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Digital innovative healthcare during a pandemic and beyond: a showcase of the large-scale and integrated Saudi smart national health command centre

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ABSTRACT

Introduction The increasing frequency of pandemics, demand for healthcare and costs of healthcare services require efficient health systems with integrated care via a command centre that ensures a centralised and coordinated approach to exercise effective leadership.

Description We present a case study using the conceptual framework of Franklin to describe the novel system-based engineering approach of the Saudi National Health Command Centre (NHCC) including its features and outcomes measured.

Discussion The NHCC is structured into four departments and four zones with real-time data integration and visualisation on 88 dashboards. To empower leadership, it harnesses artificial intelligence affordances such as machine learning algorithms to enhance functionality, decision-making processes and overall performance. This allows for the rapid assessment of available resources and to monitor healthcare system efficiency at diverse levels of clinical and system indicators. Enhanced proactive capacity management has contributed to reducing lengths of stay, average supply chain lead time and surgery waiting list; early bending of the COVID-19 curve resulting in a low mortality rate; increasing bed capacity; deploying medical staff and mechanical ventilators rapidly; rolling out the COVID-19 vaccination programme and improving patient satisfaction.

Conclusion Integrating a healthcare system with a command centre provides healthcare leaders with the necessary infrastructure to create synergy between people, processes and technologies. This substantially improves both patient and service outcomes. It also allows for immediate care coordination and resource allocations and safeguards ease of access to care.

INTRODUCTION

It is widely believed that integration of healthcare delivery is crucial for improving quality; tackling complexity; reducing costs and delivering safe, timely, efficient, effective, equitable and patient-centred care.[1–5] This belief emerges from the view that integrated health systems via the implementation of dashboard command centres equipped with artificial intelligence (AI) featuring predictive analytics provide superior leadership performance as a result of effective communication and standardised protocols.[6 7] The use of leadership frameworks such as command centres during a crisis was originally employed in the military and emergency management sectors.[7]

While command centres have long been used in airlines, the Judy Reitz Capacity Command Centre at Johns Hopkins Hospital is the first hospital-level command centre.[1] More recently, hospitals have invested significantly in the deployment of command centres to be more proactive in their management of hospital-wide patient flow.[1 7–9] Importantly, during a pandemic, the health command centre can support provision of a centralised structure with the required tools and resources to facilitate effective leadership. This is important given a pandemic is associated with significant uncertainty that exacerbates the challenges confronting healthcare leaders related to rapid decision-making and ensuring a prompt adaptive response. Moreover, a health command centre is integral for healthcare leaders to exercise strategic planning and rapid decision-making while enabling centralised coordination, effective communication and monitoring.[7] All these outcomes ensure an efficient and coordinated response and are critical to guiding efforts to optimise resource utilisations and to safeguard public health.

While our work builds on these approaches, we note that the Saudi National Health Command Centre (NHCC) is larger in scale and has been implemented at the national healthcare system level rather than at the hospital level only. In October 2019, just prior to the outbreak of the COVID-19 pandemic in the Kingdom of Saudi Arabia (KSA), the Ministry of Health (MOH) established the NHCC. Its objectives were to enhance situational awareness, coordinate operations and provide the MOH with the required analytics, predictions and recommendations to manage capacity and demand under both emergency operations (including the COVID-19 pandemic) and during routine care (beyond the pandemic). Indeed, key functions of the NHCC include coordination; resource allocation and tracking; communication; information collection, analysis and dissemination; and surveillance of the entire healthcare system, all of which are vital in driving effective leadership within the healthcare system.

The NHCC's capabilities were significantly enhanced during the COVID-19 pandemic to monitor beds, resources (including staff), supplies (eg, ventilators and protective equipment) and space (eg, negative-pressure rooms) required to

care for COVID-19 patients. Real-time data related to regional disease surveillance, hospital occupancy and the availability of resources were collected and aggregated by the NHCC. This was achieved using AI affordances such as machine learning algorithms and data mining methods to predict patient volumes, bed occupancy, resource utilisation and disease outbreak. This was important to guide decision-making around triage, patient placement and the allocation of resources both within and across hospitals. Put more simply, it was designed to centralise, simplify and standardise operational tasks for all healthcare services by anticipating and protecting primary healthcare centres (PHCs) and hospitals from organisational disruptions. This was critical to providing a 360° view of the healthcare system which is considered essential to standardising work processes across healthcare services, addressing system inefficiencies and gaps and enabling appropriate responses. A recent scoping review of various command centre designs found their widespread deployment in hospitals enhanced patient flow and safety outcomes.[7] However, peer-reviewed evidence pertaining to their design and effectiveness remains in its earliest stages.[7] This study showcases the NHCC approach, including its features and implementation outcomes. It concludes with the major lessons learnt from its establishment.

