Healthcare Disruption: Assessing COVID-19 Impact on Healthcare Delivery

HEALTHCARE DISRUPTION: ASSESSING COVID-19 IMPACT ON HEALTHCARE DELIVERY

by

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Declaration of Authorship

I declare that this thesis my own work and, to the best of my knowledge and belief, it does not contain material published or written by a third party, except where permission has been obtained and/or appropriately cited through full and accurate referencing.

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Dedication

To my beloved parents and siblings, who have always supported me and inspired me to pursue the highest education, follow my passion, and strive for excellence.

To my country, Saudi Arabia, and to the person who has empowered all women in the Kingdom, His Royal Highness Crown Prince Mohammed bin Salman bin Abdulaziz, whose Vision 2030 has involved major transformation in the healthcare sector to improve the individual and families' quality of life.

Abstract

Health emergency outbreaks, including COVID-19 pandemic, make it challenging for the healthcare (HC) system to ration medical resources and care delivered to patients. Such disastrous events have been increasing in the past years and are becoming inevitable, necessitating the need for HC to be well-prepared and resilient to unpredictable rise in demand. Additionally, quantitative- and qualitative-based decision support systems increase the effectiveness of planning, alleviating uncertainties associated with the crisis. The purpose of this study is to understand how the COVID-19 pandemic has affected the performance of the healthcare system in different areas, and to address the pandemic-related disruption. A cross-sectional online survey was distributed among healthcare workers in the Kingdom of Saudi Arabia and the United Arab Emirates, who worked during the pandemic, and have many years of experience in hospital settings (sample size = 123). The pandemic-related disruption, and its psychometric properties are assessed using Structural Equation Modeling with 30 items related to Staff Mental Health, Communication Level, Planning and Readiness, Healthcare Supply Chain, and Telehealth. Results show that the model satisfactorily fits the data, and that those factors are correlated among each other, providing a direction for more research focusing on determinants of the efficiency of healthcare delivery. The proposed work will provide decision-makers an insight into the main factors leading to disruptions in HC systems, and how they are correlated, allowing them to shape their outbreak response and better prepare for future health emergencies.

Keywords: Healthcare delivery; Disruptions; Epidemic; COVID-19; Structural equation modeling; Confirmatory factor analysis; Telehealth; Healthcare supply chain; Healthcare workers wellbeing; Planning.

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List of Abbreviations

CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
COVID-19	Coronavirus Disease 2019
Gov	Governmental Sector
HC	Healthcare
HCW	Healthcare Worker
HSC	Healthcare Supply Chain
ICU	Intensive Care Unit
IP&C	Infection Prevention and Control
KSA	Kingdom of Saudi Arabia
LV	Latent Variable
OV	Observed Variable
PE	Patient Engagement or Patient Experience
PPE	Personal Protective Equipment
RMSEA	Root Mean Square Error of Approximation
SC	Supply Chain
SEM	Structural Equation Modeling
Semi-Gov	Semi-Governmental Sector
TLI	Tucker Lewis Index
UAE	United Arab Emirates
WHO	World Health Organization

Chapter 1. Introduction

1.1. Introduction

This chapter includes a short introduction about the effects of the coronavirus disease 2019 (COVID-19) outbreak on healthcare, global response to the pandemic, and adapted solutions to improve future response. The problem investigated in this study is presented as well as the thesis contribution and general organization of the thesis.

1.2. Overview

Healthcare (HC) is considered one of the largest and most complex sectors in most countries. Its rapid increase in both expenditure and importance has become a dominant economic and political issue. Due to the continuous growth, aging of populations, and accelerated rates of avoidable injuries and non-communicable diseases, HC encounters challenges in providing consistent and adequate services for patients' safety and outcome.

Potential pandemics and mass casualty events add to the complexity and place a strain on HC systems worldwide, forcing governments to prepare and exercise complex plans to deal with events such as the COVID-19 pandemic. On January 30, 2020, the World Health Organization (WHO) declared it a pandemic due to the severe health risk posed by the COVID-19 virus [1]. The number of infected cases is rising globally, with escalating human, economic, and societal costs. The COVID-19 as a pandemic has spanned across all continents, and to date, with about over 263 million confirmed cases worldwide and nearly 5.2 million deaths, making it an unprecedented health care crisis [2]. Health systems, even the ones with the best infrastructure, are reeling under the burden of the disease and the increasing number of cases. The COVID-19 pandemic has overwhelmed HC systems resulting in morbidity, mortality, and a dramatic economic downturn. The outbreak has significantly altered health systems and impacted the level of care for patients.

1.3. Disruptions in the Health System

1.3.1 Resources planning and healthcare supply chain

In the wake of a declaration of the COVID-19 pandemic, health systems globally faced the problem of predicting the number of infected cases, severity, and risk involved. In addition to facing the problem of estimating resource demand such as healthcare workers (HCW), testing resources, hospital beds, ventilators, and Personal Protective Equipment (PPE) [3]. The latter is crucial because the increased number of patients will significantly increase the burden on health systems and hospitals, resulting in a challenging situation of allocating the limited resources.

HC systems, in general, and hospitals, in specific, are designed to cater to an average patient load in terms of staffing and infrastructure. Under-equipped hospitals with limited HCW and medical equipment, rural hospitals, for instance, will likely serve as referral hospitals, overburdening designated COVID-19 hospitals [4]. Many HC resources are evaluated at the type of the medical facility (i.e., private, governmental, etc.) or the facility size, but they are still prone to challenges when demand for care suddenly surges in an insufficiently equipped facility [5]. Regardless of the type and size of the medical facility, rationing essential HC services and resources to cater to patients has become a challenge for hospitals and the entire HC system.

The pandemic has highlighted structural weaknesses in the healthcare supply chain (HSC). Resilient HSC requires information visibility and transparency across the chain to establish sufficient flexibility to confront shifting pandemic conditions. HSCs have often been considered different from the usual supply chain due to their high level of complexity, the presence of high-valuable medical materials, and finally, the fact that they deal with human lives. Reducing and eliminating the waste and unnecessary costs add more pressure on the HC system, whose primary goal is to improve the quality and consistency of care delivered to patients [6]. As demand increased during the first peak of the pandemic, many countries experienced difficulties and extended delays in restocking essential medical supplies due to forced lockdown and travel restriction [7]. Maintaining the supply chain of medical products is not only paramount to cover the immediate medical response but will be fundamental to reducing disruption of the HC delivery system, which requires constant medicines, diagnostic tools, and vaccines for smooth functioning [8].

1.3.2 Mental health

The uncertainty associated with the pandemic and the ascending number of COVID-related deaths increase the fear of infection, overwhelming and burdening the mental health of HCW. Medical providers, especially, are exposed to susceptible cases while treating their patients. Prior to the COVID-19 vaccination control period, many HCW experienced feelings of inadequate support from their beloved ones while being isolated/quarantined. Working in these conditions put HCW at risk of severe psychological burden, affecting their health and wellbeing, as well as the care they provide to patients [9].

1.3.3 Persisting long-term disruptions in healthcare delivery

Pandemic outbreaks can also cause long-term propagating disruptions in health systems. Disruptions in HC hit not only the severe and critical cases of COVID-19 but also chronically ill patients who are highly dependent on treatments and medications that have abruptly become unavailable [10]. Health systems that are not resilient enough to effectively respond to disasters are less likely to anticipate, adapt to, or mitigate disruptions, complicating resource allocation decisions. The rise of healthcare demand and costs puts decision makers under pressure to ensure efficient capacity management across the entire healthcare system. While the world is facing the urgency of the COVID-19 pandemic, policymakers must plan to directly respond to the outbreak while minimizing its collateral impact [8].

COVID-19 has infected millions of people, resulting in millions of deaths. All countries and their health system were not prepared enough for this pandemic, even though Disaster Management, Infection Prevention and Control (IP&C), and Resource Planning in primary care practices are necessary parts of the public health infrastructure. It is evident that the health needs created by this pandemic were far from the capacity of hospitals in many countries, forcing them to dedicate hospitals for COVID-19 cases or open temporary ones.

1.4. Optimizing Healthcare Delivery During Disasters

1.4.1 Preventative measures

Most countries worldwide have responded promptly to the COVID-19 disease challenge by adopting considered and scientifically guided strategies for its containment. The response strategy has involved implementing measures to reduce transmission risk such as social distancing, face masks, stay-at-home orders, and canceling or postponing public events. Specific measures were also implemented in medical settings, including prioritizing emergent care, and rescheduling non-urgent appointments, delivering care remotely (telehealth), and strictly isolating hospital wards dedicated to treating COVID-19 cases. The strategies and measures were deployed and used to manage the infection rate and avoid fatiguing limited hospital resources because of the absence of highly effective drugs, vaccines, and abundant medical resources. Some countries made a conscious effort to develop and adopt protocols to lower infectious risk, reduce hospital burden, and reduce emergency medical care services by using predictors of survival and identifying the protocol that results in the smallest resource burden [11], [12].

1.4.2 Technology and telehealth

Technology in healthcare has been leveraged to combat this pandemic in multiple ways. The epidemiological Susceptible-Infected-Recovered model, for example, has been widely used to estimate and predict metrics, including the spread rate of infection or the number of susceptible individuals in a certain area [13]. Many researchers and health systems have conducted modeling studies for forecasting the potential spread of COVID-19 [12], predicting bed capacity, ventilator availability [14], or allocating resources [15]. These quantitative-based decision support systems establish a logical and comprehensible interface between the human user and data warehouse, allowing the transformation of raw data into timely and informed actions [16].

Telehealth technology has been useful during the outbreak, especially with those at greater risk of developing severe conditions of the COVID-19 disease (i.e., patients with genetic diseases or elderly) [17]. Medical staff can provide their services remotely via different telehealth modalities such as: video-based virtual visits, telephonic delivery, tech-enabled home medication, etc. Such technologies can facilitate optimal delivery of healthcare services to reduce cross-infection and transmission of the disease.

Nonetheless, some of the challenges for the successful provision of telehealth services include limited physical examination, lack of technological skills, information security, resource availability/accessibility, or technical issues [18].

1.4.3 Effective responses for future pandemics

Despite increasingly enforced strict containment measures, the health system faced enormous pressure, and extraordinary efforts were made to increase overall hospital beds' availability and especially intensive care unit (ICU) capacity. Nevertheless, almost all hospitals experienced a shortage of ICU beds and resources that led to hard allocating choices [19]. The COVID-19 pandemic has highlighted the importance of ICU beds in preventing death from the severe symptoms of respiratory illness associated with COVID-19, which is a concerning issue even under normal circumstances.

Shortages in HC resources during a pandemic require the development of evidence-based guidelines to optimize the delivery of care. An effective response during challenging times requires public health infrastructure and capacity, the availability of technology and supplies, a knowledgeable and prepared workforce, as well as incident management and leadership plan. Schmidt et al. [20] identified the following planning elements for effective health emergency response to improve care delivery during COVID-19 pandemic or future crises:

- Digital surveillance of infectious disease.
- Resources availability and effective distribution.
- Investment in telemedicine and other remote HC delivery.
- SC resiliency with redundant SC providers and/or manufacturers to acquire and distribute large-scale personal safety and protective equipment.
- Acquisition of testing supplies and/or contracting with outsource testing.
- Employing emergency responders, HC providers, and volunteers, and ensuring sufficient training and preparation.
- Improving surge capacity management and emergency plans for local and regional response coordination.

- Preassembling and establishing infrastructure for public health programs and operations of the health system.

An integral aspect of improving HC delivery is through "patient engagement" or "patient experience" (PE) activities. Engaging patients in decision-making allows them to reflect on the provided care and address their health needs and personal preferences; hence, better outcomes [21]. Focus groups, evaluations, and potential participation in clinical trials are among the great methods to engage patients. However, there are insufficient research studies that evaluate the impact of PE on the quality of healthcare delivery [22].

The HC sector faces serious challenges in the coming years, as the population ages, chronic diseases prevail, and health issues will likely emerge. The integration and sharing of qualitative and quantitative data are crucial in creating efficiencies, as they allow us to continuously monitor the performance of health systems and evaluate the return on investment. The future of HC enterprise may become dependent on robust data resources and the use of advanced analytic techniques in favor of keeping pace with increasing demands in the health system.

1.5. Problem Statement

The COVID-19 pandemic and previous outbreaks have been increasing in the last years, threatening the HC sector and the quality of HC services. Existing disaster management in HC, globally, has failed to adequately respond to the current pandemic. The association between the staff wellbeing, healthcare supply chain, telehealth utilization, emergency preparedness, level of communication, and the resiliency of healthcare system are often overlooked. The research questions are:

- What are the contributing factors that have affected the delivery of healthcare during the COVID-19 pandemic?
- What is the correlational relationship between HC disruptions and areas including planning, HSC, telehealth usage, communication level, patient engagement, and HCW mental health?
- How can the healthcare system prepare for future health emergencies?

1.6. Thesis Objectives

The experiences of HCW during the pandemic provide useful information about gaps in the existing plans. The objective of this work is to develop a reliable instrument assessing the pandemic-related disruption on HC delivery and evaluate its psychometric properties using structural equation modeling (SEM), particularly, confirmatory factor analysis (CFA). The model is constructed based on an online survey questionnaire covering the above-mentioned areas. This research provides a holistic approach to understand the significance of the discussed areas in creating resilient HC systems for the continuity of care during future outbreaks.

1.7. Research Contribution

The contribution of this work will involve designing a digital survey based on existing literature with concordant involvement and feedback from healthcare workers to gain more insight into the pandemic's impact on healthcare systems in the Kingdom of Saudi Arabia (KSA) and United Arab Emirates (UAE). A statistical instrument using structural equation modeling will be constructed from healthcare professionals' perspectives and experiences. The survey covers multiple areas that have been significantly impacted by the COVID-19 outbreak, which includes HC planning, workforce wellbeing, supply chain, patient engagement, telehealth, and level of communication. The correlation between those areas will be assessed with a 5-factor CFA model, providing an understanding of determinants of healthcare delivery disruption. Additionally, text mining from open-ended questions is also performed to get insights into word frequencies reflecting common thoughts and opinions by HCW.

1.8. Thesis Organization

The rest of the thesis is organized as follows: Chapter 2 provides background and literature review on the healthcare resources planning and management, telehealth technology use in healthcare, and the psychological impact of COVID-19 on HCW. The employed methods, including survey design and structural equation modeling, are discussed in Chapter 3. Chapter 4 presents the findings and interpretation of the survey responses, as well as the model evaluation and interpretation, and text mining. Finally, Chapter 5 concludes the thesis and outlines the future work.

Chapter 2. Background and Literature Review

This chapter discusses topics related to healthcare resource planning, technology, HCW wellbeing, and recent COVID-19 surveys. Additionally, background information on structural equations modeling and comparative factor analysis is also provided.

2.1. Management and Planning of Healthcare Resources

Effective emergency preparedness involves the early identification of shortages of medical resources and medical personnel. ICU beds, critical care staff, and ventilators are among the essential resources necessary to prepare for or contain an outbreak. In spatiotemporal research, the availability, shortages, and mismatches of HC workers, hospitals beds, and ventilators during outbreaks had been correlated with statistical information on space and time, providing a greater understanding of effective distribution and allocation of the resources [5], [23] [24], [25]. Taking into account the spatial and temporal patterns of HC resources help in identifying the locations in which there are shortages and imbalances between the accessibility and patients' demand. Yet, the areas of supply chain and resource planning in healthcare are insufficiently explored, as seen in Figure 1.

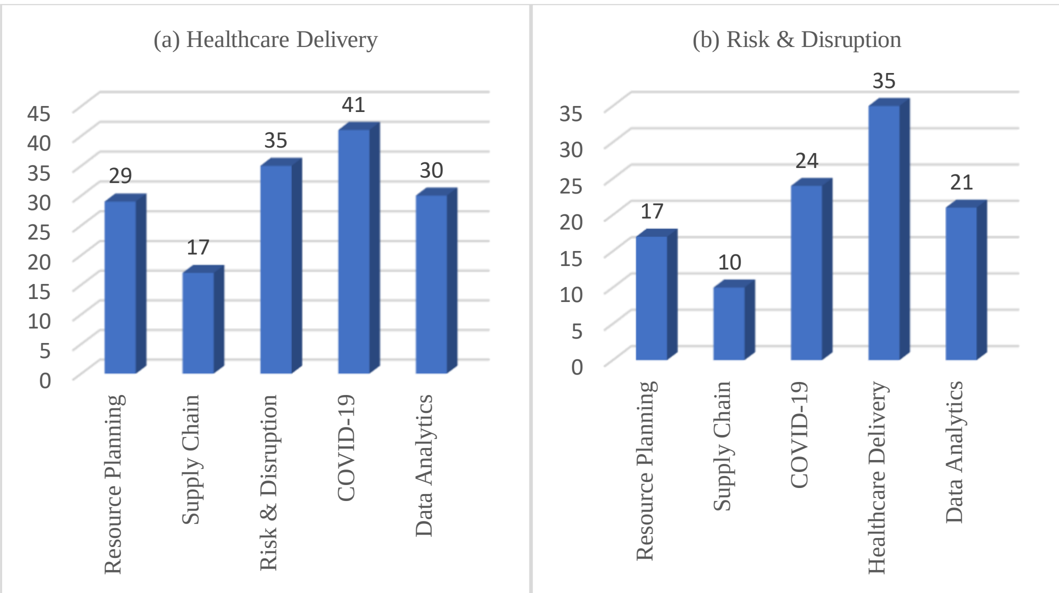

Figure 1: Summary of Reviewed Papers on Healthcare Delivery and Disruption

Sixty-two papers focusing on Resource Planning, Supply Chain, Healthcare Delivery, Data Analytics, Risk and Disruption, and COVID-19 were reviewed (see Appendix A). As demonstrated in Figure 1, it is evident that more research should be conducted to understand the significant impact of resources management (i.e., Supply Chain and Resource Planning) in healthcare delivery and disruption.

Emergency responsiveness relies on proper planning of hospital capacity; hence, effective communication and information systems across the supply chain (SC) [26]. A successful integrated SC system involves the synchronization and sharing of valuable data (e.g., visibility of the resources from suppliers to customers and vice versa) among the stakeholders. Factors such as shipment delays or travel bans during an outbreak can slow down the transport of supplies, influencing the quality of HC delivery [27]. Therefore, alternative mitigation strategies are encouraged to monitor hospitals' inventory levels and empower responsiveness. Inventory management allows for efficient mitigation strategy through having a backup supplier for long-term disruptions [28], or developing statistical forecasting methods [29]. Seventy-nine papers were reviewed to explore how data in healthcare has been leveraged to manage healthcare resources (See Appendix B). Figure 2(a) shows that only a few papers involved the use of predictive analytics in resource management, and many of the papers only proposed qualitative and conceptual approaches.

Information visibility coupled with advanced analytical tools can generate innovative and proactive solutions to improve ongoing processes within the HSC, including inventory management and resource utilization and distribution [30]. Predictive analytics can support a better-integrated health system delivering continuous, coordinated, and comprehensive person-centered care to those who could benefit most [31]. Demand uncertainties are likely to happen during an outbreak, albeit data-based tools can improve stakeholders' collaboration, real-time stock visibility and management, and effective handling of demand variability. Referring to Figure 2(b), the are significant room for improvement in literature to focus on leveraging data analytics in the management of medical equipment, workforce, bed capacity, and material such as diagnostic tools and medications.

While efforts to effectively treat and eradicate the coronavirus continue, so do the efforts of resource planning to support the provision of patient care in the event of a resurgence or future pandemic. Not controlling a disaster such as COVID-19 brings severe disruptions in SCs and the entire healthcare system and, thereby, irreparable losses will come into play [32].

