled with insufficient supply [18].
Dec 2021	Shortage of exam tables, heart defibrillators, crutches, and IV poles in New York due to the mounting demands.
Shortage of medications amidst the COVID-19 pandemic	
March 2021	Hydroxychloroquine sulfate tablets shortage with various manufacturers due to surge in demand [19].
April 2021	Shortage of remdesivir causes treatment delay, resulting in bed occupancy blocks [20].
	The surge in panic buying and increased cases led to the Favipiravir shortage [21].
August 2021	The emergence of the COVID-19 Delta variant has resulted in notable imbalances in the availability and demand for commonly used medications in hospital settings, including tocilizumab, dexamethasone, baricitinib, and remdesivir.
2022	Shortage in over 100 drugs, including critical emergency management medications such as atropine sulfate injection and calcium gluconate injection, as well as essential antibiotics like Ceftazidime and Avibactam due to issues related to manufacturing and quality, resulting in delays and discontinuations [22,23].

of a rapid unforeseen change, such as a sharp decline in local or international production due to a large-scale or catastrophic disaster which may impact the importation of essential items by the Middle Eastern kingdom NCEMA [25]. Subsequently, it was mandated as a federal requirement by the Ministry of Health and Prevention which included drugs and medical and surgical consumables [26].

In Taiwan, Chen et al. [27] evaluated the PPE stockpile model, describing its replacement approach for PPE as more cost-effective and streamlined compared to conventional procurement methods when replenishing the central stockpile. Moreover, this model has the potential to offer emergency assistance during an epidemic and serve as a foundation for international collaboration. In Korea, Kim et al. [28] investigated the necessity of implementing a frozen blood storage system to oversee a reserve of rare blood types and SNPs.

Imbert [29] has defined a stockpile as an instrument to strengthen public health emergency preparedness and healthcare systems' resilience. The constructive role that is played by the industry as a partner that supplies stocks for stockpiling and describes the design of stockpiles in terms of their physical and virtual attributes, the management and maintenance of effective stockpiles, the need and capabilities to create a stockpile, the establishment of a stockpile, and the composition of a stockpile was defined. In regard to the procurement approach, criteria to determine the quantities and quality of items and a system that facilitates information-sharing were outlined. In a post-COVID-19 era, a need to refine the definition of a stockpile has been put forward by Handfield et al. [30] who proposed that optimal governance requires meeting national supply chain contingencies. A recognition of resilience cannot be obtained without persistence, and persistence cannot be maintained without either a sensor to detect disruptions and shortages or a vantage point from which to observe what is happening in the stockpiles and other inventories in the US. Furthermore, Dornauer [31] in his policy review states that pandemic preparedness is often thought of as an abstract concept.

Stockpiles, however, render the abstract concrete, and they provide a material foundation to build and mitigate the effects of a future pandemic.

In Canada, Laing and Westervelt [32] concluded that managing emergency supply stockpiles is expensive and results in significant financial and material waste due to the management of expired supplies. As a result, they suggested a more efficient approach, proposing the integration of the country's National Emergency Stockpile System (NESS) with commercial supply chains through a "prime vendor" model. This integration aims to minimize financial and material waste by selling supplies directly to healthcare organizations. By adopting this strategy, the stockpile would be continually refreshed to ensure an adequate supply of unexpired emergency products and to provide valuable data on the supply and demand for emergency supplies.

Keohane [33] has clarified that increasing ventilator capacity can address the expected rise in patients experiencing severe respiratory failure during the COVID-19 pandemic. This expansion entails considerations such as staff availability, which is crucial for ensuring access to ventilators, as well as the significance of adequate ventilator supplies and training. Furthermore, the distribution of ventilators within states and across regions of the US is emphasized. Ramachandran et al. highlighted the importance of a national strategy for ventilator and intensive care unit resource allocation specifically during the COVID-19 crisis in New York [34].