METHODS

This study employed a descriptive design to explore the features, functions and outcomes of the NHCC in Saudi Arabia. Specifically, two descriptive approaches were used. First, we adopted the conceptual framework for describing a command centre developed by Franklin *et al*[7] to describe the features, functions and layout design of the NHCC. This approach was undertaken because the deployment of command centres in healthcare is a relatively new concept, and the evidence around their design and effectiveness is limited.[7] The description included a review of the NHCC's policies and documents (eg, organisational structure flow charts, meeting minutes and operational procedures) to deliver insights into the command centre's features and outcomes. Second, descriptive statistics (eg, frequencies and percentages) were used to describe preliminary retrospective data reported by the NHCC from October 2019 to June 2021. These data related to variables such as average length of stay, average supply chain lead time, surgery waiting list, average mortality rates, the number of beds optimised for COVID-virus patients, increase in the number of mechanical ventilators used during the pandemic, the number of people receiving COVID vaccinations and patient satisfaction levels.

Description of the NHCC

Features of the NHCC

The NHCC operates diverse healthcare services across primary, secondary and tertiary hospitals in the KSA. Specifically, the NHCC encompasses 2259 PHCs and 494 hospitals with a capacity of 75 225 beds. This equates to around 2.2 beds per 1000 population. It also includes a workforce of approximately 105 000 physicians, 184 500 nurses, 4000 pharmacists and 69 530 allied health personnel. The distinctive features embedded in the NHCC are the utilisation of AI technology (eg, machine learning algorithms and data mining methods) to generate models that predict future events or outcomes, leverage data, and advance analytics and automation to optimise and improve the allocation of resources, decision-making processes and operational efficiencies.

Functions colocated in the NHCC

The NHCC system design relies on an effective team approach to improve capacity and operational efficiencies. It aims to address barriers via three key strategies: near real-time decision support (technology), care coordination (people) and processes (eg, discharge process). Internal and external interdisciplinary and multidisciplinary teams (eg, staff from PHCs, hospitals, health clusters and directorates of health affairs) were colocated to communicate independently and concurrently to coordinate day-to-day system activities. The colocated personnel include various experts in medical and health-related fields, analysts, and business and project managers; and incorporates information technology and scientific approaches to address system complexities. The colocated personnel distributed throughout the different NHCC zones and operational centres are responsible for operational tasks including ambulance dispatch, inter-hospital transfers, clinical workflows, resources and supply chain services, bed management and transportation services. Figure 1 shows how the colocated personnel are distributed over the NHCC zones and operational centres according to their focus tasks.

As shown in figure 1, there are four zones and four operational centres within the NHCC. The aims of the NHCC zones and operational centres, as further detailed in online supplemental table 1, are as follows:

1. The Panoramic Wall Zone provides a holistic overview of the health situation in the KSA, in a high-level operational manner, to support decision-making by leaders.
2. The Public Health Operation Centre focuses on creating public health situational awareness and the indicators for evaluation, and on assessing access to PHCs and preventive care initiatives such as dental and vaccination programmes.
3. The Secondary-Tertiary Operation Centre focuses on improving access to general and specialised hospital services and on ensuring facility readiness.
4. The Supply Chain Operation Command Centre focuses on balancing the supply and demand of drugs, medical devices and consumables to ensure efficient and continuous availability.
5. The Analytics Zone represented by Ada'a measures operational performance and oversees the services provided in emergency departments (EDs), operating rooms and other facilities to ensure timely access by patients using simulation and prediction models.
6. The resource operation centre focuses on balancing supply and demand and ensuring the efficient utilisation of human resources, medical equipment, and financial and other key resources.
7. The Ticketing Zone monitors and follows up on regional interactions, with intervention and improvement tickets to improve performance quality.
8. The Situation Intelligence Zone, represented by the Health Business Intelligence Unit, enables forward-thinking technology-based decisions and the provision of trusted, structured and meaningful information to enhance readiness to respond to significant health events and patterns. The Health Business Intelligence Unit plays a distinctive role in the NHCC as it focuses on a unified data platform, continuous tracking and predictive insights using AI.