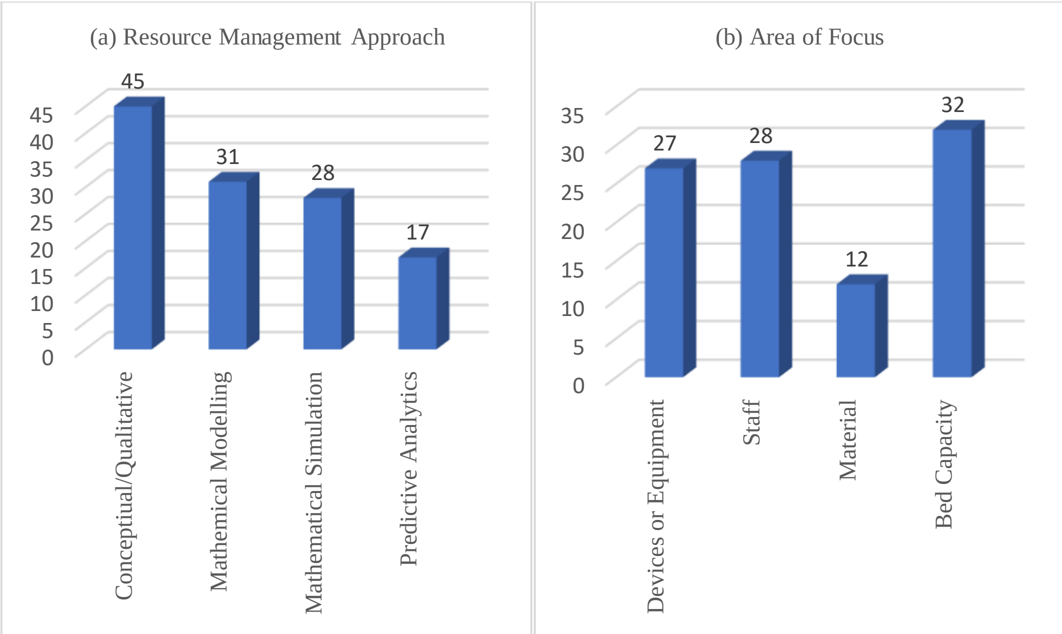

Figure 2: Summary of Reviewed Papers on Resource Planning and Data Analytics

2.2. Telehealth Technology

Global health has focused on slowing down the transmission of COVID-19 and reducing mortality associated with the pandemic by adapting strict strategies and policies. Some of the response strategies recommended by WHO include isolation of confirmed cases, and infection prevention and control measures to ensure the safety of frontliners in HC facilities [1]. Additional strategies for outpatient services were also adopted through providing mail delivery of medicine, telemedicine, virtual patient education, and monitoring [33].

Telehealth allows medical providers to deliver immediate diagnosis and consultations and monitor and screen patients [17]. In fact, a study has shown that sessions using telemedicine can take up to 10 more minutes of consultation, compared to face-to-face visits that usually last less than 10 minutes per patient [34]. Telemedicine has also been useful for patients whose non-urgent visits were canceled or postponed. Pearlman et al. [35] modeled the number of new COVID-19 cases over time in relation to the total volume of hospital encounters and telemedicine visits. With the restrictions of limiting appointments to essential visits only, stay-at-home order, and increase of telemedicine visits, a significant decrease of COVID-19 cases was observed. The adoption of telemedicine decreases the exposure to infection and ensures the safety of patients and HC providers. Additionally, it reduces the need to use medical supplies, reducing the burden on the SC. A hybrid care delivery model that combines in-person visits and telemedicine is, in fact, encouraged in the future, although it needs further assessments and evaluation of the current telehealth model [36].

2.3. Employee Wellbeing

The COVID-19 pandemic surge has caused long-term and persistent psychological consequences among the HC workforces. Several recent studies reported that most frontline employees appeared to suffer from stress, depression, anxiety, insomnia, etc. The increasing demand to combat the pandemic required longer work shifts and minimized social and family support, quickly leading to burnout physically and psychologically [37][38]. These outcomes weaken and incapacitate employees from delivering to patients the quality of care. Implementation of timely psychological counseling and intervention for HC staff are recommended to improve mental health and overall healthcare delivery [39].

2.4. Surveys on COVID-19 Impact on Healthcare

Table 1 summarizes recent literature findings of 74 papers that focused on surveying the medical workforce during the pandemic. Figure 3(a) shows that patient engagement and the effectiveness of telehealth were poorly investigated in the research. Moreover, referring to the detailed literature findings in Appendix C-D, no existing work was found to include all the different areas of focus. Most papers targeted only medical providers who were on the frontline against the pandemic, as illustrated in Figure 3(b); however, more attention should be made to the other groups of employees in healthcare (i.e. managers, support staff, patients, and medical students).

Table 1: Summary of Existing Surveys

		Hospital-Wide	Specific Department	Total
Survey Area of Focus	Staff Wellbeing	27	16	43
	Patient Engagement	3	0	3
	Resource Management	4	8	12
	Telehealth	3	4	7
	Quality of HC Delivery	15	24	39
	Education/ Training	2	6	8
Survey Participants	Managers	4	7	11
	Medical Providers	30	26	56
	Support Staff	5	7	12
	Patients	7	10	17
	Medical Students	2	3	5

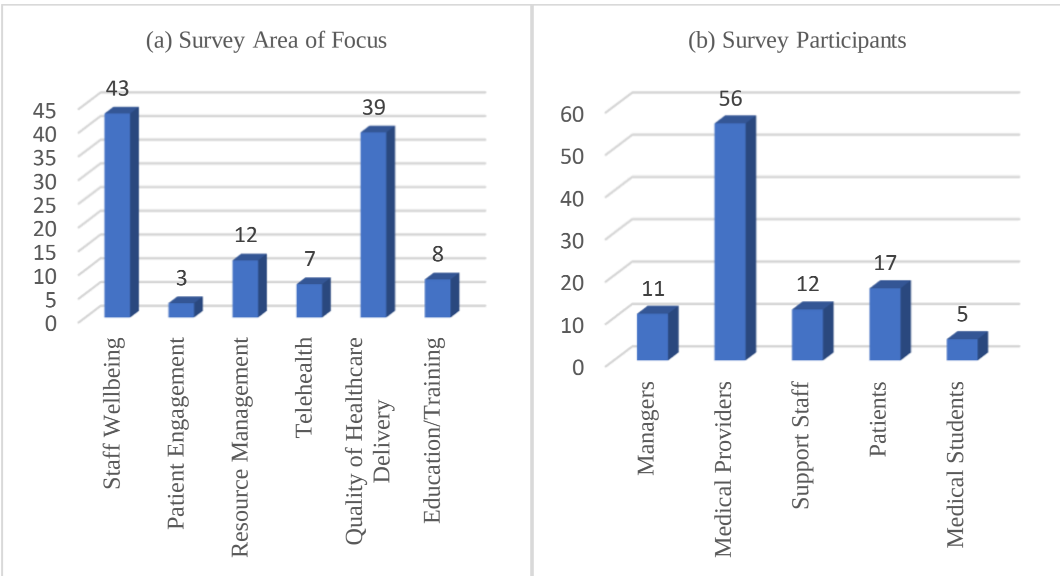

Figure 3: Summary of Reviewed Papers on COVID-19 Related Surveys

Chapter 3. Methodology

This chapter provides the research methodology that was carried out to address the research questions. Figure 4 demonstrates the steps taken from developing the survey to analyzing and interpreting the data.

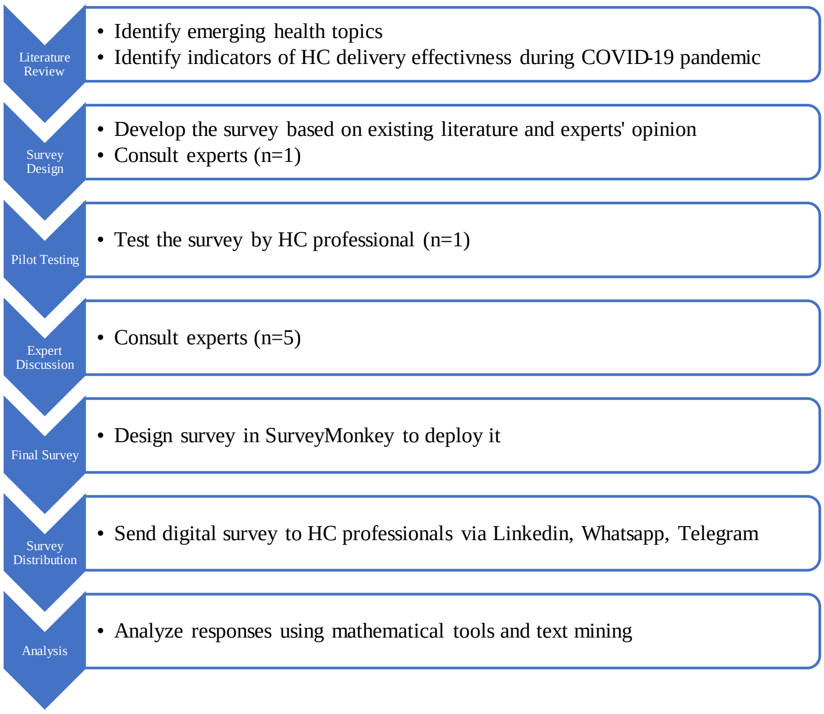

Figure 4: Research Methodology

Based on the extensive literature review on current and previous work focusing on COVID-19 impact on the healthcare system and resource planning, in addition to experts' opinions, factors that drive or determine the effectiveness of healthcare delivery were identified. To understand how the COVID-19 outbreak has affected HC systems' performance, data were collected using a digital questionnaire-based survey via the SurveyMonkey platform. Through this non-interventional research study, reliable organizational-level and personal-level information on health facilities' preparation and response to the COVID-19 pandemic are provided. Institutional Board Review approval was sought and received from the American University of Sharjah prior to survey distribution, and all respondents participated in the survey anonymously. Individuals with a high level of knowledge and/or many years of experience in healthcare were targeted for this research. Responses were later analyzed via SEM, mathematical charts, and text mining.

3.1. Survey Design

The survey consists of 8 categories: Sociodemographic, Staff Mental Health, Level of Communication, Planning & Readiness, Health Delivery Disruptions, Healthcare Supply Chain, Telehealth, and Patient Engagement. The survey questionnaire was designed to address and gather information about the different determinants that could influence the quality of HC delivery. Questions explore hospital preparedness, response, and coping mechanisms of operational, tactical, and human resources, as illustrated in Figure 5. Moreover, the pre-pandemic phase is compared with the control phase (when most people have received their COVID-19 vaccination). The format of the questionnaire is presented in rating-scale, multiple-choice, checkbox, and open-ended questions. A copy of the survey questionnaire can be found in Appendix D.

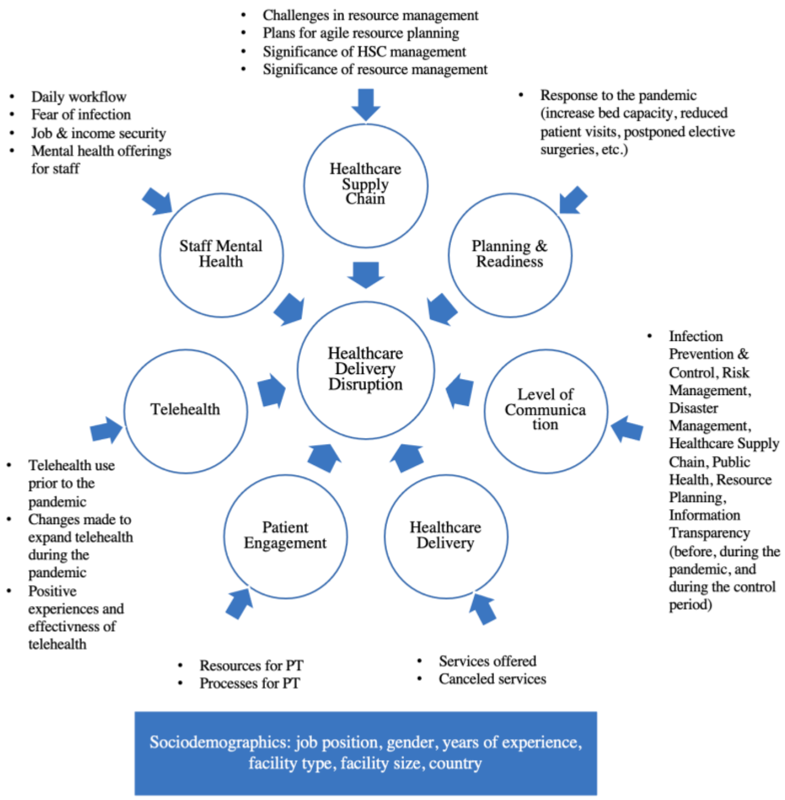

Figure 5: Survey Categories & Component

A first draft was tested by a healthcare professional, and the topics covered in the survey were reviewed by experts in academia and industry. Feedback was used to improve the questions by eliminating redundancies, bias, and unimportant details and by adding essential indicators of HC delivery during the pandemic. Once the survey was approved, three strategies of survey distribution were followed:

- Directly approached HC professionals who work in medical facilities in KSA and UAE, via Linkedin and WhatsApp (n = 289).
- Publicly shared the online survey via Linkedin posts (1000+ connections) and Telegram (11 groups; each with at least 300 members).
- Asked survey participants to share it with their colleagues and work-related WhatsApp groups.

3.2. Structural Equations Modelling

Structural equations modeling (SEM) is a causal inference approach that includes multiple statistical techniques such as multiple regression, covariance, exploratory analysis, and confirmatory factor analysis (CFA). As illustrated in Figure 6, the SEM framework involves measurement and structural models.

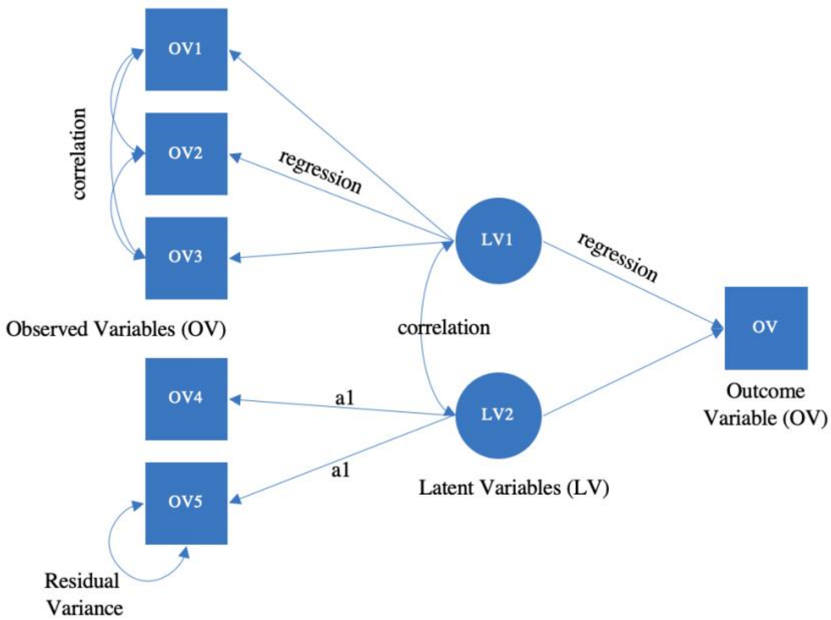

Figure 6: SEM Path Diagram

The measurement model links observed variables with latent variables, and the structural model involves causal analysis relating exogenous variables to endogenous variables [40]. Latent variables do not exist in the data but are constructed from variables observed in the data. Generally, SEM can carry out a set of observed variables (e.g., questions) that are, hypothetically, related to the variable(s) of interest (outcome variable) and represent them in an SEM as predictions of the theory being tested. The desired outcome of SEM can be numeric estimates of the hypothesized relationship or logical implications implying how variables are related and unrelated to each other (i.e., covariance-based analysis) [41].

3.2.1 Path analysis and factor analysis

Figure 6 is a SEM model with multiple latent variables (LV) that can be correlated among each other, and are functions of observed variables (OV) with some loading (e.g., a1). The correlation between observed variables can also be measured. Moreover, the outcome variable is regressed onto latent variables (observed variables, essentially). Any residuals that were not accounted for in the model are referred to as Residual Variance, and they should be of low value for the optimal good fit model.

CFA, specifically, relates latent variables to observed variables, which can be performed in SEM. As explained above regarding the measurement model, CFA allows confirming the underlying psychometric structure of a hypothesized scale that will be tested with respect to the observed data. The closer the hypothesized model is in corresponding to the characteristics of the data observed, the greater the fit. Because latent variables are only a function of the observed variables, a scale must be set for each of those variables to estimate their variances, which can be done with the variance standardization method. This method fixes the variance of each variable to 1 such that the factor loadings are freely estimated, allowing easier interpretation of correlations with relative size [42].

3.2.2 Model fit statistics

3.2.2.1.1. Statistical significance

In general, the null hypothesis states that there is no relationship between the variables being studied, whereas the alternative hypothesis proves the correlation between dependent variables and independent variables. For studies that aim to investigate the causal effects between items, the null hypothesis must be rejected. The smaller the p-value, the stronger the evidence that you should reject the null hypothesis [40].

3.2.2.1.2. Goodness-of-fit indices:

Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI) are among the commonly used relative goodness-of-fit indices in CFA. These indices mainly aim to achieve the same goal, such that they will develop a set of indices that are based on the comparison of the user model with some baseline model. The baseline model usually assume that all variables are allowed to have a variance, but none are allowed to covary with one another; in other words, it assumes that collected data are completely uncorrelated. Thus, these fit indices calculate how much improvement is there in model-fitting by comparing the chi-square and degree-of-freedom of your fitted model relative to the baseline. CFI and TLI generally range between 0 and 1, and values of 0.9-0.95 or above indicate good fit [43].

On the other hand, absolute goodness-of-fit indices, root mean square error of approximation (RMSEA), specifically, do not compare the user model to a baseline model. Instead, it compares it to the observed data and measures the discrepancy via non-centrality parameter, where non-centrality parameter = chi-square (χ^2)– degree of freedom (df). As shown in equation (1) below, the closer this number is to zero, the less discrepancy. In other words, RMSEA values less than or equal to 0.05 indicate good fit, values between 0.05 and 0.08 means that the model is in the borderline of good fit, but if RMSEA is greater than or equal to 0.1, then it is poorly fitted [44].

$$RMSEA = \sqrt{\frac{\chi^2 - df}{df\ (N-1)}}, \text{(N: number of sample)} \qquad (1)$$

3.3. Survey Collection

Data were exported from SurveyMonkey into a Microsoft Excel table, where columns represent sub-questions and rows represent participants. All data were exported in numerical values (e.g., 0, 1…) based on the scales assigned when designing the survey. Lower scores in the survey correspond to a negative impact on HC, whereas higher scores reflect positive impact on HC.

Results of all survey questions are analyzed and represented using Excel, and correlational relationships are investigated with SEM modeling using RStudio. Lastly, text mining using RapidMiner software is performed to analyze the textual responses of open-ended questions.

Chapter 4. Results and Discussion

This chapter presents the interpretation and analysis of survey responses concluded with the use of statistical and mathematical techniques. Moreover, text mining results are also included.

4.1. Data Preprocessing and Preparation

A total of 225 responses were collected from healthcare professionals over ~4 weeks (October 1-27, 2021). Survey responses with ~ 90% completion are included in the graphical representation and SEM modeling. Using RStudio, data preprocessing was performed following these steps:

1. For each category, related sub-questions were averaged to reduce dimensionality. The modified table, containing the averaged sub-questions, was read into RStudio.
2. All variables were scaled to 0:1 range because the raw data contains a different range of scales.
3. The outcome variable was defined as y, which represents "Total Healthcare Disruption" or the average of questions related to HC delivery disruption.
4. Missing Values
    i. Participants who have not answered any question from the Total Disruption were excluded from the analysis (i.e., rows with NA for y were dropped).
    ii. Any other NA value across the columns was replaced with the average responses for that specific category.

After preprocessing the raw data in RStudio to remove the missing values, 123 responses out of 225 were analyzed. All responses to the open-ended questions were analyzed separately using RapidMiner software.