Lessons learned from COVID-19 response in Abu Dhabi Health Sector

The COVID-19 pandemic has put emphasis on the necessity to reevaluate supply chain capabilities, exposing insufficiencies in stockpile management system maturity levels, deficits in stockpile governance, and operational protocol inadequacies within the working team. It brought attention to gaps in the early stages of conventional stockpile structure, processes, and performance, prompting the inevitability of an improved framework to reinforce the development of a resilient supply chain for a more efficient response to future emergencies.

Recommendations

5P SMS model

The review of literature considering the COVID-19 pandemic has revealed essential criteria for regulatory bodies, policymakers, and implementers to consider in developing an effective stockpile management system. This system encompasses a comprehensive supply chain, encompassing critical components such as life-saving medicines, treatments for chronic conditions, provisions for chemical, biological, radiological, nuclear, or explosive incidents, medical consumables, and blood bank resources.

Consequently, there was an effort to devise a supportive model aimed at aiding the health sector by improving supply chain capabilities and ensuring a more efficient response to potential future health emergencies. Figure 2 depicts the 5P SMS model.

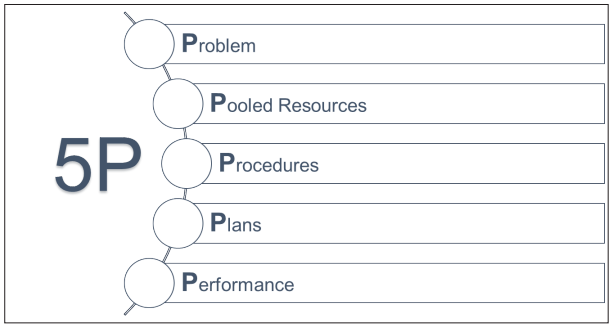

Figure 2. *5P SMS model (source: property of the author[s]).*

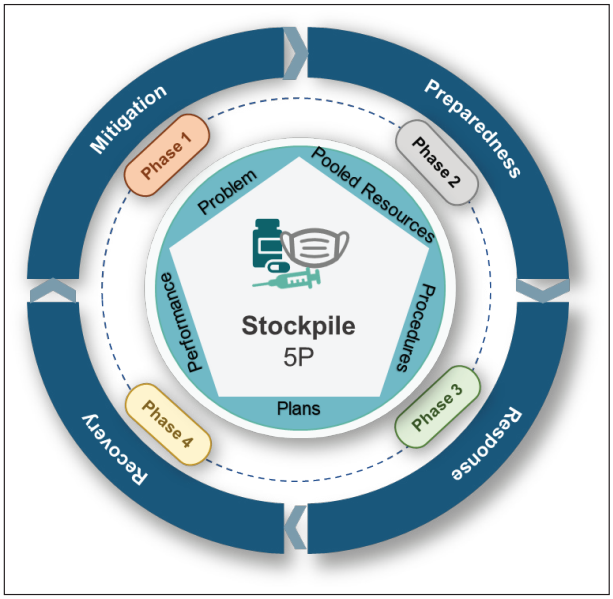

Figure 3. *5P SMS model is embedded in the emergency management cycle (source: property of the author[s]).*

Embedding the 5P SMS model in the emergency management cycle

It is worthwhile to consider the four phases of an emergency management cycle that were outlined by the Federal Emergency Management Agency [35] in the US. They include mitigation, preparedness, response, and recovery. In doing so, the requirements of the 5P SMS model are embedded in every phase of the emergency management cycle (Figure 3).

The model shown in Figure 3 is described in detail in the following sections. Specifically, five requirements of the 5P SMS model are articulated in every phase of the emergency management cycle.

Phase 1: Mitigation

This phase encompasses activities aimed at preventing the stockpile from entering an emergency state, minimizing the likelihood of emergencies, or mitigating the damaging effects of unavoidable emergencies. These efforts are essential for sustaining a supply chain capable of responding effectively to emergencies. Mitigation activities occur both before and after an emergency. Figure 3A outlines the 5P requirements for SMS.