Outcome measures of the NHCC

The NHCC arranges the identified key performance indicators (KPIs) into three domains according to the Donabedian model:

Figure 1 Colocated personnel within the NHCC's zones and operational centres. NHCC, National Health Command Centre.

structures, processes and outcomes.[10] Various metrics identified by national accrediting bodies (eg, Committee for Quality Assurance) as key indicators include structural metrics (occupancy, boarding and discharge volume, time spent assigning beds to patients), processes (timely patient discharge, ED approach) and outcomes (length of stay, delays in exiting operating room, capacity issues). There are two rationalisations for using the Donabedian model: to easily facilitate future comparisons of hospital performance, and because it remains the preferred framework of the Agency for Healthcare Research and Quality, as well as patient safety and health service research communities.[11] Other reported outcome measures related to diverse indicators within the healthcare system include clinical indicators (eg, number of COVID-19 cases across regions), appointment utilisation, patient experiences, supply chain (eg, number of zero items for drugs, and medical and laboratory devices), resource performance (eg, working status of mechanical ventilators) and predictive trends for regional vaccination efforts, to name a few.

Real-time data

Data are collected by the NHCC through various mechanisms from PHCs, general and specialist hospitals, and e-health applications. Generally, data are collected indirectly through third parties on behalf of the MOH or directly from programme operators. These operators include (1) Ada'a: an MOH performance programme for PHCs and hospitals; (2) the Health Electronic Surveillance Network which serves as a national communicable disease surveillance platform; (3) Mawared; the official self-service portal for MOH staff to perform human resource-related activities; (4) Mawid: an appointment programme that facilitates appointment reservation, rescheduling or cancellation; (5) Mystery Shopper App: an application that enables users to evaluate the offered services and (6) Sharek: a programme to transfer supplies between regional healthcare centres.[12] Collected data sent to the NHCC are processed according to appropriate policies and compliance requirements. Healthcare performances are analysed and monitored via 88 screen dashboards within the NHCC.

PRELIMINARY RESULTS

Results show feasible improvements in efficiency and operational outcomes in the NHCC via the creation of surveillance, tracking and preparedness databases. The databases included proactive KPIs to enhance the coordination of care and the organisation and allocation of resources and to ensure ease of access to care.

The NHCC succeeded in enhancing healthcare system performance by reducing planned surgery waiting times from 36 days to 17 days, reducing length of stay in intensive care units (ICUs) by approximately 10%, and by increasing the number of patients who receive care within 4 hours in EDs from 36% to 87%. Importantly, capacity management is no longer a burden within the MOH, as the NHCC now facilitates this as a major function within the healthcare delivery structure. This helped to bend the curve of the first wave of the COVID-19 pandemic early through

its recommendation for preventative measures, resulting in a low mortality rate (2%). The NHCC also responded to the crisis in importing mechanical ventilators during the COVID-19 pandemic by repairing and reusing 1170 mechanical ventilators and distributing them to public and private healthcare organisations. The accumulated cost reduction of this action was estimated at US$25 million. Moreover, the NHCC increased hospital bed capacity from 6000 to 10 400 across the KSA.

Additionally, the NHCC facilitated patient referrals to private sector hospitals when public hospitals reached bed occupancy rates of 95%. Furthermore, it postponed elective surgeries when the number of COVID-19 cases was high and coordinated the transfer of anaesthetists and surgeons to ICUs. The NHCC reduced the average supply chain lead time from more than 60 days to 25 days. Additionally, it created a standardised optimum stock of all drugs and medical and laboratory supplies, removing 193 unnecessary items from the essential drugs list in only 11 weeks, and reducing the number of zero-stock items (ie, unavailable items) from 254 to 53. The NHCC also oversaw operations of the KSA's high-volume COVID-19 vaccination centres or hubs (n=587) within 3 months of the vaccination rollout, with 20 million vaccine doses successfully administered. These healthcare deliverables led to better outcomes in other quality measurements. For instance, the NHCC tracked patient satisfaction levels across the entire healthcare system, with reported rates of satisfaction increasing from 67% in 2019 to 79% in 2021. More specifically, patient satisfaction with the COVID-19 vaccination programme was at 98%.

Hence, the NHCC's role in helping to deliver effective crisis leadership during the COVID-19 pandemic cannot be ignored, particularly in its capacity to convert crisis to coordination. To support the national authorities in KSA to control COVID-19 transmission, the government established the High National Committee—chaired by the Minister of Health and comprising 23 entities—to lead implementation of all precautionary measures. The NHCC served as a guiding light in assisting the High National Committee to make and implement informed decisions, adapt to changing circumstances, facilitate collaboration and establish clear channels of communication and responsibilities across Ministries and other private and governmental entities. Committee leaders could access NHCC data to successfully navigate the crisis and mitigate its impact to facilitate the implementation of more than 100 preventive measures including suspending Umrah, restricting all international and domestic flights, introducing mass field testing and drive-through screening services, school closures, establishing four field hospitals with a capacity of more than 1000 beds each, a partial then total curfew and home quarantine for infected individuals. Moreover, the use of NHCC data was vital to inform daily and weekly press conferences as well as joint conferences to promote public awareness and education about all developments related to the COVID-19 pandemic.