4.2. Survey Results

Table 2 shows details related to the job position, gender, years of experience, type and size of the hospital facility, and country of the 123 respondents. In this work, responses were collected from HCW working in KSA (68%) and UAE (31%) due to the similar structure of the health system in those countries. Participants were classified as managers (n = 56), physicians (n = 13), nurses (n = 5), other medical professionals (n

= 10), and support staff (n = 39). Over three-quarters of them (78%) were male, and 71% of the sample were from large-sized health facilities. Most of the respondents have many years of experience in hospital settings: 60% have more 10 years, 18% have 5-10 years, and 19% have 1-5 years of experience. About the same number of the employees work in a governmental (Gov) health facility (n = 54) and in a private facility (n = 55), but only 14 work in a semi-governmental (Semi-Gov) facility.

Table 2: Sociodemographic characteristics of the study sample.

		Total sample N = 123	Manager n = 56	Physician n = 13	Nurse n = 5	Other MP* n = 10	Support staff* n = 39
Gender, n (%)	Male	96 (78.05)	47 (38.21)	9 (7.32)	1 (0.81)	5 (4.07)	34 (27.64)
	Female	27 (21.95)	9 (7.32)	4 (3.25)	4 (3.25)	5 (4.07)	5 (4.07)
Years of Experience, n (%)	>10	75 (60.98)	43 (34.96)	13 (10.57)	2 (1.63)		17 (13.82)
	5-10	23 (18.70)	11 (8.94)		1 (0.81)	2 (1.63)	9 (7.32)
	1-5	24 (19.51)	2 (1.63)		2 (1.63)	8 (6.50)	12 (9.76)
	<1	1 (0.81)					1 (0.81)
Type of Health Facility, n (%)	Gov	54 (43.90)	14 (11.38)	8 (6.50)	4 (3.25)	7 (5.69)	21 (17.07)
	Private	55 (44.72)	38 (30.89)	5 (4.07)	1 (0.81)	2 (1.63)	9 (7.32)
	Semi-Gov	14 (11.38)	4 (3.25)			1 (0.81)	9 (7.32)
Size of Health Facility, n (%)	Large	88 (71.54)	36 (29.27)	6 (4.88)	4 (3.25)	6 (4.88)	36 (29.27)
	Medium	34 (27.64)	20 (16.26)	6 (4.88)	1 (0.81)	4 (3.25)	3 (2.44)
	Small	1 (0.81)		1 (0.81)			
Country, n (%)	KSA	84 (68.29)	28 (22.76)	9 (7.32)	4 (3.25)	10 (8.13)	33 (26.83)
	UAE	39 (31.71)	28 (22.76)	4 (3.25)	1 (0.81)		6 (4.88)

*Other MP (medical professional) include therapists, radiographers, pharmacists, etc.
*Non-clinical support staff include biomedical engineer, IT, admin assistant, receptionist, etc.

The following tables (Table 3-17) summarize the results of the survey questions. The percentage rates correspond to the count of scores for each question. As mentioned, low scores are assigned to choices implying a negative effect on HC. In Table 3, for example, “Strongly Agree” has “0” score in Q9. Conversely, high scores are assigned to items implying a positive effect on HC. For Q11, “Very Good” has a score of “5”.

Table 3: Psychological Impact on HCW

Q9. Rate how much you agree with the following statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
COVID-19 pandemic has impacted my daily workflow	52.05%	43.09%	2.44%	0.81%	1.63%
I feel overwhelmed at work due to the COVID-19 pandemic	24.39%	47.21%	19.51%	6.50%	2.44%
I would want more information about the pandemic from the hospital leadership	14.63%	39.21%	23.58%	18.70%	4.07%
Q10. How much does each affect your psych during the pandemic:	**Very Much**	**Somewhat**	**Very Little**	**Not At All**	**Not Applicable**
The fear of being infected by/with COVID-19	27.64%	39.50%	25.20%	5.69%	2.44%
The fear of relatives being infected by/with COVID-19	54.47%	31.71%	10.57%	0.81%	2.44%
Change of work mode/style	31.71%	52.09%	9.76%	6.50%	0.00%
Lower income	21.14%	28.46%	13.01%	26.83%	10.57%
Isolation and restrictions	39.02%	38.45%	15.45%	6.50%	0.81%
Uncertainty regarding the pandemic duration	48.78%	34.15%	11.38%	4.88%	0.81%
Job security	22.76%	26.10%	17.07%	23.58%	10.57%

Table 4: Psychological Impact on HCW (cont.)

Q11. How good are mental health benefits/offerings to support employees at your facility:	Very Good	Good	Neutral	Bad	Very Bad	There are no benefits / offerings
Existing mental health benefits/offerings (prior to the pandemic)	26.02%	26.83%	26.02%	5.69%	2.44%	13.01%
Newly added mental health benefits/offerings (during the pandemic)	21.14%	28.46%	26.02%	4.88%	2.44%	17.07%

Table 5: Level of Communication

Q12. Before COVID-19 pandemic:	Very Good	Good	Neutral	Bad	Very Bad
IP&C	45.53%	43.90%	8.94%	1.63%	0.00%
Risk Management	34.15%	47.97%	17.07%	0.81%	0.00%
Disaster Management	34.96%	51.22%	11.38%	1.63%	0.81%
HSC	31.71%	52.85%	10.57%	2.44%	2.44%
Public Health	24.39%	54.47%	17.07%	4.07%	0.00%
Resource Planning	24.80%	51.22%	17.07%	5.69%	1.63%
Information Transparency	19.51%	54.90%	19.51%	5.69%	0.81%
Q13. During the peak of the pandemic:	Very Good	Good	Neutral	Bad	Very Bad
IP&C	67.21%	25.41%	4.92%	2.46%	0.00%
Risk Management	56.56%	33.61%	8.20%	1.64%	0.00%
Disaster Management	59.02%	34.43%	4.92%	1.64%	0.00%
HSC	43.80%	33.61%	10.66%	8.20%	4.10%
Public Health	48.54%	36.07%	13.11%	1.64%	0.82%
Resource Planning	43.44%	37.70%	12.30%	6.56%	0.00%
Information Transparency	50.82%	33.61%	8.20%	5.74%	1.64%
Q14. During the control phase:	Very Good	Good	Neutral	Bad	Very Bad
IP&C	68.50%	30.00%	0.83%	0.83%	0.00%
Risk Management	63.01%	33.33%	3.33%	0.00%	0.83%
Disaster Management	62.83%	30.83%	5.00%	0.83%	0.83%
HSC	49.17%	39.17%	8.33%	1.67%	1.67%
Public Health	55.17%	33.33%	10.00%	1.67%	0.00%

Resource Planning	50.00%	35.83%	10.83%	1.67%	1.67%
Information Transparency	48.33%	40.00%	9.17%	1.67%	0.83%

Table 6: Planning and Readiness

Q15. How has your facility changed the treatment plans during the COVID-49 pandemic?	
Nothing has changed	22.31%
Canceled all treatments until the end of the pandemic	5.79%
Canceled all treatment until the end of the alert phase of the pandemic	15.70%
Performed emergency treatments	56.20%

Table 7: Planning and Readiness (cont.)

Q16. During the peak of the pandemic, how successful was your facility in:	Very Successful	Successful	Somewhat Successful	Unsuccessful	Very Unsuccessful	I Don't Know or Not Applicable
Increasing the number of hospital beds	42.28%	30.89%	15.45%	1.63%	1.63%	8.13%
Building tents outside the hospital to deliver medical services	23.58%	24.39%	12.20%	4.88%	2.44%	32.52%
Decreasing emergency room visits and hospital admission	30.08%	36.59%	21.95%	1.63%	0.81%	8.94%
Expanding medical clinic hours	30.08%	30.08%	11.38%	9.76%	1.63%	17.07%
Expediting discharge of hospitalized stable patients	39.02%	39.84%	11.38%	2.44%	0.00%	7.32%
Canceling or postponing elective surgeries	44.72%	32.52%	16.26%	0.00%	0.00%	6.50%
Converting operating rooms into intensive care units	21.14%	22.76%	10.57%	4.07%	1.63%	39.84%

Converting regular hospital beds into acute patient rooms	38.21%	33.33%	15.45%	1.63%	0.00%	11.38%
Converting "flat spaces" (lobbies, waiting rooms, hallways) to operating bed capacity	13.82%	17.89%	8.94%	4.07%	2.44%	52.85%
Maintaining an appropriate staffing level	26.02%	38.21%	28.46%	2.44%	4.88%	0.00%
Identifying the minimum staffing needs and prioritizing critical services based on essential hospital operations	36.59%	31.71%	21.14%	3.25%	3.25%	4.07%

Table 8: Healthcare Delivery

Q19. What were the reasons behind cancelling any elective service during the peak of pandemic?	
Less beds are available due to occupancy by COVID-19 patients.	34.96%
Patients were postponed because they were required to do a coronavirus test.	31.71%
Some patients were found to have a positive test.	32.52%
Patients chose to postpone their surgeries for fear of getting infected in the hospital.	45.53%
Less staff at the hospital because some of them had positive tests	19.51%
The department was locked down temporarily for disinfection.	24.39%
You have chosen to reduce or cancel elective procedures for fear of cross-infection.	43.09%
You have chosen to reduce or cancel elective procedures for fear of cross-infection.	8.13%

Table 9: Healthcare Delivery Disruption

How much do you agree with the statement below?	Totally Disagree	Disagree	Neutral	Agree	Totally Agree
Q20. "At the peak of the pandemic, the hospital experienced a surge of	4.92%	14.75%	31.15%	34.43%	14.75%

emergency patients in compared with other facilities"					
Q21. "The COVID-19 pandemic has impacted the everyday clinical practice in my facility"	7.38%	3.28%	13.93%	48.36%	27.05%

Table 10: Healthcare Delivery Disruption (cont.)

Q23. How significant are each of the following in being an obstacle to patient care during this crisis?	Highly Significant	Moderately Significant	A Little Significant	Not At All
Insufficient healthcare workers prior to the pandemic	24.17%	41.67%	16.67%	17.50%
Insufficient healthcare workers due to sick leave or exposure to high-risk contacts	36.67%	34.17%	20.00%	9.17%
Lack of personal protective equipment	18.33%	25.00%	22.50%	34.20%
Lack of medicine	12.50%	20.83%	23.33%	43.67%
Insufficient hospitalization room	22.50%	30.83%	27.50%	19.17%
Unawareness or absence of COVID-19 care protocols	15.20%	25.83%	21.67%	37.30%
Lack of ventilators or other life support devices	15.83%	29.17%	23.33%	31.70%
Lack of serological tests or PCR to identify positive cases	13.33%	24.17%	18.33%	44.32%
Forced lockdown restrictions	30.25%	30.25%	21.01%	18.49%
Q24. How much do you think COVID-19 will have an impact on each of the following:	High Impact	Moderate Impact	Little Impact	Not At All
Appointment planning	50.00%	31.67%	11.67%	6.67%
Patient accessibility to services	44.17%	30.00%	20.83%	5.00%
Collection of patient data	29.20%	29.20%	25.83%	15.83%
Examination	37.05%	30.83%	20.00%	12.50%
Treatment planning	35.33%	32.50%	19.17%	13.33%
Patient throughput	32.83%	27.50%	27.50%	12.50%
Patient follow-ups	35.33%	35.83%	16.67%	13.33%
Personnel availability	39.33%	28.33%	20.00%	12.50%
Healthcare supply chain	43.50%	31.67%	11.67%	13.33%
	Yes	In Progress	No	I Don't Know

Q25. Is a plan being developed or already in place to monitor the impact of the temporary suspension of emergency and elective services?	74.79%	5.88%	6.72%	12.61%

Table 11: Healthcare Supply Chain

Q26. Has your facility encountered any of the following resources challenges during the outbreak?	Yes	No	I Don't Know
High consumption of COVID-19 related supplies	78.89%	8.89%	12.22%
Shortage in COVID-19 diagnostic testing supplies	36.67%	46.67%	16.67%
Shortage in ventilators or other life-support devices.	33.33%	51.11%	14.44%
Overstocked and obsolete inventory due to canceled services	26.67%	37.78%	32.22%
Extended delays in receiving medical supplies from vendors/suppliers	63.33%	13.33%	21.11%
Challenges in estimating the quantities of required supplies	61.11%	20.00%	18.89%
Challenges in prioritizing patients with emergency needs due to limited capacity/resources	48.89%	31.11%	20.00%
Q27. Which of the following statements is valid about your facility?	**Yes**	**No**	**I Don't Know**
We estimated the quantities of essential patient care medications, materials and equipment, and PPE that would be needed during the pandemic phase	77.79%	7.14%	15.18%
We developed a list of alternative suppliers for essential medications and devices and a strategy to address shortages	71.54%	10.71%	17.86%
We made a plan to ensure the availability of essential patient care medications, materials and equipment, and PPE needed during the lockdown	76.79%	6.25%	16.96%

Table 12: Healthcare Delivery Disruption (cont.)

Q28. How significant are each of the following in disrupting the healthcare supply chain at your facility during the outbreak?	Highly Significant	Moderately Significant	A Little Significant	Not At All
Insufficient hospital capacity planning	19.82%	33.43%	27.03%	19.82%
Inadequate profits for healthcare firms	20.72%	30.63%	21.62%	27.03%
Improper management of risk, waste, and inventory (e.g., tracking, visibility…)	18.92%	31.63%	23.42%	26.13%
Lack of collaborative and strategic planning	14.41%	29.83%	24.32%	31.63%
Lack of communication, transparency, flexibility, and trust	16.22%	28.83%	21.62%	33.53%
Reduced supply chain diversification	12.61%	44.54%	23.42%	19.82%
Unsustainable just-in-time manufacturing.	15.32%	36.33%	29.73%	18.92%
Forced lockdown restrictions	28.97%	34.64%	24.30%	13.08%
Q29. How significant is each of the following in managing the healthcare supply chain and mitigating pandemic disruptions?	**Highly Significant**	**Moderately Significant**	**A Little Significant**	**Not At All**
Include multiple suppliers and safety stock	38.18%	36.36%	20.91%	4.55%
Improve cooperation between suppliers, consumers, and governmental entities	45.45%	33.64%	14.55%	6.36%
Develop risk management and emergency plans	50.90%	36.36%	8.18%	5.45%
Implement or enhance the use of information technology and analytics	49.09%	33.64%	11.82%	5.45%
Develop an agile and innovative culture in the supply chain	38.18%	40.10%	15.45%	6.36%

Table 13: Telehealth Usage

Q30. Rate each of the following statement:	Yes	Somewhat	No	I Don't Know
Before COVID-19, telehealth was never used	26.17%	43.93%	22.43%	7.48%

Telehealth application has been reduced with the control period in the COVID-19 era (vaccination)	29.91%	50.47%	12.15%	7.48%
Telehealth has been excessively used during the first wave	47.66%	38.32%	7.48%	6.54%
My facility has made changes to expand the accessibility to better telehealth	59.81%	30.84%	3.74%	5.61%
Changes in telehealth accessibility will become permanent in my facility	50.81%	35.51%	2.80%	11.21%

Table 14: Telehealth Usage (cont.)

Q31. Which telehealth modalities has your facility practiced and were effective?	
Virtual home health	52.43%
Near-virtual office visits	21.36%
Virtual visits	62.14%
On-demand virtual urgent care	32.04%
Tech-enabled home medication administration	33.98%
Telephonic delivery	53.40%
Video-based virtual visits	52.43%
Q34. Virtual visits have been most effective for these services	
Initial assessment of condition	58.65%
Ongoing treatment of condition	74.04%
Emergency attention	33.65%
Mental/behavioral health	41.35%

Table 15: Telehealth Usage (cont.)

Q33. How much do you agree or disagree with the following statements?	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
I view telehealth more favorably than I did before the pandemic, and I'm motivated to increase its use in my practice	49.52%	22.86%	18.10%	8.57%	0.95%
Telehealth improved the health of the patients	35.24%	28.57%	26.67%	8.57%	0.95%

Telehealth improved the satisfaction of my work	35.24%	23.81%	31.43%	7.62%	1.90%
Improved the timeliness of care for the patients	38.10%	36.19%	21.90%	3.81%	0.00%
Telehealth needs incentive structures to realize its full potential	48.57%	31.43%	17.14%	2.86%	0.00%
Telehealth will become an important priority in our health care activities post-pandemic	44.76%	27.62%	24.76%	2.86%	0.00%
Telehealth is improving the traditional health care delivery system	42.86%	32.38%	20.95%	3.81%	0.00%
Telehealth will decrease the cost of health care	39.10%	33.33%	24.76%	2.86%	0.00%
Telehealth may carry the risk of jeopardizing the safety and privacy of patients	29.52%	33.38%	24.76%	11.43%	0.95%

Table 16: Resources and Processes for Patient Engagement (PE)

Q35 and Q36: Which of the following processes and resources dealing with PE have existed or newly implanted in your facility?	Exist but not implemented	Never existed and not implemented	Exist before, and is implemented	Newly implemented
Hospital strategic plan includes PE	3.25%	0.00%	63.41%	33.33%
Policy specific to PE	4.07%	17.07%	66.67%	12.20%
Operational funding dedicated to PE activities	16.26%	8.13%	69.92%	5.69%
Executive/manager responsible for PE	9.76%	13.01%	67.48%	9.76%
Senior executives promote or incentivize PE	9.76%	4.88%	82.93%	2.44%
Staff working for PE manager on PE	10.57%	12.20%	68.29%	8.94%

Staff liaison for patients involved in PE	10.57%	10.57%	75.61%	3.25%
PE training for patients	7.32%	8.13%	81.30%	3.25%
PE training for clinicians/staff	4.88%	12.20%	78.86%	4.07%
Ongoing training for patients after onboarding	11.38%	7.32%	78.05%	3.25%
Patient involvement in evaluation of PE	8.94%	5.69%	78.05%	7.32%

Table 17: Specialities with canceled services, significant disruption, and telehealth offerings

Specialty	Canceled services during the peak	Disrupted services during the pandemic	Offered telehealth services
Emergency	5.69%	47.97%	15.45%
General Medicine	17.89%	24.39%	57.72%
Cardiology	5.69%	15.45%	34.15%
ICU*	4.07%	39.84%	10.57%
Neurology	11.38%	8.94%	30.89%
Oncology	5.69%	11.38%	21.95%
Gynecology	8.94%	16.26%	23.58%
Urology	13.82%	11.38%	26.02%
ENT*	27.64%	24.39%	27.64%
Radiology	5.69%	13.01%	10.57%
Pathology	4.88%	8.94%	6.50%
General Surgery	34.96%	30.89%	13.01%
Neurosurgery	14.63%	18.70%	12.20%
Cardiac Surgery	11.38%	18.70%	9.76%
Nephrology	9.76%	12.20%	17.07%

Gastroenterology	13.82%	12.20%	23.58%
Dermatology	34.15%	19.51%	34.96%
Dental/Oral	50.41%	31.71%	10.57%
Ophthalmology	25.20%	17.07%	18.70%
Psychiatry	17.07%	10.57%	30.08%
Rheumatology	15.45%	8.13%	23.58%
Hematology	10.57%	8.94%	19.51%
Pulmonary Medicine	6.50%	25.20%	21.95%
Infectious Diseases	4.07%	30.89%	26.83%

*ICU: Intensive Care Units, ENT: Ear, Nose and Throat Medicine.

4.3. Graphical Interpretation

4.3.1 Responding to the COVID-19 outbreak

When WHO declared the COVID-19 outbreak in the early year of 2020, rapid efforts were made to keep patients and HCW from viral transmissions and health complications while working with governments worldwide. Most health facilities followed strict safety measures and implemented strategies to deliver optimal care during the pandemic while minimizing cross-infection. Protocols include postponing elective treatments, leveraging telehealth technologies, and improving the management of healthcare resources [1]. More than 55.20% of the surveyed participants reported that their facility only performed emergency procedures at the beginning of the outbreak. Besides following the suggested measures by WHO, there were other multiple reasons related to hospital capacity and patient preferences, as shown in Figure 7. The top two reasons were either the facility (43.09%) or the patient (45.53%) choosing to postpone elective procedures due to fear of cross-contamination in hospitals.