Phase 2: Preparedness

This phase includes plans or preparations that are related to a stockpile that facilitate its operations and response to an emergency. Activities that are taken in the preparedness phase occur before an emergency arises. Figure 3B defines the 5P requirements for SMS.

Phase 3: response

In this phase, actions include dissemination, distribution, and disbursement of stockpiles to save lives during an emergency. The response involves a translation of mitigation/preparedness plans into concrete and practical actions, and activities that occur during an emergency. Figure 3C depicts the stockpile response activities of the 5P SMS model.

Phase 4: recovery

In the final phase, actions are taken to return to a normal or even safer situation following an emergency. Recovery activities occur after an emergency and stockpiles are

Figure 3A. *5P SMS model in the mitigation phase of the emergency management cycle (source: property of the author[s]).*

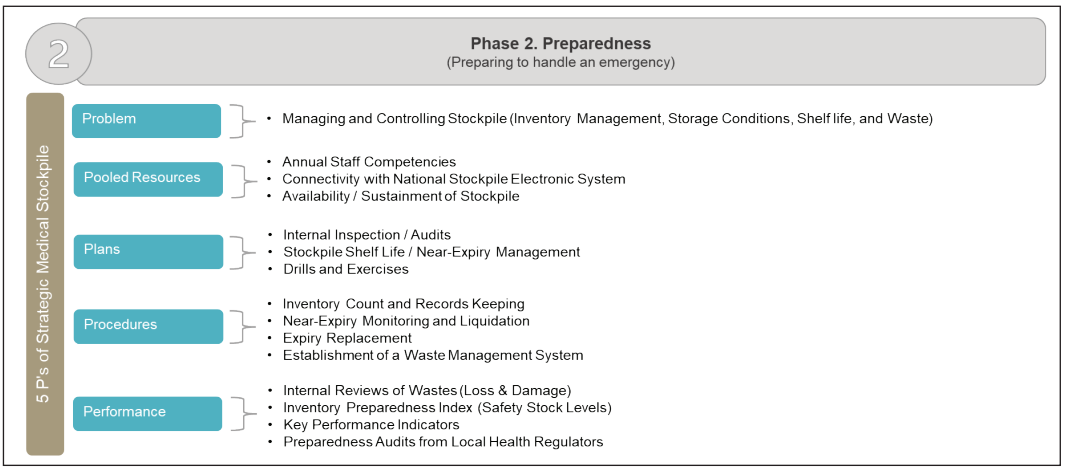

Figure 3B. *5P SMS model in the preparedness phase of the emergency management cycle (source: property of the author[s]).*