DISCUSSION

Our study demonstrates that leveraging of AI technology by the NHCC supported improvement in effective healthcare leadership during the COVID-19 pandemic. This was manifested by favourably increasing healthcare sector capacity and efficiency related to outcomes such as patient tracking, bed availability, ED flow, reducing patient wait times, accelerating discharge, and tracking and improving operating room flow. Importantly, targeting the human aspects within clinical and safety coordination has positioned the patient experience as the driver of healthcare improvement. Particularly, NHCC dashboards displaying collaborative data, wellness trend predictions, risk estimations, proactive acuity status monitoring, knowledge of complex diseases, and various operational and financial metrics were based on the MOH's strategic goals to enhance value by increasing quality and reducing costs. Importantly, while navigating the COVID-19 pandemic, health systems across the KSA experienced first-hand the importance of having a large-scale system with real-time situational awareness to track patient surges, bed capacity and staffing needs, or to predict other vital operational and outcome solutions.

Similar to our design, Johns Hopkins Hospital in the USA was the first to leverage The Judy Reitz Capacity Command Center to optimise hospital system efficiency.[13] The centre encompasses 50 health systems across the USA. Like our findings, early results from The Judy Reitz Capacity Command Center demonstrate improved patient experience and operational outcomes including patient transfers (60% improvement), ambulance dispatch times (63 min sooner to pick up patients from outside hospitals), ED bed assignations (30% faster after admission) and operating room transfers (70% reduction in delays).[13 14] Lastly, other studies have reported that deployment of a hospital capacity command centre led to a decrease in mean ED boarding hours per month by 3036 from June 2010 to March 2013[8]; a decrease in median ED boarding times from 9.7 to 6.3 hours at constant occupancy from 2017 to 2018[1]; and that ED boarding times remained flat (with a 7% increase in ED admission volume) from 2013 to 2015.[9]

Notwithstanding the similar positive results, it is difficult to compare our outcomes with previous findings due to the relative paucity of research employing the same framework design or measures. Although a few studies have examined the impacts of a command centre, studies of the framework applied and the effects of using data for healthcare system improvements are rare, with usability case reports published only for The Judy Reitz Capacity Command Center.[15] It is, therefore, difficult to make comparisons of capacity command centre results due to considerable variation in interventions and the reporting of outcomes. Moreover, most evidence in support of capacity command centres has been published in the business press, suggesting some limitations around its objectivity.[7] Furthermore, similar previous research has adopted study designs focusing on the hospital level only,[1 8 9] whereas the NHCC has been modelled on a scalable or country-level operation. Irrespective of the similarities or differences in our findings with previous studies, it is important to understand that there is no universally accepted definition of command centre capacity and utilisation effectiveness.[7] Arguably, some hospitals may need capacity command centre only in times of a surge in demand. The objective of the Saudi NHCC is to go beyond the pandemic and to proactively anticipate and manage capacity and demand to avoid or diminish the recurrent capacity challenges routinely experienced across the Saudi acute care system.

Notably, the NHCC's feasibility as the nerve centre of effective leadership during a crisis cannot be underestimated. During a pandemic, trust in leadership and the projection of a sense of control to the public are critical. Therefore, the command centre has a critical role in supporting leaders to take timely and appropriate action via preparation and planning, accessing vital information, guiding adaptation and safeguarding a coordinated response. As part of its role, the command centre functions as a central information hub to provide four key benefits.[1 7] First, it provides leaders with real-time updates from internal and external sources which empowers them to clearly communicate

a comprehensive picture of the evolving situation. Second, it facilitates informed, collaborative and timely decision-making based on real-time data. Third, it brings leaders from various sectors together to coordinate a swift and unified approach to addressing the challenges. Fourth, it improves response efficiency by assessing available resources, identifying resource gaps and supporting informed decision-making on the efficient use of resources. This ultimately minimises the damage incurred during the pandemic and accelerates the rate of recovery.

LESSONS LEARNT

- Scaling up the capacity of command centres from the hospital level to the country level is critical to tackling complexity, unifying leadership, eliminating waste and allocating resources more effectively and efficiently.
- A command centre approach to healthcare design and delivery creates synergy between people, processes and technology facilitating substantial improvements in both patient and service outcomes.
- Data must be rapidly analysed to recognise efficient and feasible methods. AI technologies are, therefore, promising tools for utilisation by the NHCC to detect and predict health-risk progression and to rapidly enable interventions to improve health outcomes.
- During a pandemic, the NHCC can consolidate decision-making across ministerial levels and assist leaders to communicate effectively and transparently by providing frequent updates.
- During a pandemic, the NHCC can act as the nerve centre of effective leadership to foster communication, decision-making and response efficiency, as well as to build and sustain trust in times of uncertainty.