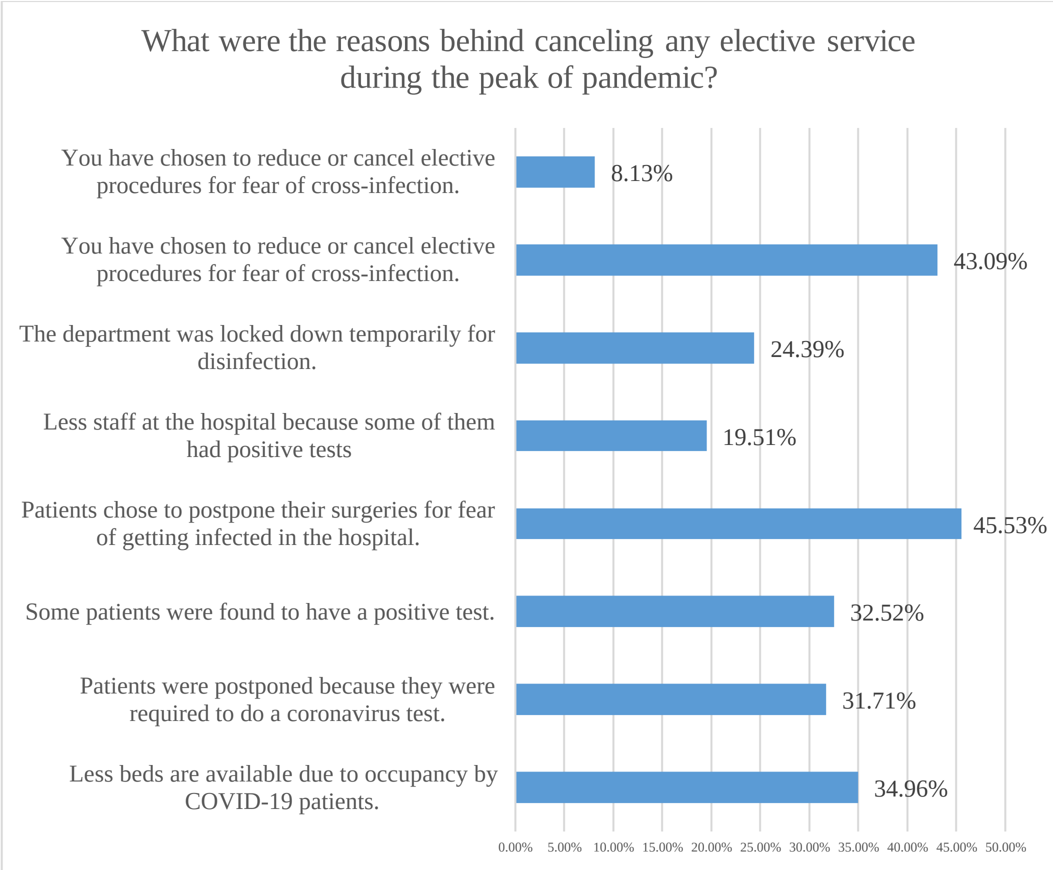

Figure 7: Response rate for the reasons behind canceling elective services during the outbreak.

To accommodate more patients, many hospitals had to increase the capacity of their resources while prioritizing critical services based on essential hospital operations. Some had to convert waiting rooms or lobbies to operating bed capacity or even build tents outside the hospital to deliver medical services. When participants were asked to rate how successful was their facility in fighting the pandemic in terms of operational excellence, large-sized governmental facilities scored higher success (see Table 18).

Table 18: Very Successful response rate to the question: how successful was your facility in:

	Gov			Private		Semi-Gov	
	Large	Medium	Small	Large	Medium	Large	Medium
Increasing hospital beds	23	1		15	8	5	

Building tents	14			5	5	5	
Decreasing ED visits and hospital admission	21	3		4	4	5	
Expanding clinic hours	14	3		7	9	4	
Expediting discharge of stable patients	18	4		8	11	6	1
Canceling or postponing elective surgeries	24	3	1	9	12	5	1
Converting OR into ICU	13	1		7	2	3	
Converting regular beds into acute patient rooms	23	3		9	8	4	
Converting flat spaces to operating bed capacity	8			3	2	4	
Maintaining staffing level	14	1	1	6	5	5	
Identifying staffing needs	19	3	1	7	8	6	1

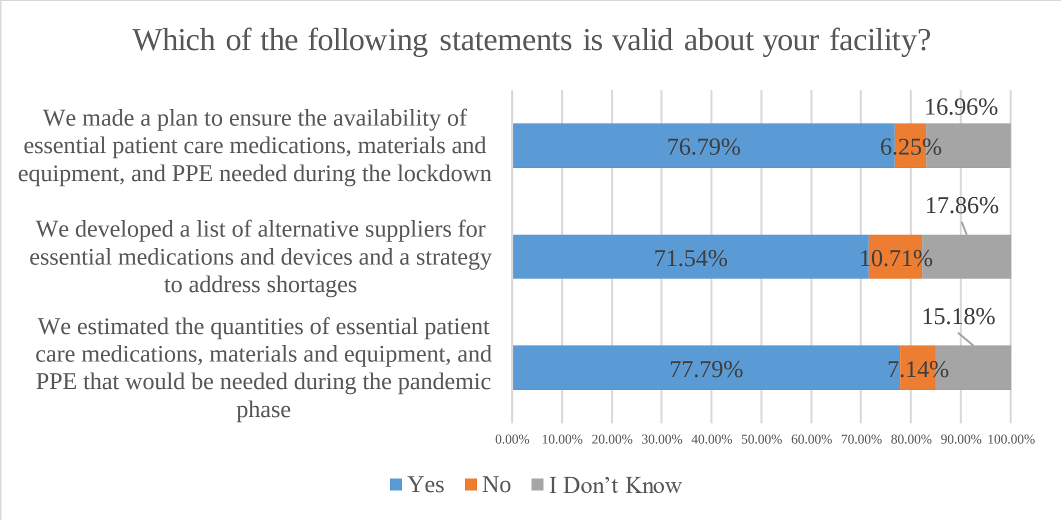

Figure 8: Plans for the supplies availability

A few participants working in private and governmental facilities said that their facility hadn't developed a list of alternative suppliers or a strategy to address shortages (Table 19). However, over 77% reported that their facility has had a plan to estimate the quantities and ensure the availability of essential supplies during the outbreak (Figure 8). Similarly, 74% of the participants agree that there is a plan to monitor the impact of service suspension, but 6.72% working in private (n = 42), governmental (n = 37), and semi-governmental (n = 10) facilities reported no plans (Figure 9, Table 20).

Table 19: "No" response rate to statements regarding resource planning.

	We estimated the quantities of essential patient care medications, materials and equipment, and PPE that would be needed during the pandemic phase.	We developed a list of alternative suppliers for essential medications and devices and a strategy to address shortages.	We made a plan to ensure the availability of essential patient care medications, materials and equipment, and PPE needed during the lockdown.
Gov	3	6	3
Private	5	6	4

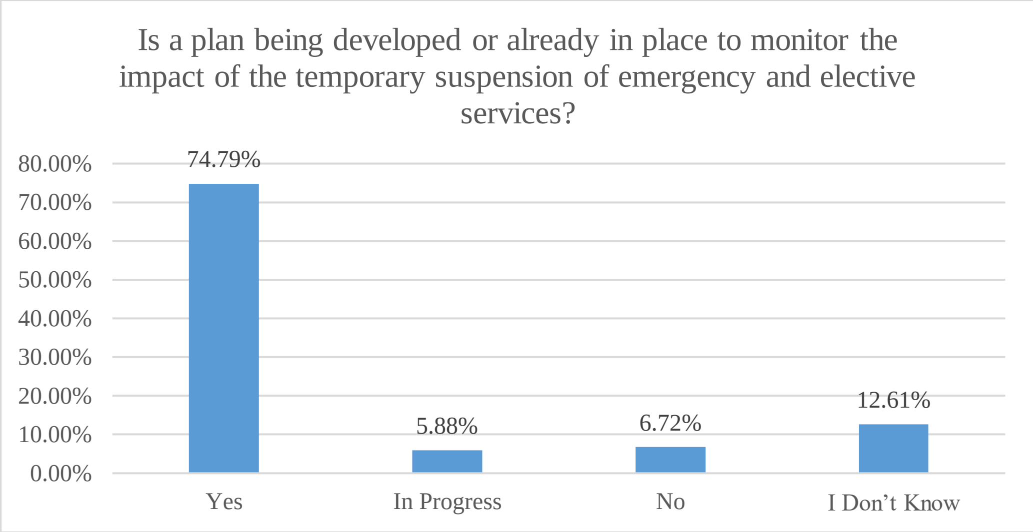

Figure 9: Existing plan to monitor the impact of services suspension

Table 20: "No" response rate to "Is a plan being developed or already in place to monitor the impact of the temporary suspension of emergency and elective services?".

Is a plan being developed or already in place to monitor the impact of the temporary suspension of emergency and elective services?	
Governmental Sector	37
Private Sector	42
Semi-Government Sector	10

4.3.2 Challenges encountered

4.3.2.1. Challenges in resource planning and capacity management

As many patient-care services were canceled in the early period, insufficient medical resources and capacity were not a direct obstacle to patient care. A high number of participants working in governmental facilities reported that lack of resources was not a significant obstacle to patient care, nor to the healthcare supply chain (see Table 21 and Table 22). Perhaps because many of their patient-care services were canceled at the peak of the pandemic and alternative care delivery modalities took place, and/or because they were provided with enough resources to withstand the outbreak. However, about 60% believe that forced lockdown restrictions have high-to-moderate significance in being an obstacle to patient care (Figure 10).

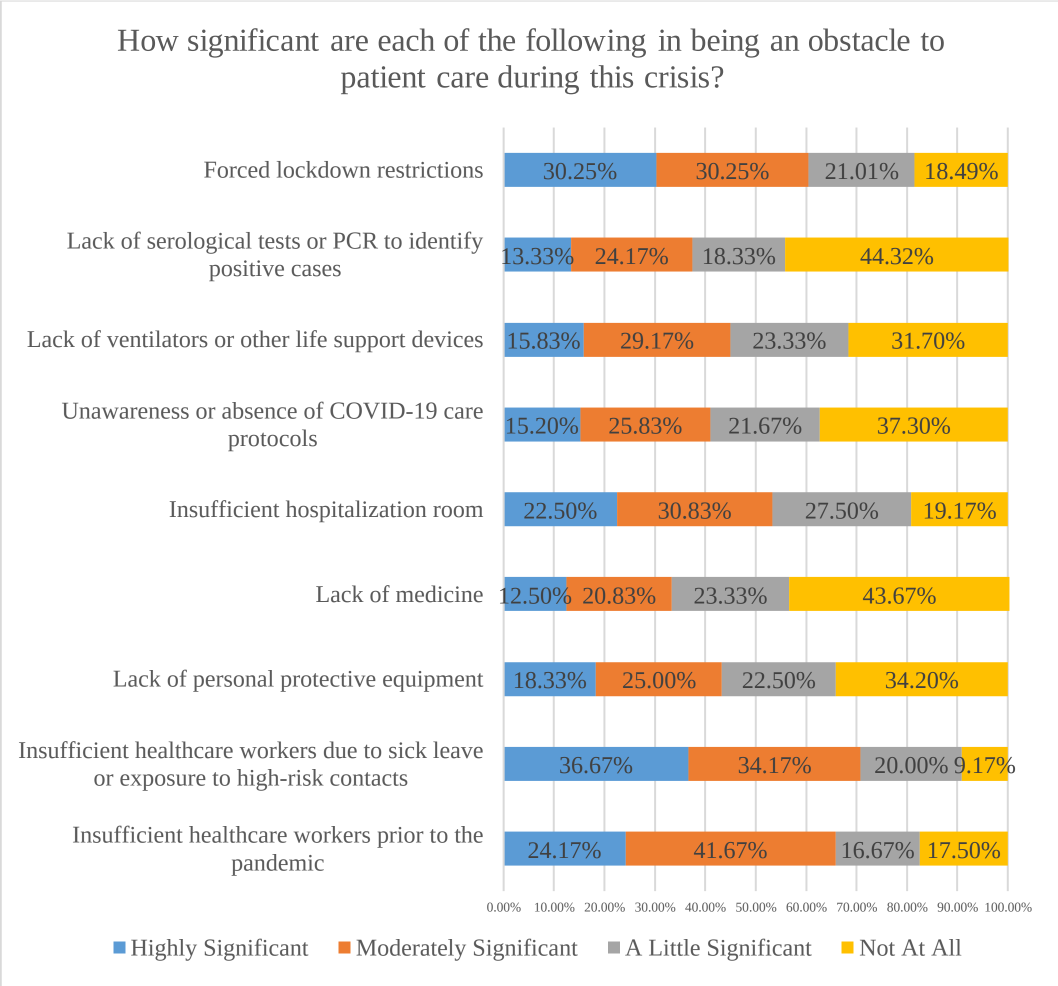

Figure 10: Obstacles to patient care during the outbreak

Table 21: "Not At All" response rates to how significant these items in being obstacles to patient care.

	Gov			Private		Semi- Gov	
	Large	Medium	Small	Large	Medium	Large	Medium
Insufficient healthcare workers prior to the pandemic.	9		1	4	5	2	

Insufficient healthcare workers due to sick leave or exposure to high-risk contacts.	6	1		3		1	
Lack of personal protective equipment.	20	1		5	9	4	1
Lack of medicine.	22	2	1	5	13	6	1
Insufficient hospitalizatio n room.	10	1		2	7	2	1
Unawareness or absence of COVID-19 care protocols.	19	2		7	12	4	
Lack of ventilators or other life support devices.	17	2	1	3	10	3	1
Lack of serological tests or PCR to identify positive cases.	22	3	1	9	12	4	
Forced lockdown restrictions.	7	3		3	7	2	

Table 22: "Not At All" response rate to the following items being a factor to disrupt HSC.

	Gov			Private		Semi- Gov	
	Large	Medium	Small	Large	Medium	Large	Medium
Insufficient hospital capacity planning	10			3	6	3	
Inadequate profits for healthcare firms.	19	1	1	4	2	2	1
Improper management of risk, waste, and inventory (e.g. tracking, visibility…).	13	2	1	5	5	3	
Lack of collaborative and strategic planning.	15	2	1	7	5	4	
Lack of communication, transparency, flexibility, and trust.	14	3	1	7	7	3	
Reduced supply chain diversification.	8	2	1	4	3	4	
Unsustainable just-in-time manufacturing.	8	1	1	4	4	3	
Forced lockdown restrictions.	7			2	4	1	

Approximately 27%, mostly working in large governmental hospitals, stated that inadequate profits were insignificant in disrupting HSC (Figure 11 and Table 23). Indeed, the size of investment determines the capital investment in planning [45].

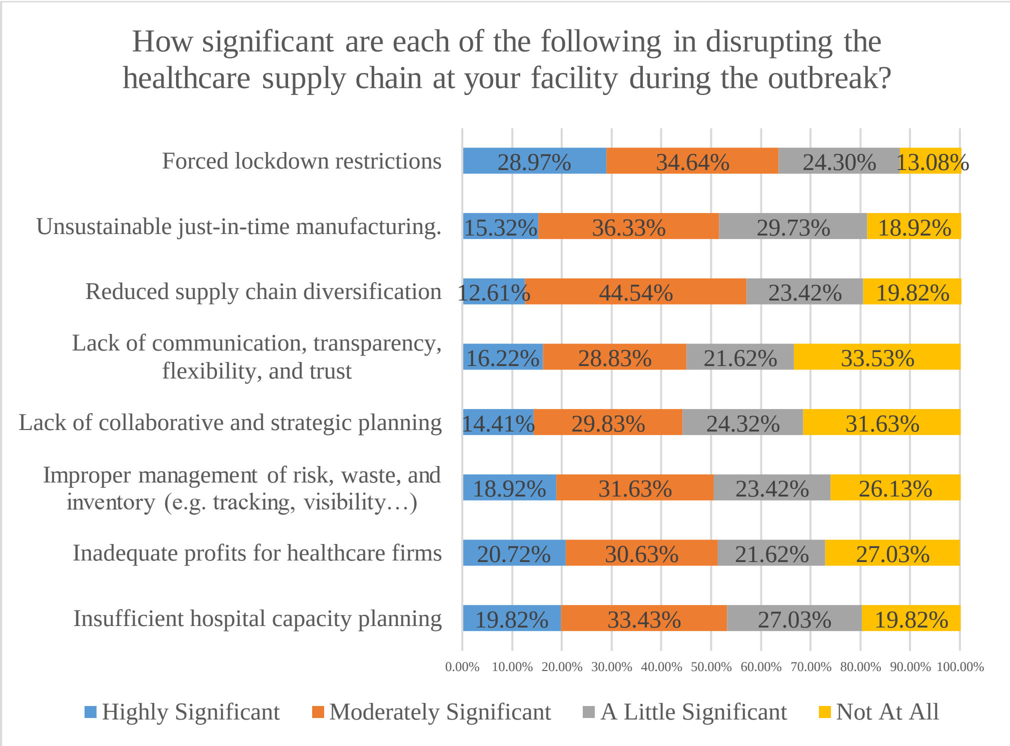

Figure 11: Factors disrupting HSC during the pandemic

Table 23: "Not At All" response rate to inadequate profit being a factor to disrupt HSC

Significance of (Inadequate profits for healthcare firms) in disrupting HSC		
Governmental	Large facility	19
	Medium facility	1
	Small facility	1
Private	Large facility	4
	Medium facility	2
Semi- Governmental	Large facility	2
	Medium facility	1

Hospitals with designated wards for COVID-19 patients were overburdened during the first peak, especially that under-equipped or rural hospitals referred those patients to them [4]. Over 48% of respondents agree and totally agree that their hospital experienced a surge of emergency patients compared with other facilities; many of them worked in large governmental hospitals, as shown in Figure 12 and Table 24. Additionally, more than 95% of the participants agree and totally agree that the pandemic has affected their everyday workflow, and over 71% feel overwhelmed at work (Figure 13).

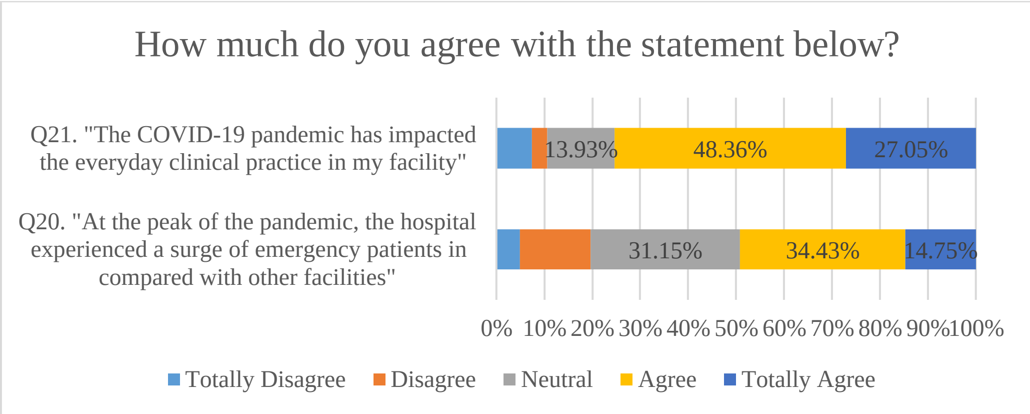

Figure 12: COVID-19 impact on clinical practice, and patients surge

Table 24: "Agree" and "Totally Agree" responses rates to Q20.

