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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 collocated 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 collocated to communicate independently and concurrently to coordinate day-to-day system activities. The collocated 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 collocated 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 collocated 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 assignments (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 2013⁸; a decrease in median ED boarding times from 9.7 to 6.3 hours at constant occupancy from 2017 to 2018¹; 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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