CONCLUSION

The NHCC uses diverse digital health technologies that rapidly enable integrated healthcare at the system level. The command centre was developed with an integrated structure that allows groups of leaders, clinicians and organisations to work together to provide coordinated care. It also replicates historical processes in healthcare systems where operational sensitivity and situational awareness have traditionally had high levels of subjectivity. Importantly, the NHCC addresses subjectivity and improves leadership efficacy by accelerating intelligent decision support for pandemic crisis prediction and management, and by coordinating the various departments which allows for collaboration around patient access and throughput. As such, the NHCC has successfully managed the complexity of healthcare delivery in the KSA and has replicated the reliance on information-based processes with actionable data. This has built a fairer system to tackle structural inequalities in healthcare access and outcomes, which will be critical to delivering successful health system responses during any future pandemic period and beyond.

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REFERENCES

1 Kane EM, Scheulen JJ, Püttgen A, *et al*. Use of systems engineering to design a hospital command center. *Jt Comm J Qual Patient Saf* 2019;45:370–9.
2 Komashie A, Ward J, Bashford T, *et al*. Systems approach to health service design, delivery and improvement: a systematic review and meta-analysis. *BMJ Open* 2021;11:e037667.
3 Prommas P. How the function of care coordination can be integrated into cancer care pathways to facilitate diagnosis and treatments in 6 selected Asian countries? *Int J Integr Care* 2021;20:198.
4 Wang Z, Liu Z. Older adults' demand for integrated care and its influencing factors: a scoping review. *Int J Integr Care* 2021;21:28:28:.
5 Barraclough F, Smith-Merry J, Stein V, *et al*. Workforce development in integrated care: a scoping review. *Int J Integr Care* 2021;21:23.
6 Moisan L, Fournier PL, Lagacé D, *et al*. The integrated performance management system: a key to service trajectory integration. *Int J Integr Care* 2021;21:25.
7 Franklin BJ, Mueller SK, Bates DW, *et al*. Use of hospital capacity command centers to improve patient flow and safety: a scoping review. *J Patient Saf* 2022;18:e912–21.
8 Lovett PB, Illg ML, Sweeney BE. A successful model for a comprehensive patient flow management center at an academic health system. *Am J Med Qual* 2016;31:246–55.
9 Davenport PB, Carter KF, Echternach JM, *et al*. Integrating high-reliability principles to transform access and throughput by creating a centralized operations center. *J Adv Nurs* 2018;48:93–9.
10 Donabedian A. The quality of care. How can it be assessed? *JAMA* 1988;260:1743–8.
11 Agency for Healthcare Research and Quality. Types of quality measures. 2011. Available: http://www.ahrq.gov/professionals/quality-patient- safety/talkingquality/create/types.html [Accessed 10 Jun 2022].
12 Alanzi T. A review of mobile applications available in the app and Google play stores used during the COVID-19 outbreak. *J Multidiscip Healthc* 2021;14:45–57.
13 Polyniak K, Matthews J. The Johns Hopkins hospital launches capacity command center to enhance hospital operations. 2019. Available: https://www.hopkinsmedicine.org/news/media/releases/the_johns_hopkins_hospi tal_launches_capacity_command_center_to_enhance_hospital_operations [Accessed 23 May 2022].
14 Martinez DA, Kane EM, Jalalpour M, *et al*. An electronic dashboard to monitor patient flow at the Johns Hopkins hospital: communication of key performance indicators using the Donabedian model. *J Med Syst* 2018;42:1–8.
15 Kwon H, An S, Lee HY, *et al*. Review of smart hospital services in real healthcare environments. *Healthc Inform Res* 2022;28:3–15.

Table 1. Mission, Vision, and Key Performance Indicators of the NHCC Zones and Centres