		Agree	Totally Agree
Gov	Large	21	6
	Medium	1	2
	Small	1	
Private	Large	6	5
	Medium	9	5
Semi-Gov	Large	4	
	Medium		

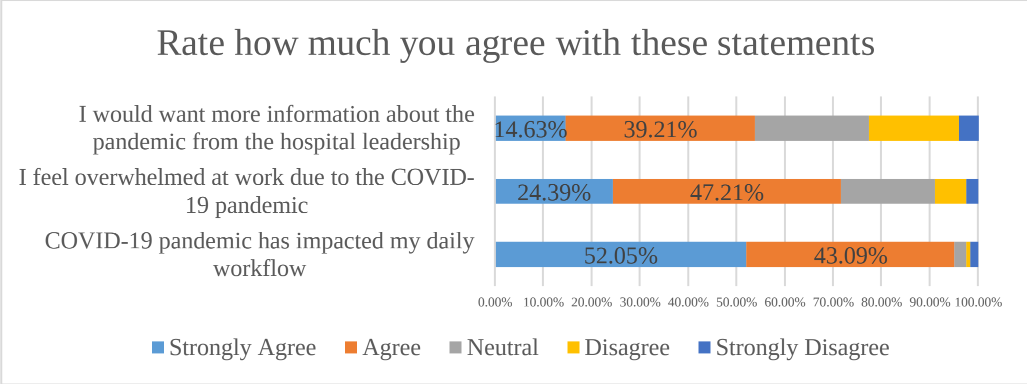

Figure 13: The pandemic's overwhelming influence on HCW

4.3.2.2. Psychological impact on healthcare workers

The unprecedented demand of HCW forced them to work long hours under pressure, lacking some resources and exposed to COVID-patients [46]. A high percentage of participants say that their mental health is greatly or somewhat affected by "fear of being infected" (~67%), "fear of infecting relatives" (~86%), "isolation and restriction" (~77%), "change of work mode" (~83%), and "pandemic-associated uncertainty" (~82%) (Figure 14). Respondents also reported an overall good rating of mental health offerings for employees, but around 26% feel neutral about them (Figure 15).

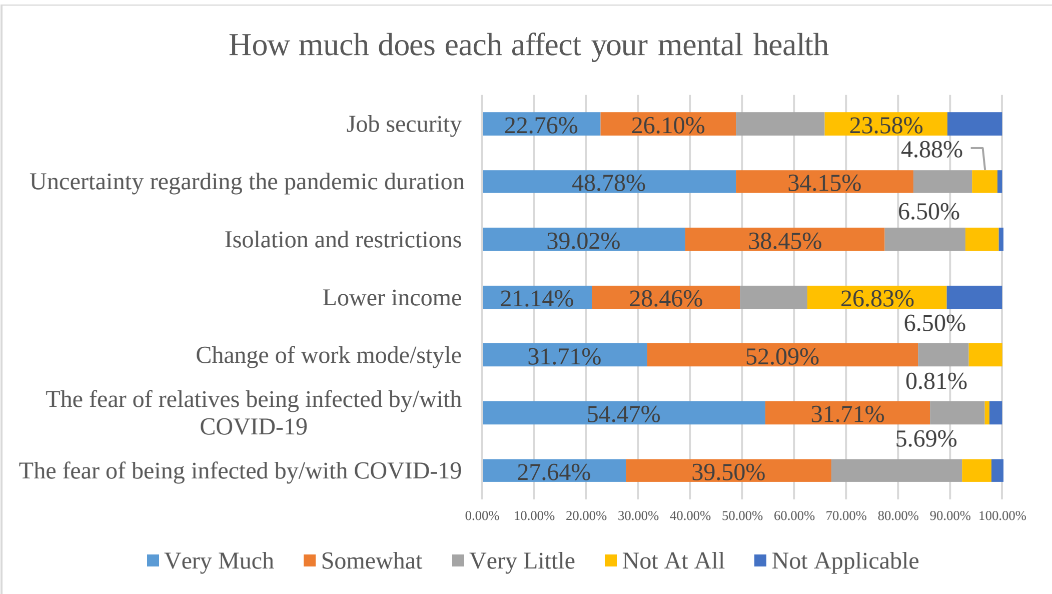

Figure 14: COVID-19 impact on psychological wellbeing

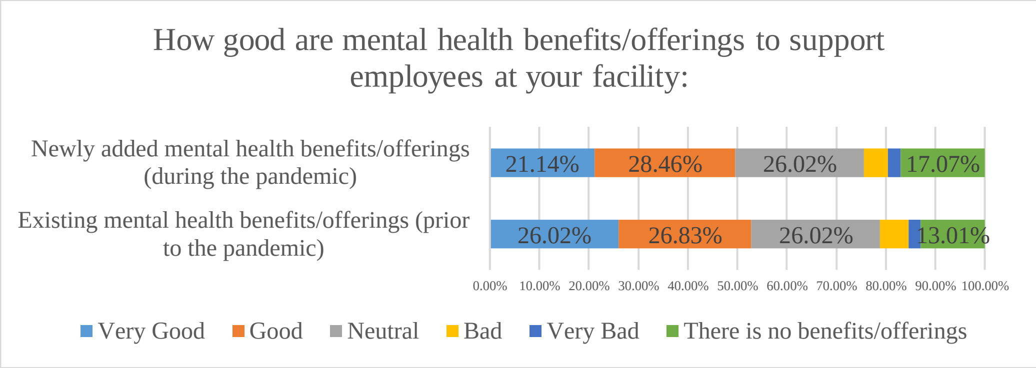

Figure 15: Mental health offerings for HCW

Surprisingly, job security and lower income did not affect the mental health of some participants. Looking at Table 25, many of the participants who answered "Not At All" to those two factors have a working experience for more than 10 years, are considered managers or support staff, and/or are working in governmental hospitals.

Table 25: " Not At All" response rate to Job Security and Low Income impacting the psychological wellbeing.

	Job Security	Lower income
Manager	13	15
More than 10 years	11	12
Governmental Sector	1	4
Private Sector	9	7
Semi-Government Sector	1	1
5-10 years	2	3
Governmental Sector	2	2
Private Sector		1
Non-clinical support staff	13	12
More than 10 years	11	7
Governmental Sector	8	4
Private Sector		1

Semi-Government Sector	3	2
5-10 years	2	1
Governmental Sector	1	1
Private Sector	1	
1-5 years		4
Governmental Sector		2
Private Sector		1
Semi-Government Sector		1
Other medical professional	2	2
5-10 years	1	1
Governmental Sector	1	1
1-5 years	1	1
Governmental Sector	1	1
Physician	1	4
More than 10 years	1	4
Governmental Sector	1	3
Private Sector		1

4.3.2.3. Persisting disruption

Substantial disruptions to essential health services have persisted over one year into this pandemic [1]. As expected from the literature [18], a high percentage of participants reported that they encountered challenges in estimating the required supplies quantities, prioritizing patients with limited resources, high consumption of COVID-related supplies, and extended delays from suppliers/vendors (Figure 16). Participants who did not experience shortages in COVID testing supplies or life-support devices, including ventilators, were mostly from governmental facilities (Table 26). Interestingly enough, around 32% reported that they "don’t know” if their facility faced issues with overstocking and obsolete inventory, raising concerns about information transparency and HSC agility.

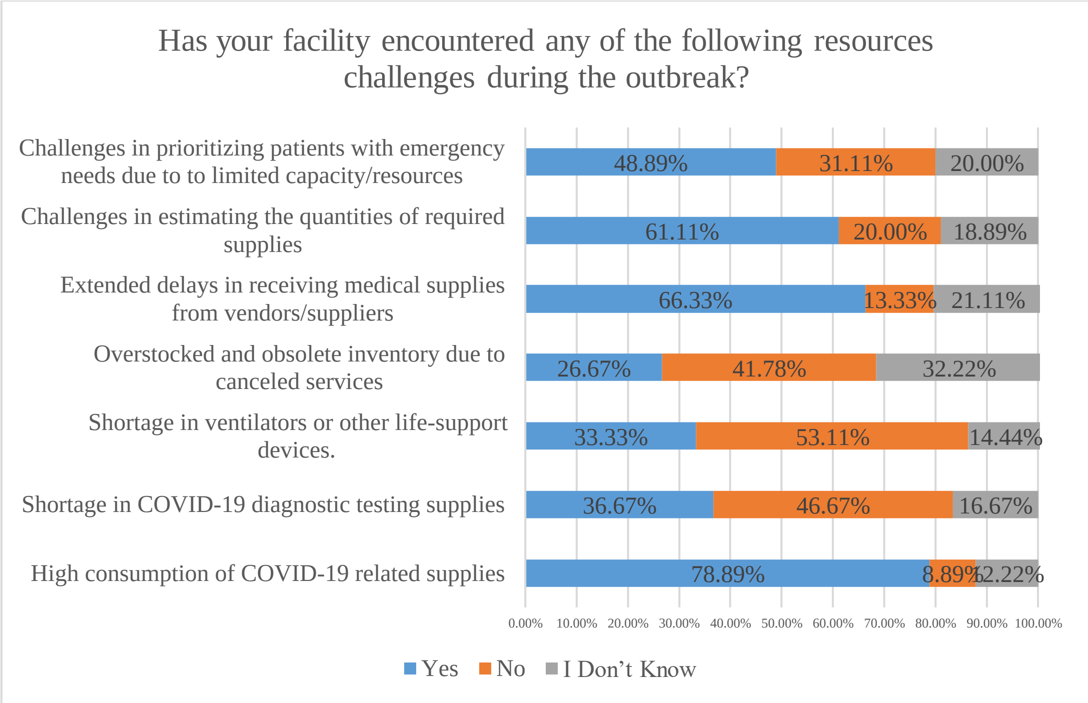

Figure 16: Response rate for resources challenges encountered during the pandemic.

Table 26: "No" response rate to experiencing shortages

	Shortage in COVID-19 diagnostic testing supplies.	Shortage in ventilators or other life-support devices.
Gov	24	33
Private	23	23
Semi-Gov	2	5

Referring to Figure 17, many respondents reported that COVID-19 has a high impact on appointment planning (50%), patient accessibility (44.17%), patient data collection (29.20%), examination (37.05%), patient throughput (32.83%), staff availability (39.33%), and HSC (43.50%); however, moderate impact on patient follow-ups (35.83%). In fact, 74.04% of participants said that virtual visits services were most effective in patient follow-ups (Figure 18).

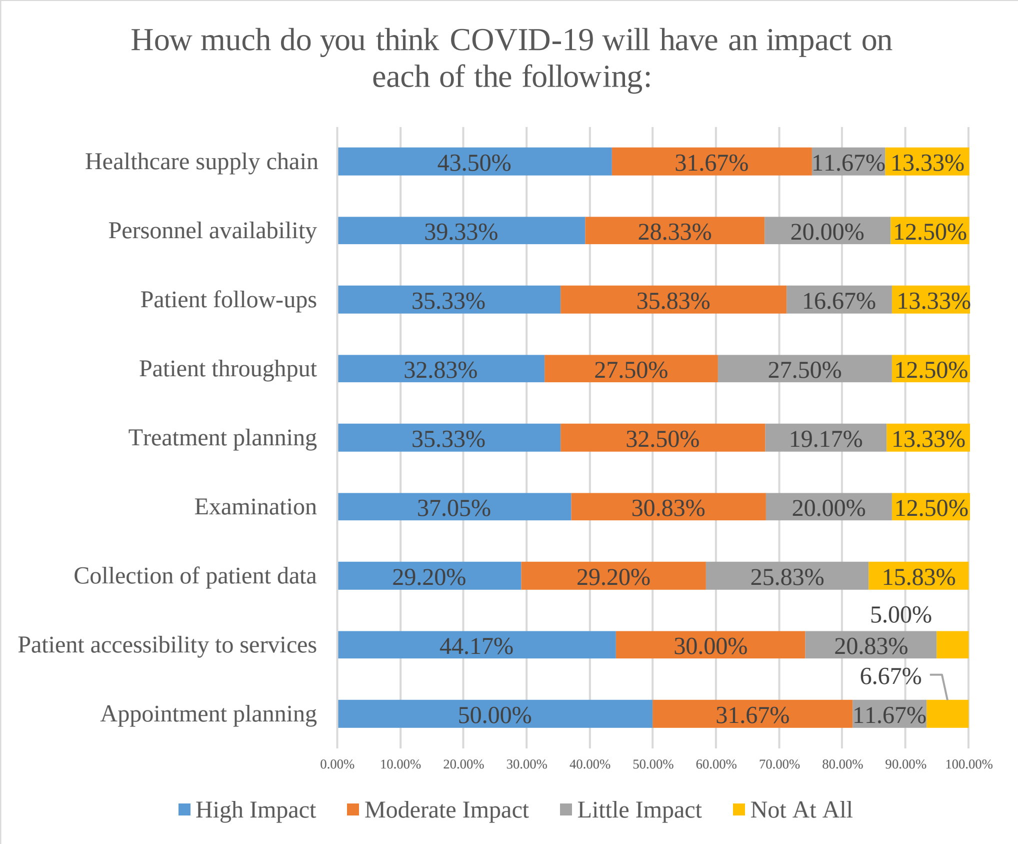

Figure 17: Response rate to COVID-19 impact different areas in the HC system.

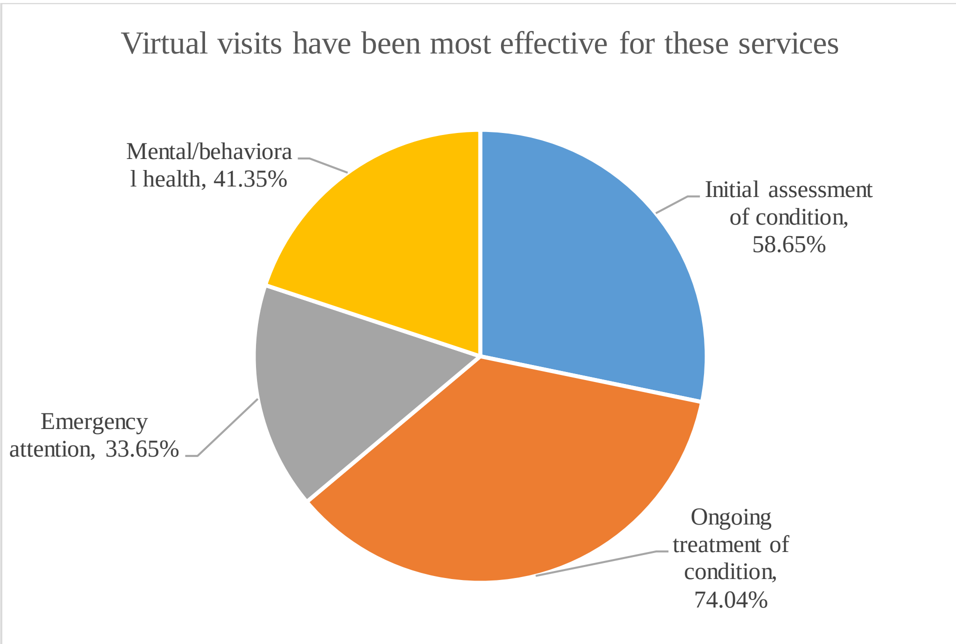

Figure 18: Response rate to HC services benefiting from telehealth.

4.3.3 Level of communication

4.3.3.1. Telehealth

Healthcare systems increased virtual health offerings in response to the outbreak. Patient-centered care can be delivered virtually in different ways; telephonic, video-based, tech-enabled medication, etc. According to the survey results, the most common telehealth modalities that were effectively practiced include video-based visits (52.43%), telephonic care delivery (53.40%), and virtual home health (52.43%). Nearly 43% reported that telehealth was somewhat never used before the COVID-19 crisis (Figure 19).

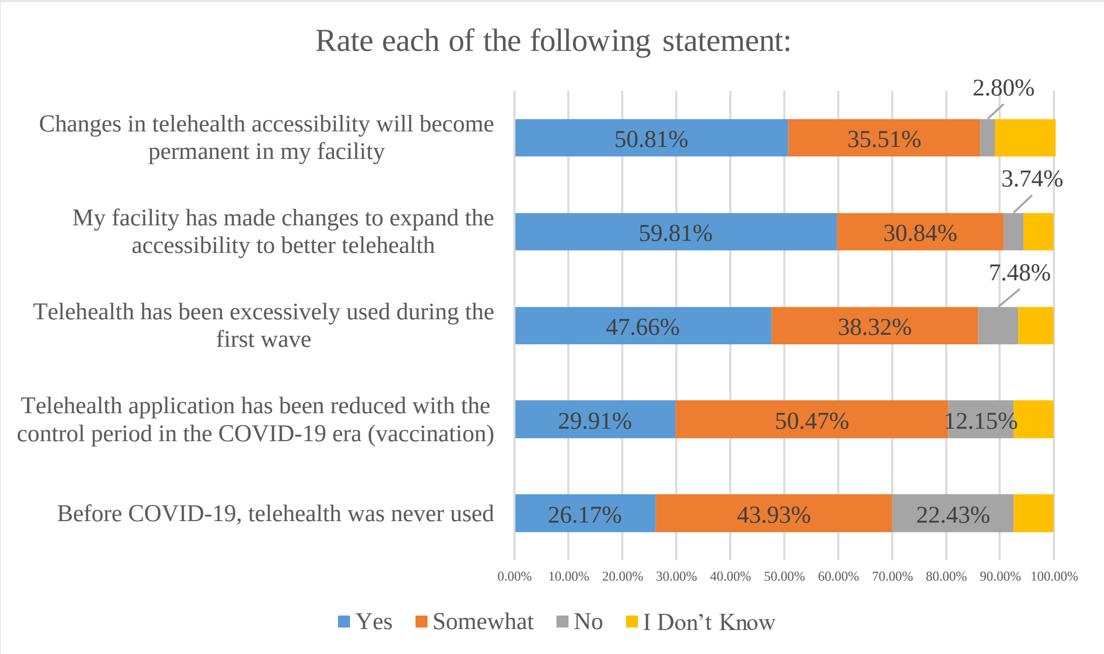

Figure 19: Response rate to different decision regarding telehealth.

The pandemic has changed the outlook for telehealth. This mode of delivery has been excessively used during the first wave of the COVID-19 pandemic, as agreed by ~47% of the participants. In addition, over 59% stated that their facilities have made significant changes to expand the accessibility to better telehealth and that those changes will become permanent (Figure 20). Figure 20 shows overall positive feedback of telehealth use in healthcare, but 29.52% strongly think that telehealth may jeopardize patients' safety and privacy. Furthermore, 50% feel that telehealth application has somewhat been reduced as more people are vaccinated during the control period.