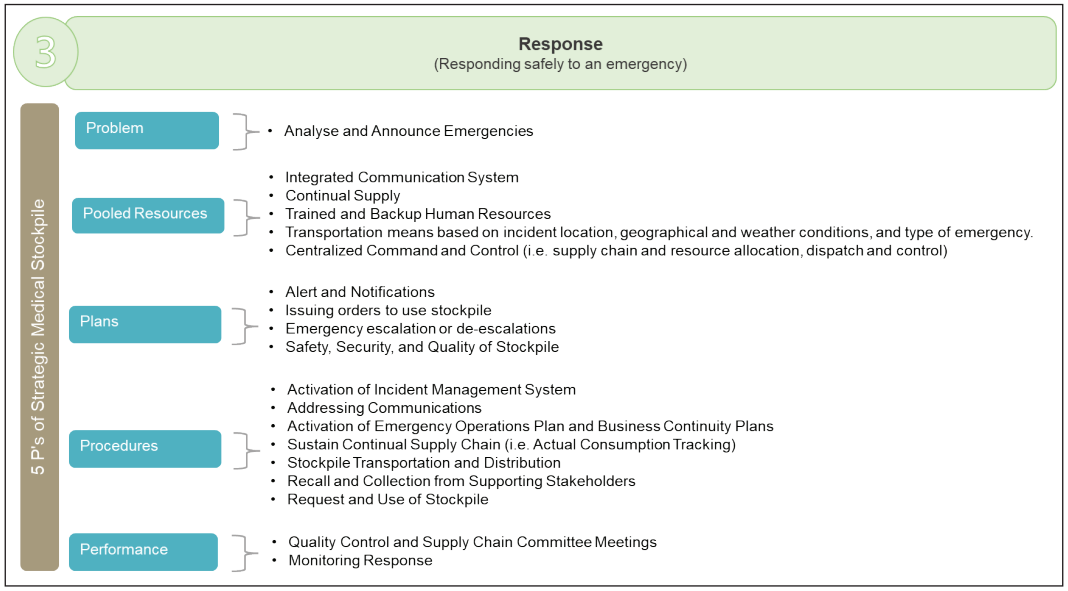

Figure 3C. *5P SMS model in the response phase of the emergency management cycle (source: property of the author[s]).*

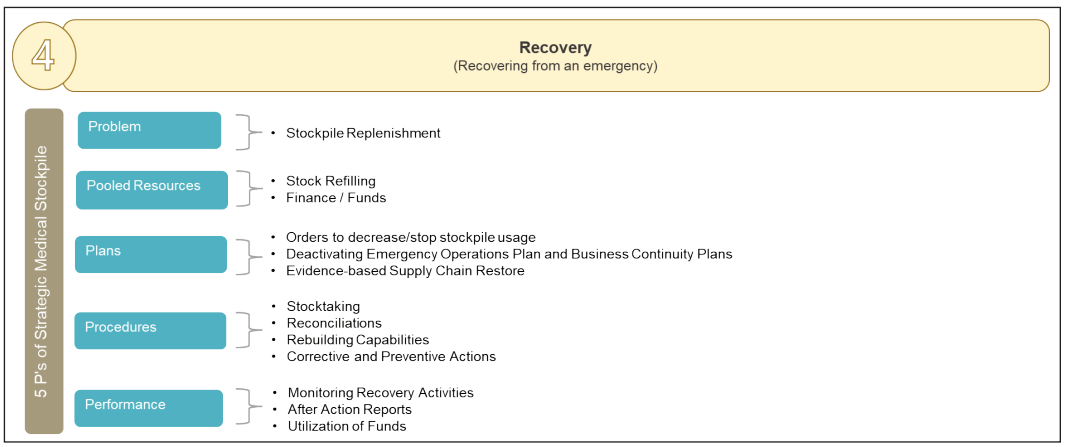

Figure 3D. *5P SMS model in the recovery phase of the emergency management cycle (source: property of the author[s]).*

rebuilt to manage a future emergency. Figure 3D depicts the requirements that can support stockpile recovery activities.

Conclusion

A review of the literature and insights gained from responding to the COVID-19 pandemic have highlighted a critical necessity: to address the shortcomings of the current medical supply chain in effectively managing disruptions caused by such crises. To meet this need, a 5P SMS model can be implemented, aiming to construct an optimal and resilient supply chain. Achieving this requires thorough planning and consensus-building between public entities and private enterprises to bolster state and local supplies during public health emergencies. By securing lifesaving medications and essential health products through SMS, they can serve as a vital buffer when immediate supplies are not readily accessible.

Owing to the remarkable impact that was caused by the COVID-19 pandemic, stakeholders who are responsible for managing a health emergency must analyze and assess on improvement of SMS for future pandemics. In doing so, they can adapt the 5P SMS model by mapping it to national contingency strategies.

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List of Abbreviations

NCEMA	National emergency, crisis, and disaster management authority
PPE	Personnel protective equipment

SMS	Strategic medical stockpile
WHO	World Health Organization

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The authors declare that there is no conflict of interest regarding the publication of this article.

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