Unit	Mission	Vision	Key Performance Indicators
Panoramic Wall Zone	-Offer a view of the health status of the entire healthcare system in Saudi Arabia -Empower leaders in the MOH to take immediate action	-Build a Panoramic Wall for each regional health command center	-Sixteen tiles on the Panoramic Wall represent an integrated feed of all NHCC units in the healthcare system. Indicators get updated regularly with a clear view of: (1) The current situation (e.g. COVID-19 situation tiles, weekly increase in COVID-19 cases, deaths by region, cases in ICUs, lab capacity usage, the vaccinated population, and fever clinic visits) (2) Pre-hospital service tiles (e.g. PHC appointment slots and availability) (3) Hospital service tiles (e.g. ER and ICU occupancy rates, waiting times for elective surgery, referral acceptance rate, supply and resource availability, and COVID-19 situational awareness) (4) Post-hospital services (e.g. patient satisfaction, patient experience and mystery shopper)
Situational Intelligence Zone/Health Business Intelligence Unit (HBIU)	-Digitize and unify data platforms across multiple internal and external data sources -Continuously track several KPIs coupled with an event-based surveillance system to reflect the current state of the healthcare system -Process and valorize data and create predictive insights and media intelligence information using machine learning and artificial intelligence (AI)	-Be at the global forefront of using AI and, more specifically, machine learning to detect and understand health risks, predict risk progression, and enable data-based health interventions to improve health outcomes	-Twenty tiles on the HBIU executive wall. The unit uses data from several KPIs that are not available in the stakeholders' e-platforms, coupled with an event-based surveillance system. Examples of the tiles include: (1) An overview tile (e.g. PHC patients and emergency cases, communicable diseases, total outpatient visits, total no. of ER patients, increases in the average no. of cases in the last 14 days by final diagnosis and ER diagnosis, daily new COVID-19 cases per 100,000 population per region, daily cases per population, and daily positivity rate) (2) Outpatients and drugs tile (e.g. total no. of outpatients, average no. of visits and wait time per patient, changes in the no. of visits in the last 14 days by diagnosis, no. of outpatients by demographic data, total drug consumption, drug consumption per patient, changes in drug consumption in the last 14 days for the 10 most commonly prescribed drugs, and drugs by region) (3) Communicable diseases tile (e.g. no. of tests conducted, no. of positive cases, changes in the no. of positive cases in the last 14 days by region, the no. of prime cases vs. positive cases, total no. of beds, no. of available beds, % of ICU beds available, changes in bed occupancy rate in the last 14 days by region, and ICU occupancy rate in the last 14 days by region) (4) Calls and appointments tile (e.g. emergency and non-emergency calls, toxicology and community calls, lifesaving calls, Red Crescent calls, changes in the no. of calls in the last 14 days for the 10 most common toxicology categories, no. of calls by age, hospital category, Seha and 937 calls, total no. of appointments, changes in the no. of appointments in the last 14 days for the 10 most commonly used services, % of walk-in patients, and no. of booked slots for the next 5 days and per population) (5) Emergency cases tile (e.g. total no. of ER cases, variance in the no. of ER cases in the last 14 days compared to the biweekly average for the last 12 months; and changes in the no. of ER cases in the last 14 days by diagnosis, region, and facility)

			(6) Diagnosis and mortality tile (e.g. Hesn diagnosis, total no. of diseases and diagnoses, diagnosis accuracy rate, changes in the no. of cases in the last 14 days by final diagnosis, lowest accuracy from preliminary diagnosis, and no. of cases by age)
Public Health Operation Center (PHOC)	-Monitor and assess the utilization and quality of care of PHCs and dental and vaccination programs - Monitor public health KPIs and assess preparedness -Provide predictive measures to Hajj programs -Ensure ease of access to healthcare services	-Create a unified database of all public health KPIs from all sectors (public and private) in the Kingdom -Create training programs for staff to have standardized skills for reviewing indicators in the PHOC	-Sixteen tiles on the PHOC wall represent PHC operating rooms and dental and vaccination KPIs. Examples of tiles include: (1) Outpatient PHC optimizer (e.g. regional distribution of scheduling among PHCs, active services, services utilized, availability rate, and no. of slots per day) (2) Tetamman fever clinics (e.g. immediate referrals; appointment confirmation; morning, night, and evening appointments; no. of visits; and working hours). (3) Dental composite KPIs (e.g. clinic utilization, available appointments, appointment scheduling, working clinics, and overall composite) (4) Saudi Arabia COVID-19 vaccination progress (e.g. slots open; appointments; daily target [200,000]; week-by-week changes; total consumption of supplies at premium sites; total waste; no. of vaccinations by outlet; total no. of COVID-19 vaccination registrations; no. of patients with chronic diseases or immunodeficiency; no. of vaccinated individuals over 60 years, in the total population, and by region) (5) Mawid* well-baby vaccination clinics (e.g. regional distribution of scheduling, nearest available appointments, scheduling across well-baby clinics and facilities, total no. of slots, rate of available slots, rate of available appointments, and history of appointments in Mawid).
Secondary-Tertiary Healthcare Operation Center (STOC)	-Ensure timely access, assess readiness, and monitor the quality of secondary and tertiary care -Provide empowerment with predictive information and operational alignment to allow stakeholders to take immediate actions	-Establish a monitoring database to assess and coordinate the provision of advanced services, such as extracorporeal membrane oxygenation	-Eight tiles in the STOC wall represent access to and readiness of secondary and tertiary care services. Examples of tiles include: (1) Bed occupancy management (e.g. total no. of available beds in hospitals and regions) (2) Ada'a, OR, and OPD weekly reports (e.g. specialty with the most operations, surgeries performed, waiting times, estimated time needed to clear backlog by week, % of patients with virtual appointments, and total no. of future appointments booked) (3) Readiness reports for ICUs and EDs in the MOH (4) Ehalati referral program (e.g. total no. of referrals; no. of accepted, rejected, and pending referrals; average processing [hours] and patient transfer time [hours]; type of referral; reason for referral; referral date; referral number; sending and receiving directorates, sectors, and hospitals) (5) Saudi Red Crescent (e.g. total no. of hospitals, patient acceptance and rejection rates, and average length of stay) via the Sahab program (6) Hayat program (e.g. pregnancy, delivery, and infant rates; 90 KPIs)
Supply Chain Operation Command Center (SOC)	-Track, predict, and coordinate the supply chain (drugs and medical and laboratory devices) including planning, demand, supply, purchase, storage, and transportation	-Build a comprehensive tracking database using digital barcodes for all supply chain items used in MOH, non-MOH governmental and private sector facilities, including hospitals and pharmacies	-Eight tiles in the SOC wall represent oversight of the healthcare system supply chain. Examples of tiles include: (1) No. of zero items for drugs, medical and laboratory devices, and blood and emergency bank supplies in warehouses by health region (e.g. health directorate region warehouses; no. of zero items; warehouse with less than 100 items out of stock, 100-180 items out of stock, and over 180 items out of stock)