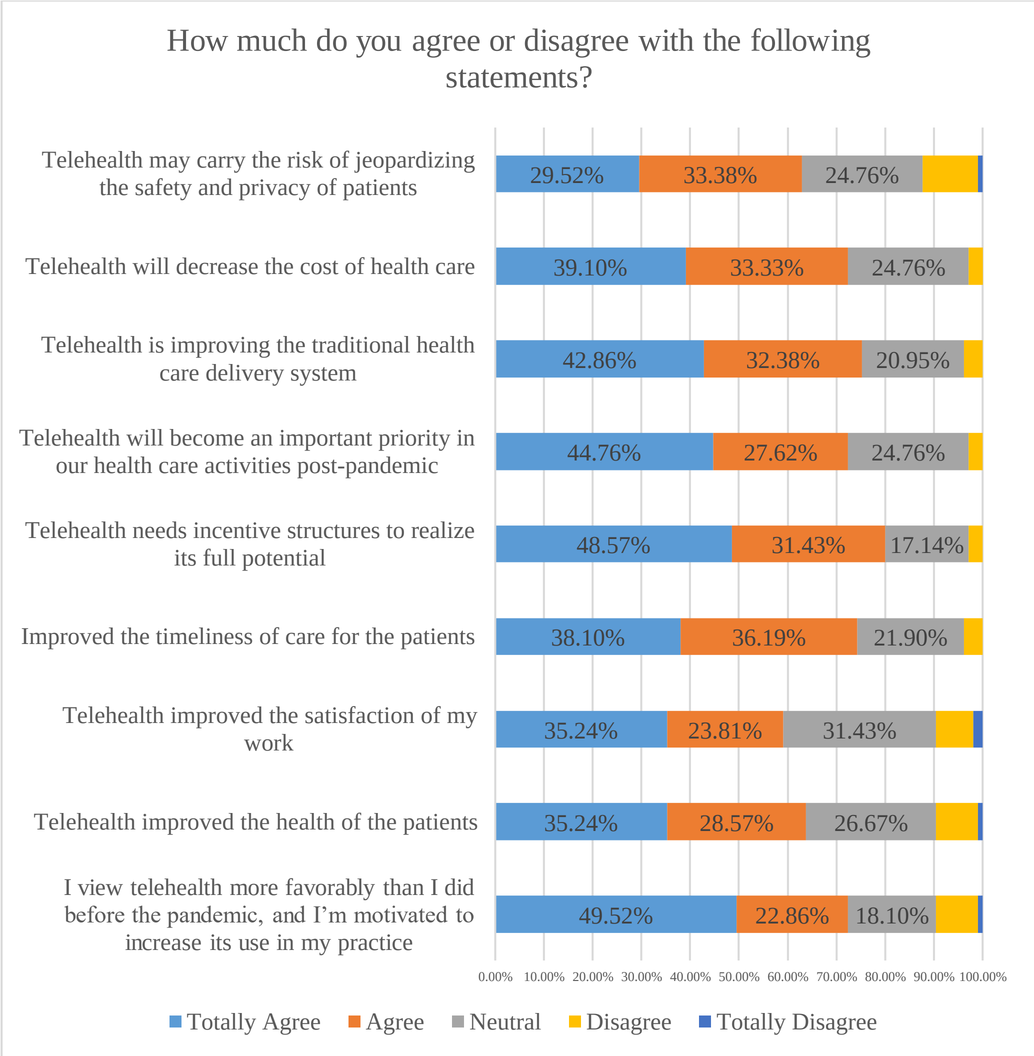

Figure 20: Response rate to telehealth effects.

4.3.3.2. Patient engagement

A high level of communication across the healthcare system influences the quality of working and job satisfaction for employees, in addition to the patient-caregiver relationship [47]. Figure 21 shows which of the resources and processes intended for patient engagement are being implemented during COVID-19 pandemic, and which of them exist in the facility.

Many of the PE resources and processes have existed in the facility prior to the outbreak and are being implemented. A few reported such elements have never existed in their hospital or exist but has not been implemented during the outbreak.

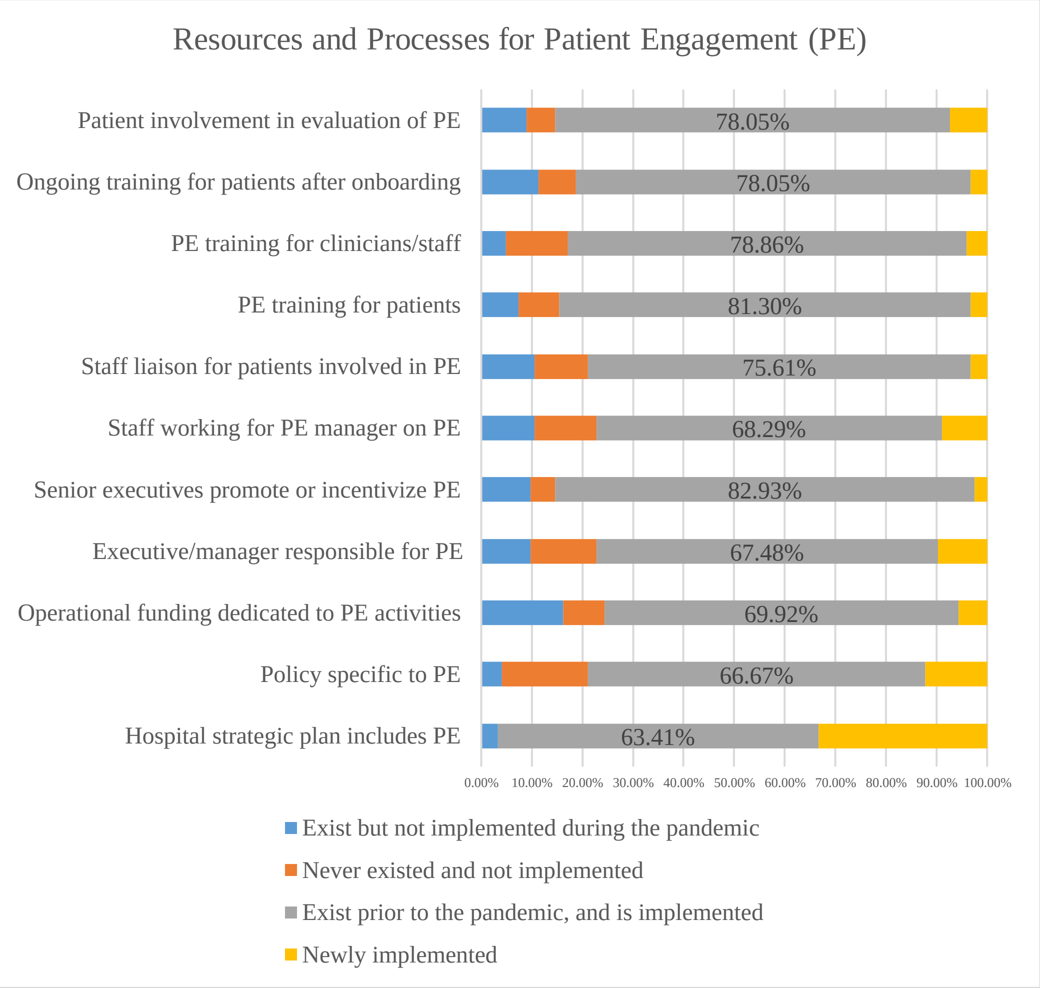

Figure 21: Response rate to the existence and implementation of resources and processed dealing with PE in health facilities.

4.3.3.3. Communication across the health system

Nevertheless, the pandemic has helped elevate healthcare management, assuring the need for an agile system to confront health emergencies. Participants reported huge improvement (Very Good response) in: IP&C, Risk Management, Disaster Management, HSC, Public Health, and Resource Planning, during the peak of the outbreak and the control phase, in comparison to pre-pandemic levels. As illustrated in Figure 22, unfortunately, Information Transparency has slightly reduced towards the control period. This is a concern because as recommended by many, including Schmidt et al. [20] continuous surveillance of infectious disease and investment in resilient system are essential to improve care delivery for future crises.

Figure 22: Very Good response rates to levels of communication before and after the peak of the pandemic.

More than 38% strongly believe that mitigating pandemic disruptions can be achieved through having multiple suppliers (38.18%) with improved cooperation between the organizations (45.45%) and developing an agile and innovative culture in the SC (38.18%). Similarly, up to half of the respondents reported that developing risk management plans (50.90%) and implementing/enhancing the use of IT and analytics (49.09%) are significant in managing the HSC and reducing the associated disruptions (Figure 23).

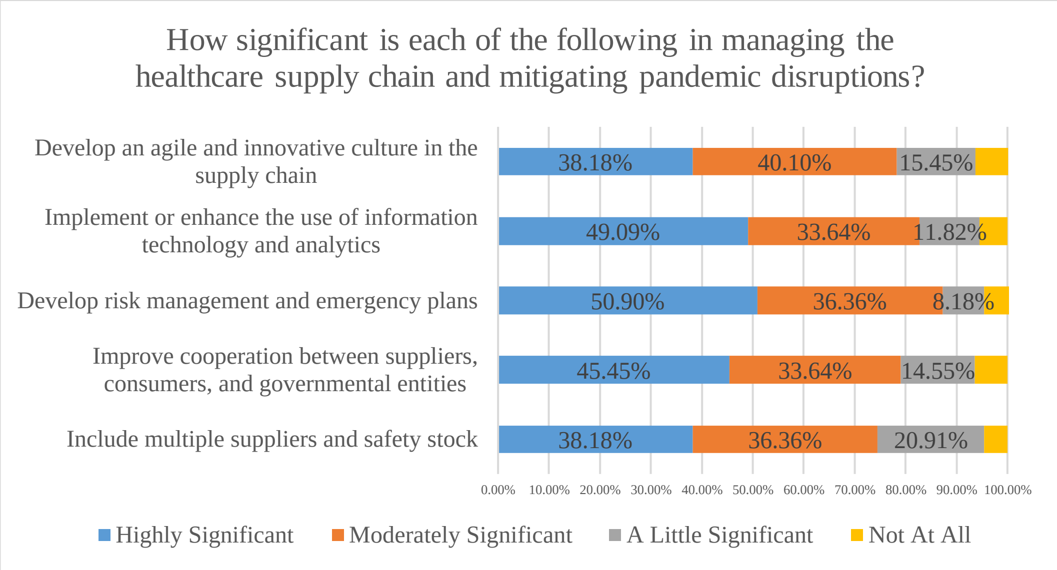

Figure 23: Response rate to essential elements to HSC management.

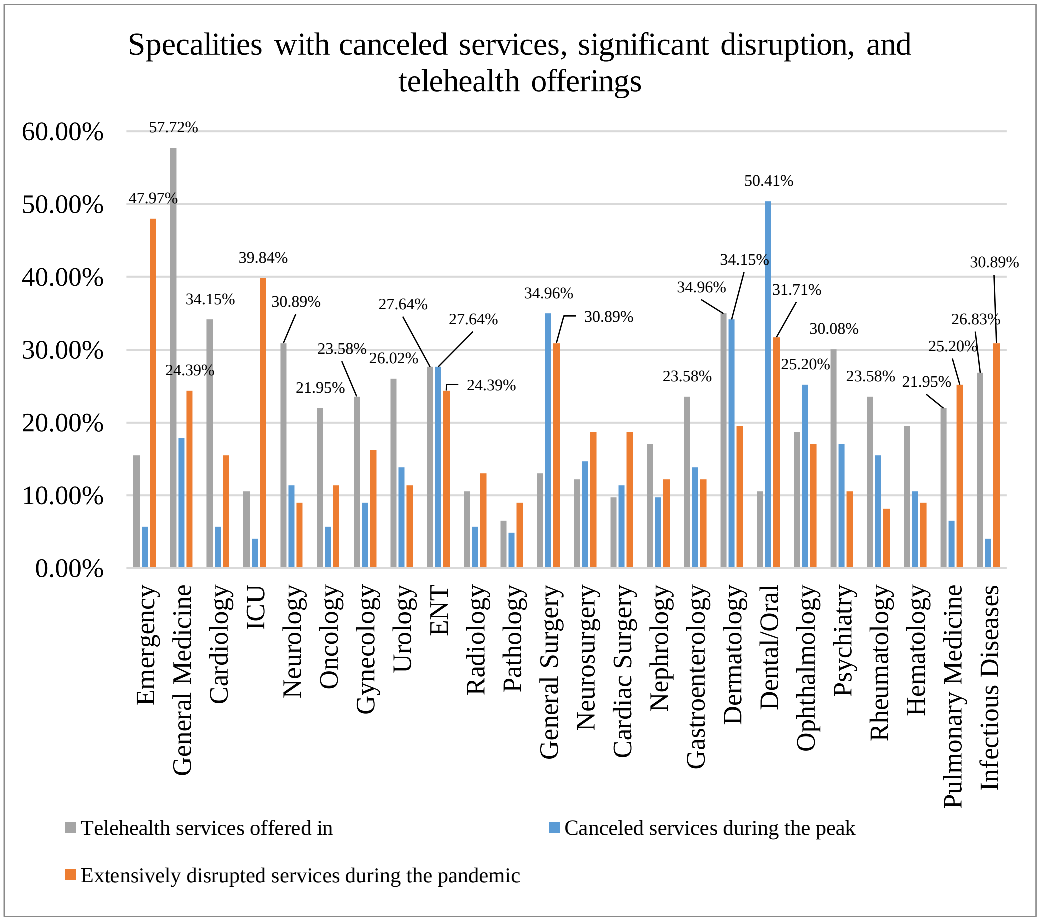

Figure 24: COVID-19 impact on different specialities

Figure 24 shows how the pandemic influenced healthcare services in different specialties due to high risk of COVID-19 infection. Many of the non-emergency procedures in dental practices were postponed at the beginning of the pandemic, and dentists faced problems providing PPE [48]. More than 50.41% of the respondents reported that their dental/oral services were postponed or canceled during the outbreak, and around 31.71% said dental/oral services were extensively disrupted. As part of the preventative measures recommended by WHO elective general surgeries have been widely postponed to reduce cross-infection [1]; this, however, resulted in greater impact even when services began to resume with the control period. Up to 34% reported cancellation of general surgeries, and 30% reported disruption in that specialty. The number of dermatology services offered also declined, as reported by 34% of the sample group, but 34.96% said they had virtual services for those departments. The most disrupted services were the ones offered in Emergency Department (47.97%), and ICU (39.84%). Many hospitals reduced the number of ED visits to contain the virus, and patients' also feared to utilize ED services during the peak [49]. The ICU, in contrast, experienced a surge of critically ill patients as the number of confirmed COVID-19 cases increased [50]. Effective expansions of healthcare capacity and medical services need to be improved to ensure the continuity of care.

Pandemic-related disruptions can be alleviated with telehealth offerings, especially with challenges related to lockdowns and resources shortages [34][17]. Fortunately, respondents reported that their facility had telehealth offerings to provide consultations and services for General Medicine (57.72%), Dermatology (34.96%), Cardiology (34.15%), Neurology (30.89%), Psychiatry (30.08%), ENT (27.64%), Infectious Diseases (26.83%), Urology (26.02%). In addition, 23.58% of participants said they offered Gynecology, Gastroenterology, and Rheumatology services through telehealth, and 21.95% said they offered virtual services for Pulmonary Medicine and Oncology. However, telehealth systems need to be enhanced in the long run given the significant advantages of cost savings, patient convenience, and support for resources constraint [51].

4.4. Interpretation with SEM

Structural equations modeling was developed in RStudio to visualize the covariance and regression relationship between the survey components. Since the relationship between the survey components can be hypothesized, CFA was carried out to test the hypothesized model and confirm the known relationship (based on literature review, HCW opinion, etc.). Using 123 responses, this study develops a 5-factor model, described in Table 27, which includes selective 30 questions from the survey that are likely related to the disruption of HC delivery. Table 27 list the 23 questions (indicators) that constructed the latent variables (factors). The average of two scale-questions were included in the outcome variables (y), as mentioned in data preparation. The two questions were: "*The COVID-19 pandemic has impacted the everyday clinical practice in my facility*", and "*COVID-19 will have an impact on the overall delivery of care*". The model also included 5 questions related to sociodemographic characteristics: Job Position (Q1), Gender (Q2), Years (Q3), Facility Type (Q4), and Facility Size (Q5).

Table 27: Description of the indicators for each factor

Factors	Items/Indicators
Staff Mental Health (f1)	Q9: COVID-19 has impacted on my daily workflow.
	Q10abe: How much does "fear of infection/infecting" and "isolation" affect your psychological state?
	Q10cdfg: How much does "change of work mode", "job security", "lowered income", "uncertainty" affect your psychological state?
	Q11ab: How good are mental health benefits/offerings in your facility?
Communication Level (f2)	Q12abc: Before COVID, how good was risk factors and management?
	Q12defg: Before COVID, how good was Healthcare Planning & Management?
	Q13abc: During the peak, how good was risk factors and management?
	Q13defg: During the peak, how good was Healthcare Planning & Management?
	Q14abc: During the control, how good was risk factors and management?
	Q14defg: During the control, how good was Healthcare Planning & Management?
Planning & Readiness (f3)	Q15: How has your facility changed the treatment plans during the COVID-19 pandemic?
	Q16: How successful was your facility in combating COVID with resource management?
	Q3536: Which of the following resources and processes dealing with PE have existed or newly implemented?

Healthcare Supply Chain (f4)	Q26a-g: Has your facility encountered challenges in resource management during the outbreak?
	Q27a-c: Were plans been made to create agile resource planning?
	Q28a-g: How significant is poor resource management in disrupting the healthcare supply chain at your facility.
	Q28h: How significant was lockdown restrictions in disrupting the healthcare supply chain at your facility during the outbreak?
	Q29a-e: How significant is HSC management in mitigating pandemic disruptions?
Telehealth (f5)	Q30ac: Use of telehealth was low before COVID or will become reduced after COVID.
	Q30bde: Great change are being made to expand telehealth use.
	Q31: Which telehealth modalities has your facility practiced and were effective?
	Q33a-j: Positive experience and opinion regarding Telehealth.
	Q34: Virtual visits have been most effective for these services.

* Healthcare Planning & Management: HSC, Public Health, Resource Planning, Information Transparency.
* Risk factors and management: IP&C, Risk Management, Disaster Management.

The following subsections explain how the model was built in RStudio, the evaluation model-of-fit-indices, and results interpretation.

4.4.1 Building SEM model in RStudio

1. Building SEM model
   a. SEM model was built using lavaan package in RStudio.
   b. Measurement Relationship: identified the latent variables (*f1*-*f5*) from the corresponding sub-questions, as shown in Table 28.
   c. Correlation: identified the correlation among the latent variables *f1*-*f5*.
   d. Regression: set *y* as a function of *f1* through *f5*.
   e. Correlation: identified the correlation among the sub-questions of the same category.
   f. Covariance: set each latent variable as a function of selected variables from the selected sociodemographic information.
2. Fitting SEM model
   a. To fit the model to the dataset, the function "cfa" provided by lavaan package was used. The variance standardization method was used for identification.

   b. Included "modindices" function, referring to modification indices, to provide suggestions of what can be removed to improve the model.
3. The model was plotted using the function "semPaths" to visualize the entire model.

4.4.2 Evaluating model fit

Multiple models with different combinations of factors and indicators were tested out, and the best model satisfying measurement fit and confirming the hypothesis was chosen. Based on model-of-fit indices, the model fit can be further improved by improving those indices [52]. The 5-factor model (with df = 289) has a value of 0.910 for CFI, and 0.876 for TLI. Having values of TLI and CFI closer to 1 means that this model fits the dataset almost perfectly (i.e., a saturated model) [43].

Although both of those indices are recommended to be above or equal to 0.9 for the best fitting model, the p-value (χ^2) is less than 0.001 and RMSEA is 0.046, which, respectively, mean that the results are significant in terms of supporting the theory being investigated and that the model is a close-fit. Additionally, CFA models consider the ratio of χ^2/df, and it is recommended to be less than 0.001 [53]. This model has a ratio of ~0.0000346; hence, the model resulted in an acceptable fit.

Table 28: Model Fit Measurement

	χ^2	CFI	TLI	RMSEA	χ^2/df
Model-of-fit indices	<0.001	0.910	0.876	0.046	<0.000

4.4.3 Model estimate parameters

Parameter estimates in SEM represent the weight of loading among variables. The SEM model for this paper is presented in Figure 25 with the variable of interest (*y*), the latent variables or factors (*f1*-*f5*) and their associated observed variables (indicators). The values of estimates for each correlation are presented, and greater loadings are illustrated in darker shades (i.e., dark blue and dark red). Dotted lines indicate fixed parameters as seen in factors' variances and covariances among sociodemographic items.

The correlation estimates between a latent variable and an observed indicator are listed in Table 29. This shows that causal relationships do exist between the selected survey questions and the constructs (unobserved variables). The highest the parameter estimate, the greater the correlation.

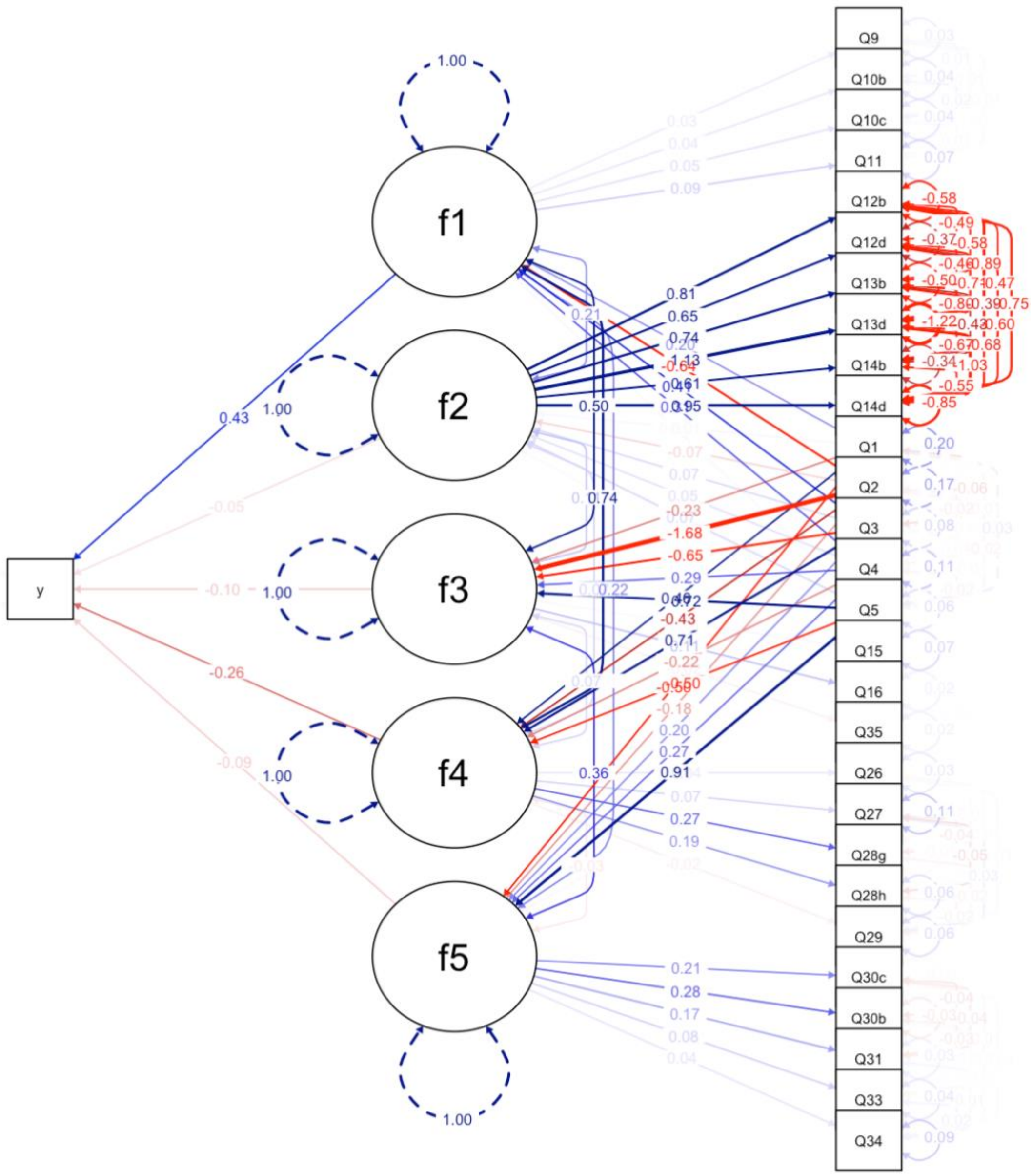

Figure 25: Structural Equations Model

Table 29: Factors loading

Item/Indicators	Factors	Parameter Estimate
Q9	f1	0.033
Q10abe	f1	0.040
Q10cdfg	f1	0.052
Q11ab	f1	**0.089**
Q12abc	f2	0.806
Q12defg	f2	0.650
Q13abc	f2	0.741
Q13defg	f2	**1.133**
Q14abc	f2	0.606
Q14defg	f2	**0.949**
Q15	f3	0.009
Q16	f3	**0.112**
Q3536	f3	-0.021
Q26a-g	f4	0.037
Q27a-c	f4	0.072
Q28a-g	f4	**0.273**
Q28h	f4	0.190
Q29a-e	f4	-0.023
Q30ac	f5	0.212
Q30bde	f5	**0.284**
Q31	f5	0.166
Q33a-j	f5	0.082
Q34	f5	0.045

Table 30: Regression between the outcome and latent variables

Variable of Interest	Latent Variables	Parameter Estimate
Healthcare Delivery Disruption (*y*)	Staff Mental Health (f1)	**0.434**
	Communication Level (f2)	-0.053
	Planning and Readiness (f3)	-0.096
	Healthcare Supply Chain (f4)	**-0.260**
	Telehealth (f5)	-0.085

Table 30 include regression estimates *y* and the factors. From the rate of responses, the variable of interest is expected to carry out an average low value because most responses were of low scores (negative impact on HC). Referring to Table 30, the observed variables for *f2, f3, f4,* and *f5* consist of high scores (positive impact on HC), opposing the direction of *y*. This means that Communication Level, Planning and

Readiness, Healthcare Supply Chain, and Telehealth are negatively correlated with Healthcare Delivery Disruption by estimates of: -0.053, -0.096, -0.260, and -0.085, respectively. Therefore, improving the communication level, planning, HSC, and telehealth usage, reduce disruptions in the quality of care.

On the other hand, *f1* consists of low scores, which goes linearly with *y*. Accordingly, staff mental health is positively correlated with healthcare delivery disruption; hence, increasing the burden effect on HCW mental state by 0.434, disrupts the delivery of care by ~0.434. Regardless of the direction, the top highest contributors to varying Healthcare Delivery Disruption are Staff Mental Health (0.434) and Healthcare Supply Chain (-2.260). In other words, the psychological wellbeing of HCW, and HSC significantly affect the quality of healthcare delivery.

Table 31: Regression between factors and sociodemographic

	f1	f2	f3	f4	f5
Q1: Job Position	0.196	0.011	-0.232	0.455	-0.500
Q2: Gender	-0.641	-0.070	-1.677	-0.434	-0.181
Q3: Years of Experience	**0.412**	0.066	-0.647	**0.711**	0.202
Q4: Facility Type	0.308	0.052	0.291	-0.216	0.269
Q5: Facility Size	0.009	**0.070**	**0.724**	-0.504	**0.912**

Sociodemographic characteristics were also regressed onto the latent variables to observe possible correlations (Table 31). According to the model results in Table 31, the size of the hospital setting is positively correlated with Telehealth (0.912), Planning and Readiness (0.724), and Communication Level (0.070). Having a large capacity within the HC system allows for greater implementation of telehealth, and greater resources for planning and communication. Additionally, responses to HSC were mostly answered by participants with higher experience in healthcare, explaining the high correlation value of 0.724.

The SEM model also measured covariances among the latent variables, as shown in Table 32. Mental health (*f1*) and HSC (*f4*) were found to have the strongest covariance relationship in the model with a value of 0.754. Many current survey studies, in fact, have been investigating the effect of supplies availability on the mental wellbeing of

HCW. In a recent study [54], a measurement scale that measures the resilience and ability of nurses to overcome challenges (i.e. anxiety or depression) has been shown to be lower among the groups who had adequate PPE. Similarly, Planning and Readiness is strongly related to Telehealth by an estimated value of 0.359 and related to Communication Level by an estimated value of 0.110. WHO recommends that the risk planning process include the development of remote methods such as online consultations and teleworking for the continuity of health services [55]. Moreover, for proactive planning, it is imperative to maintain the highest levels of communication across the HC system.

Table 32: Covariances between latent variables

	f1	f2	f3	f4
f2	0.209			
f3	0.503	**0.110**		
f4	**0.742**	0.071	0.070	
f5	0.221	0.007	**0.359**	-0.034

4.5. Text Analysis

4.5.1 Text mining with RapidMiner

At the end of the survey, participants were asked two open-ended questions: (1) How did COVID-19 pandemic positively affect your facility? (2) What are your recommendations for better preparation and responses to future health outbreaks?

Responses for these two questions were, separately, analyzed with text mining techniques in RapidMiner software. Analysis of word occurrence frequency was performed using the following operators in the software:

1) "Declare Missing Value" and "Filter Examples" operators allow to detect any missing content in the Excel file and remove them.
2) "Nominal to Text" converts all entries from nominal to string attributes.
3) Further text analysis was implemented inside the "Process Documents from Data" operators:
    a. "Tokenize" breaks sentences into words, prefix, symbols, etc.

b. "Transform Cases" converts all characters to lower- or upper-case letters.
c. "Filter Stopwords (English)" removes stop words from the data.
d. "Filter Tokens (by Length)" sets the minimum and maximum number of characters.
e. "Stem (Porter)" eliminates word suffixes to ensure different parts of speech of the same word are grouped together.
f. "Replace Tokens" was used in this work to group synonyms in the same attribute.

Figure 26 demonstrates a sample of the process window, where the previous operators are implemented in RapidMiner. Figure 27 includes the operators used inside "Process Documents from Data" operator.

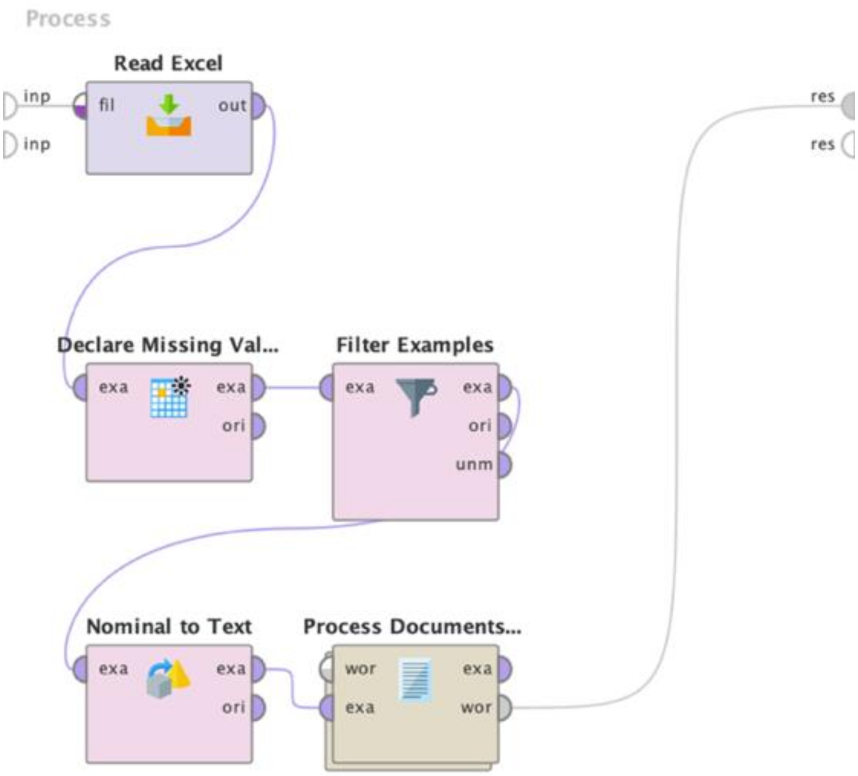

Figure 26: Process Window in RapidMiner

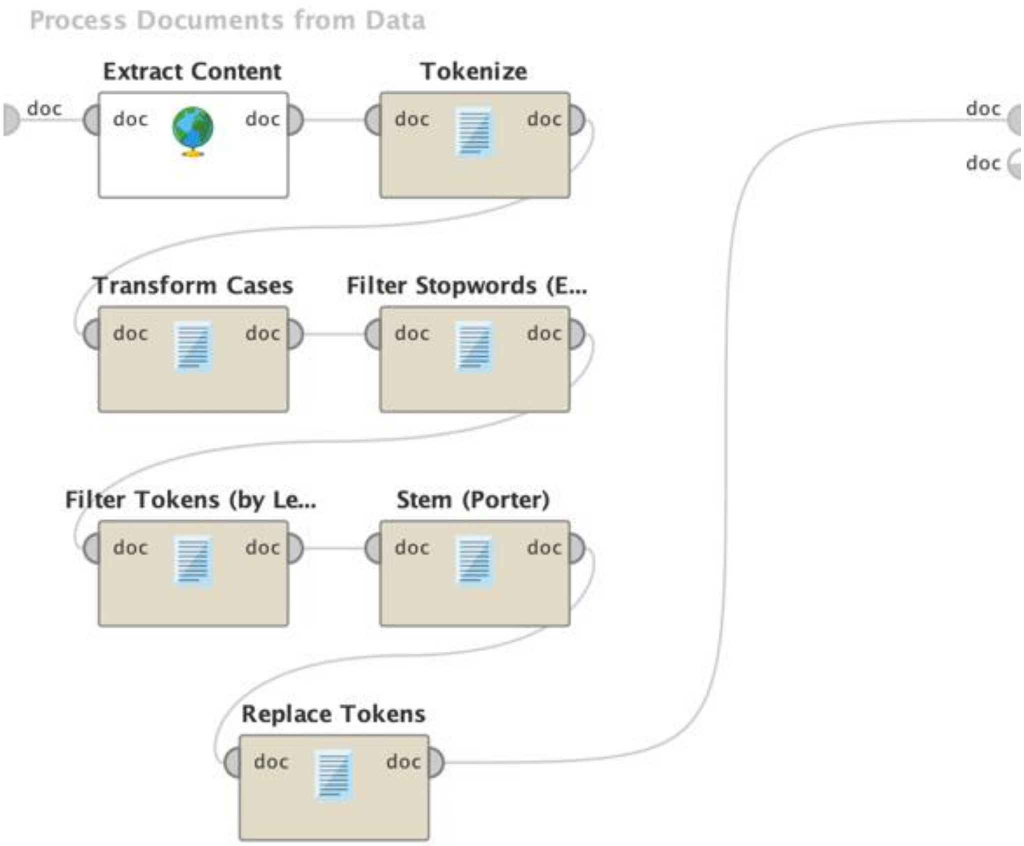

Figure 27: Process Documents from Data Window in RapidMiner

4.5.2 Text mining results

To extract meaningful insights of the two open-ended questions asked in the survey, Figure 28 and Figure 29 represent the percentage of word frequencies detected in the texts using RapidMiner. Eighty-seven participants responded to the first open-ended question, "*How did COVID-19 pandemic positively affect your facility?*", and 16% of the responses reported that the pandemic had improved the management and planning in their facility. Other responses imply that this pandemic has positively affected their facility through prioritization of patient care and resource management, raising awareness and dealing with health emergency disasters, becoming more proactive and agile, improving the quality and infection control, enhancing teamwork and communication, and technologies such as the use of telehealth and remote work.

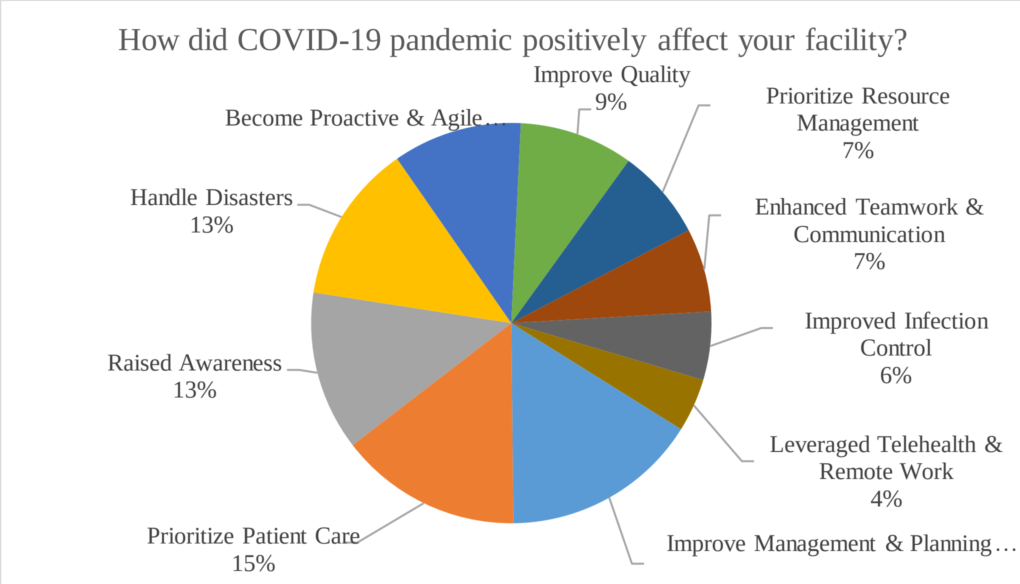

Figure 28: Total Word Occurrences (COVID-19 Positive Impact)

Views from participants regarding COVID-19 positive effects:

- *"Learn to handle challenges, work in a team environment, patient care experiences to new level."*
- *"Flexibility in working place, staff can work anywhere they want."*
- *"Our preparation for a pandemic is definitely better now. Our reaction time to certain medical conditions, which require mass activation and flexibility in process, has improved. Our strategic plans are inclusive of opportunities which will arise post the pandemic. Our infection control and risk management departments are more efficient and authoritative in their actions."*
- *"Improved the practice of infection control, high awareness of protocols, increased quality practice, risk management and establishment of disaster department."*
- *"Made us aware of our vulnerabilities in several areas in Supply Chain and workforce planning. It also opened the doors for a more agile healthcare model."*

The second question "*What are your recommendations for better preparation and responses to future health outbreak?*" recorded 86 answers. The majority of responses (33% occurrences) emphasized the necessity of proactive planning for future outbreaks.

Other recommendations included: improving resource planning and supporting HCW, preparing for an unprecedented increase in patient demand, strengthening risk management and infection surveillance, building a culture of teamwork, and educating and training all staff and patients about strategic response plans.

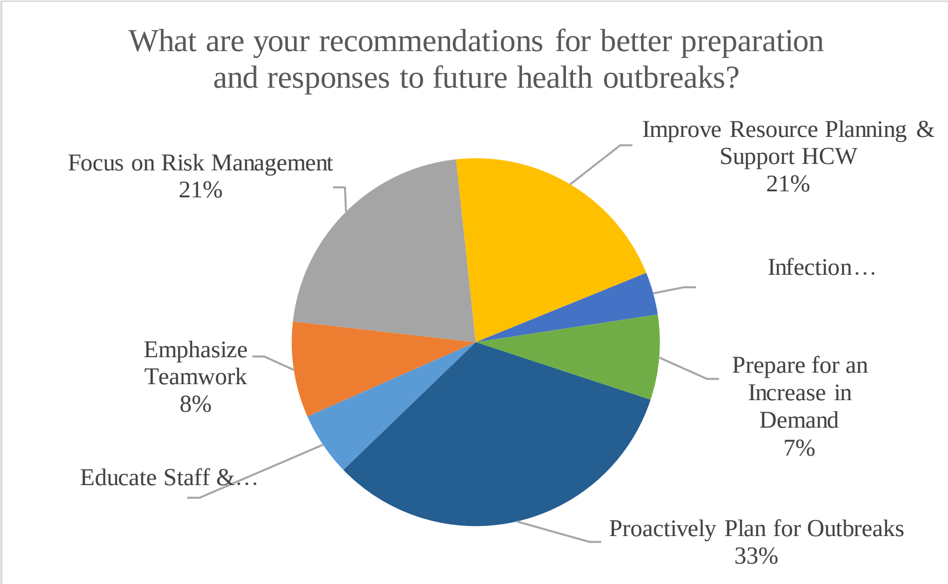

Figure 29: Total Word Occurrences (Recommendations for Future Outbreaks)

Views from participants regarding recommendations for future outbreaks:

- *"Our biggest learning networking between hospitals for staff and material needs are of top priority. Scientific collaboration in terms of excellence in treatment protocols have to be shared more often than not between the elite doctor community with the smaller facilities as well. Using technology to upgrade our services should not be optional but mandatory from the health authorities."*
- *"Use more technology to improve the service, engage patient in such decision if there is any pandemic how we can reach and treat you, engage more staff in decisions and to innovate solutions for the future care."*
- *"More and more communication from authorities and hospitals to be part of command center communications and transparency from all stakeholders.*
- *"It was something new for everyone. Lockdowns stopping of elective surgeries. But it has impacted on the financial of the organization. We should plan this in*

future how to overcome these financial burdens by putting something behind to manage and overcome these financial crises."