	-Continuously refine and update supply chain data		(2) Comparison index and % change in the no. of zero drug items (e.g. % and no. of zero drug items over time) (3) Stock replenishment index at the hospital level (e.g. health directorate region, no. of hospitals, and hospital names) (4) Direct supply purchase rate by region health directorate (5) Classification index for medical and laboratory supplies (e.g. % of items, health region directorates, no. of zero items, items almost out of stock, items at optimal stock, and items overstocked). (6) Drug supply response index (e.g. average lead time with NUPCO stakeholder) (&) Sharek index for transferring supplies between regions
Lab Operation Center (LOC)	-Enhance and monitor laboratory capacity preparedness including infrastructure, supplies, workforce, and training -Coordinate and manage laboratories based on testing demand, utilization, and community transmission/viral spread -Build and monitor KPIs for laboratory capacity and utilization -Implement advanced technology solutions and platforms to monitor daily laboratory workflows and reports for timely decisions and actions	-Build a sustainable lab capacity that provides innovative, timely, and quality medical laboratories services.	-Twelve tiles in the LOC represent the preparedness of laboratories in the entire healthcare system. Examples of tiles include: (1) Lab performance (e.g. cumulative turnaround time [TAT]) for mass testing laboratories, regional labs, and the Kingdom overall. Red, TAT > 24 hours from swab to results; yellow, TAT = 24 hours; brown, TAT ≤ 18 hours; green, TAT ≤ 14 hours (2) Kingdom of Saudi Arabia map - laboratory segmentation (e.g. MT, mass testing [red], primary healthcare [yellow], and regional [green] laboratories) (3) Laboratory utilization (e.g. average no. of daily tests for the MOH and mass testing laboratories and the % change in the no. of daily tests) (4) The cumulative no. of tests for all laboratories (e.g. MOH, non-MOH, and the month-to-month % increase) (5) Pending samples (e.g. correlation between the no. of pending samples and the no. of 937 complaint calls received; yellow line: pending time > 24 hours, red line: pending time > 48 hours) (6) Daily reports from the five dedicated COVID-19 mass testing laboratories and regional laboratories (e.g. achieved capacity, inflow, outflow, reprocessing rate [%], rejection rate [%] for each laboratory and overall) (7) Supply chain dashboard (e.g. for mass testing laboratories, the number and status of critical supplies/equipment to avoid shortages). Green indicates a "working equipment" status, and red indicates a "down" status (8) Mass testing laboratory quality assurance dashboard (e.g. sensitivity and specificity per region, test results per region and overall; true positive [green] and negative [brown] results and false positive [orange] and negative [red] results)
Analytics Zone/Ada'a	-Develop, enhance, and facilitate access to care in the Kingdom -Advance national healthcare excellence and the efficiency of PHCs and hospitals through integration and the provision of	-Become a reliable national partner and a globally recognized pioneer in driving healthcare performance excellence and efficiency	-Eight tiles on the Ada'a wall represent KPIs of MOH healthcare delivery. Examples of tiles related to the National Transformation Program (NTP) include: (1) ED tile (e.g. door to disposition within 4 hours, % of non-urgent patients, % of patients with disposition as LAMA or DAMA, and mortality rate (2) OR tile (e.g. % of elective or utilization surgeries, surgical cancellation rate, day of admission to day of surgery, waiting time for elective surgeries, and day surgery KPIs)