- *"Daily debrief and weekly steering of hospital readiness committee is a must* Proper *resource planning is a must."*

Chapter 5. Conclusion and Future Work

The massive, unprecedented disruption in healthcare caused by the COVID-19 outbreak has forced policymakers to rethink healthcare delivery and disaster preparedness. The poor performance of the healthcare systems globally, especially during the initial response to the pandemic, has showcased the vital roles of a resilient healthcare system and effective utilization of data and technology in preparation for health emergencies.

Using structural equation modeling (specifically, confirmatory factor analysis), the goal of this research was to assess the influence of the COVID-19 pandemic on the delivery of healthcare systems. The developed instrument was based on complex survey data (collected from healthcare workers in KSA and UAE) covering the areas of staff psychological wellbeing, healthcare supply chain, telehealth, planning, level of communication, and HC delivery disruption. The 5-factor model was found to be of a reasonably good fit for the hypothesized model, as all of the fit indices (CFI = 0.910, TLI = 0.876, $p < 0.001$, RMSEA = 0.046) are within acceptable values. This proposed model with its promising correlations among the variables, can help the healthcare system to further investigate and validate the significant impact of those areas on the quality of healthcare delivery, and explain their covariance.

The instrument needs more evidence of construct validity and reliability, as well as a larger sample size. With more dataset and relevant observed variables, measurement fit indices can be improved; the closer the CFI and TLI values to 1, the greater the user fit to a saturated or perfect fit. Apart from improving the fit indices, a measurement model with less than 7 factors (each with +3 indicators), is recommended to have a minimum sample size of 150 to ensure significant construct and convergent validity. About 45% of the total survey takers did not complete the survey, thus only 123 responses were considered for analysis. Moreover, parameter estimates or loadings are greater when questions (observed variables) are perfectly matching the intended meaning of the factors (latent variables). Misinterpretation of the questions wording in the survey may have resulted in confusion, influencing the actual scores of latent variables. An improved instrument can potentially be used to assess the measure of healthcare delivery disruption, or be used as a key performance indicator to mitigate disruption in future pandemics.

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Appendices

Appendix A: Reviewed Papers on Healthcare Delivery and Disruption

Ref	Area of Focus						Research Method			
	Resource Planning	Supply Chain	Risk & Disruption	COVID -19	Healthcare Delivery	Data Analytic s	Mathematical Modeling and/or Simulation	Framework	Qualitative Study	Conceptual
[33]		√		√	√			√		√
[17]				√	√					√
[34]			√	√	√			√		√
[35]	√		√	√	√	√	√	√	√	√
[36]				√	√			√		√
[57]			√		√					√
[58]	√		√	√	√			√		√
[59]			√	√	√	√	√			
[60]	√	√	√	√	√	√	√		√	
[61]			√	√	√	√	√			

[62]			√	√	√	√	√			
[25]	√	√	√	√	√	√	√			
[23]	√	√	√	√	√	√	√			
[27]			√	√	√			√		√
[46]			√	√	√				√	√
[63]			√	√	√	√	√		√	
[15]	√		√	√	√	√	√			
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[68]	√			√	√			√		√
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[70]	√			√	√			√		√
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[73]	√			√	√	√	√			

[74]	√			√	√			√		√
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[76]	√			√	√					√
[77]	√		√	√	√			√		√
[78]			√	√	√			√		√
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[83]			√		√	√	√			
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[87]				√	√	√	√			
[88]			√	√	√					√
[89]	√			√	√	√	√	√		
[90]	√	√		√	√			√		√

[6]	√	√	√	√	√	√	√	√		
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[92]	√	√			√			√		√
[93]	√		√		√	√	√			
[94]			√		√	√	√	√		
[30]	√	√			√	√		√		√
[95]	√	√			√		√	√		
[96]	√				√	√	√			
[97]	√	√			√			√		√
[98]	√	√	√		√	√	√			
[99]	√				√			√		√
[100]	√	√				√				√
[101]	√		√		√	√	√			
[24]	√		√		√	√	√			
[102]		√	√		√			√		√

Appendix B: Reviewed Papers on Resource Planning and Data Analytics

Ref	Type of Methodology				Area of Focus			
	Conceptual/ Qualitative	Mathematical Modelling	Mathematical Simulation	Predictive Analytics	Devices or Equipment	Staff	Material	Bed Capacity
[103]	√	√	√	√				√
[39]						√		
[104]	√	√						√
[105]		√				√		√
[106]		√		√	√	√	√	√
[107]		√	√	√	√			√
[107]		√		√				
[108]	√							
[70]	√		√	√		√		
[32]		√	√	√	√			√
[109]		√	√		√	√	√	√
[24]				√	√			√

[81]	√							ß
[3]	√						√	
[110]	√					√		√
[78]	√							
[111]		√	√	√	√		√	
[112]	√	√	√					
[113]	√					√		
[114]			√			√		
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[119]					√			√

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[90]	√				√	√	√	√
[87]	√							
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[63]		√						√
[15]		√	√	√	√			√
[89]		√	√	√		√		√
[23]	√	√				√		√
[25]	√					√		√
[121]	√							
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[124]		√	√		√			√
[125]	√				√	√		
[72]	√				√			
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[127]	√							
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[128]						√		
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[94]		√		√	√	√		√
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[98]		√		√				√
[144]		√	√					√
[145]			√					
[73]			√	√	√	√	√	√
[146]	√	√				√		√
[147]		√	√		√			√

Appendix C: Reviewed Papers on COVID-19 Related Surveys

Ref	Area of Focus						Application Area		Participants Target				
	Staff Wellbeing	Patient Engagement	Resource Management	Telehealth	Quality of Healthcare Delivery	Education/Training	Specific Department	Hospital-wide	Managers	Medical Providers	Support Staff	Patients	Students
[148]	√							√		√			
[149]		√			√			√				√	
[150]	√						√		√	√			
[151]						√		√		√			
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Appendix D: Survey Questions

1) What best describes your job position? *(MCQ)*
    - Manager
    - Physician
    - Nurse
    - Other medical professional (therapist, phlebotomist, radiographer, pharmacist...)
    - Non-clinical support staff (biomedical engineer, IT, admin assistant, data entry, receptionist...)
2) Gender *(MCQ)*
    - Male
    - Female
3) Years of Experience *(MCQ)*
    - Less than a year
    - 1-5 years
    - 5-10 years
    - More than 10 years
4) Type of your health facility *(MCQ)*
    - Governmental Sector
    - Private Sector
    - Semi-Government Sector
5) Size of your health facility *(MCQ)*
    - Small size facility
    - Medium size facility
    - Large size facility
6) Country *(MCQ)*
    - KSA
    - UAE
7) Choose your region in Saudi Arabia *(MCQ)*
    - Central Region
    - Western Region
    - Eastern Region
    - Northern Region
    - Southern Region
8) Choose your emirate *(MCQ)*
    - Abu Dhabi
    - Dubai
    - Sharjah
    - Fujairah
    - Ajman
    - Umm Al Quwain

- Ras Al Khaimah

9) Rate how much you agree with the following statements: [Strongly Agree; Agree; Neutral; Disagree; Strongly Disagree] *(Rate Scale)*
   - COVID-19 pandemic has impacted my daily workflow.
   - I feel overwhelmed at work due to the COVID-19 pandemic.
   - I would want more information about the pandemic from the hospital leadership.
10) How much does each affect your psych during the pandemic? [Very Much; Somewhat; Very Little; Not At all; Not Applicable] *(Rate Scale)*
    - The fear of being infected by/with SARS-COV-2.
    - The fear of relatives being infected by/with SARS-COV-2.
    - Change of work mode/style.
    - Lower income.
    - Isolation and restrictions.
    - Uncertainty regarding the pandemic duration.
    - Job security.
11) How good are mental health benefits/offerings to support employees at your facility? [Very Good; Good; Neutral; Bad; Very Bad; There is no benefits / offerings] *(Rate Scale)*
    - EXISTING mental health benefits/offerings (prior to the pandemic).
    - NEWLY ADDED mental health benefits/offerings (during the pandemic).
12) Before COVID-19 pandemic, rate how good was each of the following: [Very Good; Good; Neutral; Bad; Very Bad] *(Rate Scale)*
    - Infection Prevention & Control
    - Risk Management
    - Disaster & Crisis Management
    - Healthcare Supply Chain
    - Public Health
    - Resource Planning
    - Information Transparency
13) During the peak of the pandemic, rate how good was each of the following: [Very Good; Good; Neutral; Bad; Very Bad] *(Rate Scale)*
    - Infection Prevention & Control
    - Risk Management
    - Disaster & Crisis Management
    - Healthcare Supply Chain
    - Public Health
    - Resource Planning
    - Information Transparency
14) During the control phase (with COVID-19 vaccination), rate how good is each of the following: [Very Good; Good; Neutral; Bad; Very Bad] *(Rate Scale)*

- Infection Prevention & Control
- Risk Management
- Disaster & Crisis Management
- Healthcare Supply Chain
- Public Health
- Resource Planning
- Information Transparency

15) How has your facility changed the treatment plans during the COVID-19 pandemic? *(MCQ)*
    - Nothing has changed.
    - Canceled all treatments until the end of the pandemic.
    - Canceled all treatment until the end of the alert phase of the pandemic.
    - Performed emergency treatments.
16) During the peak of the pandemic, how successful was your facility in: [Very Successful; Successful; Somewhat Successful; Unsuccessful; Very Unsuccessful; I don't Know or Not Applicable] *(Rate Scale)*
    - Increasing the number of hospital beds.
    - Building tents outside the hospital to deliver medical services.
    - Decreasing emergency room visits and hospital admission.
    - Expanding medical clinic hours.
    - Expediting discharge of hospitalized stable patients.
    - Canceling or postponing elective surgeries.
    - Converting operating rooms into intensive care units.
    - Converting regular hospital beds into acute patient rooms.
    - Converting “flat spaces” (lobbies, waiting rooms, hallways) to operating bed capacity.
    - Maintaining an appropriate staffing level.
    - Identifying the minimum staffing needs and prioritizing critical services based on essential hospital operations.
17) Which of the services are offered at your facility? *(Checkbox)*
    - Emergency
    - General Medicine
    - Cardiology
    - Intensive Care Unit
    - Neurology
    - Oncology
    - Gynecology
    - Urology
    - ENT Medicine
    - Radiology
    - Pathology

- General Surgery
- Neurosurgery
- Cardiac Surgery
- Nephrology
- Gastroenterology
- Dermatology
- Dental/Oral
- Ophthalmology
- Psychiatry
- Rheumatology
- Hematology
- Pulmonary Medicine
- Infectious Diseases

18) During the peak of the pandemic, which of the offered services were CANCELED? *(Checkbox)*
    - Emergency
    - General Medicine
    - Cardiology
    - Intensive Care Unit
    - Neurology
    - Oncology
    - Gynecology
    - Urology
    - ENT Medicine
    - Radiology
    - Pathology
    - General Surgery
    - Neurosurgery
    - Cardiac Surgery
    - Nephrology
    - Gastroenterology
    - Dermatology
    - Dental/Oral
    - Ophthalmology
    - Psychiatry
    - Rheumatology
    - Hematology
    - Pulmonary Medicine
    - Infectious Diseases
19) What were the reasons behind cancelling any elective service during the peak of pandemic? *(MCQ)*

- Less beds are available due to occupancy by COVID-19 patients.
- Patients were postponed because they were required to do a coronavirus test.
- Some patients were found to have a positive test.
- Patients chose to postpone their surgeries for fear of getting infected in the hospital.
- Less staff at the hospital because some of them had positive tests
- The department was locked down temporarily for disinfection.
- You have chosen to reduce or cancel elective procedures for fear of cross-infection.
- Did not cancel any procedure.

20) How much do you agree with the statement below? "At the peak of the pandemic, the hospital experienced a surge of emergency patients in compared with other facilities". [Totally Disagree; Disagree; Neutral; Agree; Totally Agree] *(Rate Scale)*

21) How much do you agree with the statement below? "The COVID-19 pandemic has impacted the everyday clinical practice in my facility". [Totally Disagree; Disagree; Neutral; Agree; Totally Agree] *(Rate Scale)*

22) Which areas of healthcare services were more extensively disrupted during the pandemic? *(Checkbox)*
- Emergency
- General Medicine
- Cardiology
- Intensive Care Unit
- Neurology
- Oncology
- Gynecology
- Urology
- ENT Medicine
- Radiology
- Pathology
- General Surgery
- Neurosurgery
- Cardiac Surgery
- Nephrology
- Gastroenterology
- Dermatology
- Dental/Oral
- Ophthalmology
- Psychiatry
- Rheumatology
- Hematology

- Pulmonary Medicine
- Infectious Diseases

23) How significant are each of the following in being an obstacle to patient care during this crisis? [Highly Significant; Moderately Significant; A Little Significant; Not At All] *(Rate Scale)*
    - Insufficient healthcare workers prior to the pandemic.
    - Insufficient healthcare workers due to sick leave or exposure to high-risk contacts.
    - Lack of personal protective equipment.
    - Lack of medicine.
    - Insufficient hospitalization room.
    - Unawareness or absence of COVID-19 care protocols.
    - Lack of ventilators or other life support devices.
    - Lack of serological tests or PCR to identify positive cases.
    - Forced lockdown restrictions.
24) How much do you think COVID-19 will have an impact on each of the following: [High Impact; Moderate Impact; Little Impact; Not At All] *(Rate Scale)*
    - Appointment planning
    - Patient accessibility to services
    - Collection of patient data
    - Examination
    - Treatment planning
    - Patient throughput
    - Patient follow-ups
    - Personnel availability
    - Healthcare supply chain
25) Is a plan being developed or already in place to monitor the impact of the temporary suspension of emergency and elective services? *(MCQ)*
    - Yes
    - No
    - In Progress
    - I Don't Know
26) Has your facility encountered any of the following resources challenges during the outbreak? [Yes; No; I Don't Know or Not Applicable] *(Rate Scale)*
    - High consumption of COVID-19 related supplies.
    - Shortage in COVID-19 diagnostic testing supplies.
    - Shortage in ventilators or other life-support devices.
    - Overstocked and obsolete inventory due to canceled services.
    - Extended delays in receiving medical supplies from vendors/suppliers.
    - Challenges in estimating the quantities of required supplies.

- Challenges in prioritizing patients with emergency needs due to limited capacity/resources.

27) Which of the following statements is valid about your facility? [Yes; No; I Don't Know or Not Applicable] *(Rate Scale)*
    - We estimated the quantities of essential patient care medications, materials and equipment, and PPE that would be needed during the pandemic phase.
    - We developed a list of alternative suppliers for essential medications and devices and a strategy to address shortages.
    - We made a plan to ensure the availability of essential patient care medications, materials and equipment, and PPE needed during the lockdown.
28) How significant are each of the following in disrupting the healthcare supply chain at your facility during the outbreak? [Highly Significant; Moderately Significant; A Little Significant; Not At All] *(Rate Scale)*
    - Insufficient hospital capacity planning.
    - Inadequate profits for healthcare firms.
    - Improper management of risk, waste, and inventory (e.g. tracking, visibility…).
    - Lack of collaborative and strategic planning.
    - Lack of communication, transparency, flexibility, and trust.
    - Reduced supply chain diversification.
    - Unsustainable just-in-time manufacturing.
    - Forced lockdown restrictions.
29) How significant is each of the following in managing the healthcare supply chain and mitigating pandemic disruptions? [Highly Significant; Moderately Significant; A Little Significant; Not At All] *(Rate Scale)*
    - Include multiple suppliers and safety stock.
    - Improve cooperation between suppliers, consumers, and governmental entities.
    - Develop risk management and emergency plans.
    - Implement or enhance the use of information technology and analytics.
    - Develop an agile and innovative culture in the supply chain.
30) Rate each of the following statement [Definitely Yes; Somewhat; Definitely No; I Don't Know] *(MCQ)*
    - Before COVID-19, telehealth was never used.
    - Telehealth has been excessively used during the 1st wave.
    - Telehealth application has been reduced with the control period in the COVID-19 era (vaccination).
    - My facility has made changes to expand the accessibility to better telehealth.
    - Changes in telehealth accessibility will become permanent in my facility.
31) Which telehealth modalities has your facility practiced and were effective? *(MCQ)*
    - Virtual home health

- Near-virtual office visits
- Virtual visits
- On-demand virtual urgent care
- Tech-enabled home medication administration
- Telephonic delivery
- Video-based virtual visits

32) Telehealth were mostly practiced on the following specialities *(Checkbox)*
    - Emergency
    - General Medicine
    - Cardiology
    - Intensive Care Unit
    - Neurology
    - Oncology
    - Gynecology
    - Urology
    - ENT Medicine
    - Radiology
    - Pathology
    - General Surgery
    - Neurosurgery
    - Cardiac Surgery
    - Nephrology
    - Gastroenterology
    - Dermatology
    - Dental/Oral
    - Ophthalmology
    - Psychiatry
    - Rheumatology
    - Hematology
    - Pulmonary Medicine
    - Infectious Diseases
33) How much do you agree or disagree with the following statements? [Totally Agree; Agree; Neutral; Disagree; Totally Disagree] *(Rate Scale)*
    - I view telehealth more favorably than I did before the pandemic, and I'm motivated to increase its use in my practice.
    - Telehealth improved the health of the patients.
    - Telehealth improved the satisfaction of my work.
    - Improved the timeliness of care for the patients.
    - Telehealth needs incentive structures to realize its full potential.
    - Telehealth will become an important priority in our health care activities post-pandemic.

- Telehealth is improving the traditional health care delivery system.
- Telehealth will decrease the cost of health care.
- Telehealth may carry the risk of jeopardizing the safety and privacy of patients.

34) Virtual visits have been most effective for these services *(Checkbox)*
    - Initial assessment of condition
    - Ongoing treatment of condition
    - Emergency attention
    - Mental/behavioral health
35) Which of the following resources and processes dealing with Patient Engagement (PE) already EXISTED at your facility (PRIOR to the pandemic)? *(Checkbox)*
    - Hospital strategic plan includes PE
    - Policy specific to PE
    - Operational funding dedicated to PE activities
    - Executive/manager responsible for PE
    - Senior executives promote or incentivize PE
    - Staff working for PE manager on PE
    - Staff liaison for patients involved in PE
    - PE training for patients
    - PE training for clinicians/staff
    - Ongoing training for patients after onboarding
    - Patient involvement in evaluation of PE
36) Which of the following resources and processes dealing with Patient Engagement (PE) have been implemented at your facility (DURING the pandemic)? *(Checkbox)*
    - Hospital strategic plan includes PE
    - Policy specific to PE
    - Operational funding dedicated to PE activities
    - Executive/manager responsible for PE
    - Senior executives promote or incentivize PE
    - Staff working for PE manager on PE
    - Staff liaison for patients involved in PE
    - PE training for patients
    - PE training for clinicians/staff
    - Ongoing training for patients after onboarding
    - Patient involvement in evaluation of PE
37) In your opinion, how did COVID-19 pandemic positively affect your facility? *(Open-ended)*
38) What are your recommendations for better preparation and response to future health outbreak? *(Open-ended)*

Vita

Maymunah Fatani was born in 1995, in Saudi Arabia. She received her primary and secondary education in Jeddah, Saudi Arabia. Then received her B.Sc. degree in Bioengineering from George Mason University, United States, in 2018. In December 2019, Maymunah joined the American University of Sharjah, UAE, to pursue her master's degree in Biomedical Engineering.

Besides her work as a graduate teaching assistant at AUS during her master’s study, Ms. Fatani has completed two summer volunteering internships in Jeddah, KSA; she worked at the Performance Improvement Management (Patient Experience Division) at the International Medical Center. She also worked in the Clinical Engineering Department at the Ministry of National Guard Health Affairs. Her research interests are in healthcare management, data analytics, and healthcare business intelligence.