	accurate data to support decision making	-Build a portal system for Ada'a to reduce data-processing time and move to data automation	(3) Critical care tile (e.g. ALOS, physician-to-bed ratio, nurse-to-bed ratio, % of long-stay patients, and bed occupancy rate) (4) Inpatient department tile (e.g. % of patients seen on the first day, ALOS, % of weekend discharges, and % of long-stay patients) (5) OPD tile (e.g. waiting time for appointment, third available appointment, % of new patients, and no-show rate)
Resource Operation Center (ROC)	-Manage inventory and assess medical equipment -Provide preventative and corrective maintenance for medical equipment -Monitor the utilization of medical equipment -Monitor human resources	-Build inventory management database and an asset performance management system for all medical equipment and spare parts in the MOH, including utilization, maintenance, and coordination for the entire healthcare system	-Eight tiles on the ROC wall represent resource monitoring and utilization. Examples of tiles include: (1) Ventilators monitoring tile (e.g. working status, manufacturer, and operability by organization and region) (2) Dental units' tile (e.g. working status, facility type, and region) (3) Anesthesia, dialysis, CT, and MRI equipment utilization tiles (e.g. region, operating room, no. of items of equipment, equipment type, working status, manufacturer, no. of sessions, operational hours, serial numbers, type of therapy provided, and hospital) (4) Total human resources tile (e.g. specialty, region, cluster, service type, status, gender, and nationality) (5) Infected MOH healthcare workers tile (e.g. job category, total number, active cases, age, nationality, gender, region, and source of infection)
Ticketing Zone (TT)	-Identify, trigger, and escalate issues from the NHCC units to the appropriate MOH department or facility -Enhance the performance of NHCC units and MOH facilities -Support decision makers in the MOH with data-driven interventions	-Build and expand the TT center to all regions of Saudi Arabia, with the provision of supervision and mentoring for regional TT sub-centers and of digitized and automated triggers for ticketing requests	-Eight tiles on the TT wall represent tickets issued by all relevant NHCC units. Examples of tiles include: (1) Total no. of tickets per week tile (e.g. teams, no. of opened/solved/closed/reopened tickets, and no. of tickets with low/medium/high/critical priority level by region/cluster) (2) Ticketing tiles for different programs (e.g. supply chain, labs, HR, TeleHealth, Mawid, mass testing, and ICU bed management) (3) Vaccine ticketing platform tile (e.g. digital, operations, supply chain clinical care, communication, customer experience, no. of critical patients with a ticket less than 3 days old, closed/returned ticket status, ticket requester, and solved/unsolved ticket status by region/cluster)
Cybersecurity Operation Center	-Identify, monitor and analyse continuously cybersecurity incidents on NHCC databases -Ensure availability of protective solutions (i.e. defending, investigating and reporting) for potential security incidents	-Develop cybersecurity strategies and implement protective measures for NHCC databases.	Generally, the Cybersecurity Operation Cente monitors for threat alerts, identify internal and external security breaches.

Abbreviations: (ALOS) average length of stay, (CT) computed tomography, (DAMA) discharge against medical advice, (ED) emergency department, (ER) emergency room, (ICU) intensive care unit, (LAMA) leave against medical advice, (NUPCO) National Unified Procurement Company, (OR) operating room, (OPD) outpatient department, (PHCs) primary healthcare centers and (MRI) magnetic resonance imaging.

Terms Definitions: (Ada'a) an MOH performance program for PHCs and hospitals, (Ehalati) an e-system referral program that facilitates the referral of patients between hospitals within the region or between health affairs directorates across the Kingdom, (Hayat) a pregnancy-related program, (Hesn) the Health Electronic Surveillance Network serves as a national communicable disease surveillance platform, (Mawid) an appointment program that facilitates appointment reservation, rescheduling, or cancellation, (Mystery Shopper App) an application to that enables the user to evaluate the offered services from a patient's' perspective to and seek improvements for in medical services, (Sahab) a program to determine and manage the geographical location of callers and ambulance service seekers and to connects them directly to the operating rooms through mobile networks, (Sharek) a program to transfer supplies between regional healthcare centers, (Seha) a virtual medical consultation via text, voice messages, images and videos, (Tetamman) an application that enables users to book appointments for COVID-19 tests and follow -up on their cases and provides protection and health care for individuals referred to quarantine.