ORIGINAL PAPER

Rapid Development and Utilization of a Clinical Intelligence Dashboard for Frontline Clinicians to Optimize Critical Resources During Covid-19

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ABSTRACT

Introduction: The COVID-19 pandemic has created an unprecedented situation where sudden and prolonged surges of critically ill patients have disrupted healthcare systems worldwide. A major concern for hospitals worldwide is how to best manage large numbers of COVID-19 infected and non-infected patients, while still maintaining high-quality clinical care. **Aim:** This manuscript describes the system development, collaborative efforts and the challenges encountered in developing an in-house clinical intelligence dashboard.

Methods: Through a longitudinal, interdepartmental collaboration, a COVID-19 clinical intelligence dashboard was created using Microsoft Power BI and Cerner Computer Language (CCL) to demonstrate clinical severity of patients and patient location in a single screen. A color-coding schema was applied to produce a red highlight for patients whose condition is deteriorating, whether due to increasing oxygen demand or worsening laboratory values. An additional function enabled users to drill down into the patient's clinical and laboratory parameters for the past 5 days, and ultimately to the respective patient chart for further assessment. **Results:** The development of an in-house clinical intelligence dashboard is a feasible, effective tool to allow frontline clinicians to monitor patient status in multiple wards and proactively intervene as clinically necessary and transfer patients to the appropriate level of care. Comparing the 30 days before and 30 days after the implementation of the dashboard, the percentage of patients who required urgent intubation or cardiac resuscitation on the general medical ward, rather than a critical care setting, declined by over 50% (8 out of 34, 33% vs. 7 out of 55, 13%; two-tailed $p < 0.05$ by Fisher's exact test; OR 3.43; CI 1.07 to 10.95). **Conclusion:** The dashboard has enabled physicians to efficiently assess patient volumes and case severity to prioritize clinical care and appropriately allocate scarce resources. The dashboard can be replicated by developing healthcare systems that are continuing to grapple with the pandemic.

Keywords: COVID-19, clinical intelligence dashboard, resource allocation, patient care, informatics.

1. INTRODUCTION

The COVID-19 pandemic has created an unprecedented situation where sudden and prolonged surges of critically ill patients have disrupted healthcare systems worldwide (1). A major concern for hospitals is how to best manage large numbers of COVID-19 infected and non-infected patients, while still maintaining high-quality clinical care. During the peak of the pandemic in many countries, resource allocation became an important concern for institutions experiencing manpower shortages, bed

crises, as well as limited supplies of ventilators and personal protective equipment (PPE). As hospitals in developed nations with emergency stockpiles and well established disaster plans became overwhelmed, countries with emerging healthcare systems had little time to develop or procure patient management systems. In our institution, frontline physicians, suddenly facing large volumes of critically ill patients, needed a reliable, easily accessible visualization system to monitor patients in multiple wards and proactively identify those needing early

clinical intervention or transfer to a different level of care. Given the urgency of the situation, a team of physicians and information technology (IT) professionals conducted a needs assessment and identified a critical need for a data-driven decision support tool to guide clinicians in their day-to-day patient management.

The answer quickly came in the form of a clinical intelligence dashboard. Originally developed in the business sector, dashboards have been part of the healthcare ecosystem for many years. Clinical intelligence dashboards serve a crucial role in patient data organization and interpretation. They connect physicians with critical, at-a-glance information, relevant to patient management. Clinical intelligence dashboards analyze data from multiple sources using easy-to-read, color-coded graphical displays of up-to-date information, in order to instantly track patients' changing conditions. Dashboards can, thereby, improve care quality and delivery through decreasing the time spent on data gathering and reducing time to task completion (2). Having combined data in one visual improves situational awareness and has been shown to decrease physicians' cognitive load and errors (3). Further, dashboard reports can be easily shared between users, enabling the free flow of information between multiple healthcare providers.

2. AIM

In this manuscript, we describe the system development, collaborative efforts and challenges encountered in developing an in-house clinical intelligence dashboard, in order to inform the wider healthcare and informatics communities, as hospitals worldwide continue to grapple with the pandemic.

3. METHODS

Setting

The United Arab Emirates (UAE) is a major business and travel destination in the Middle East. The country has made recent investment in the healthcare sector, but the COVID-19 pandemic provided little time for vital preparation. With a population of approximately 9 million residents, to date, there are over 54,000 confirmed COVID-19 cases in the country (4). Sheikh Khalifa Medical City (SKMC) is the largest government hospital in the UAE capital of Abu Dhabi, and has become a designated regional referral center for COVID-19, managing approximately 8000 patients since the outbreak began, including a large number of high acuity and critical cases.

Dashboard Development

While personal healthcare information is universally considered high security, the UAE has additional precautions to protect patient data. Therefore, the dashboard was created using only internal hospital servers. The literature on dashboard conception and design suggests a timeline of 6 to 12 months for initial development and implementation (5). In the midst of a pandemic, we acted quickly as a team of frontline clinicians and IT specialists to focus on the various ways IT could best support ongoing clinical needs, and the dashboard was established within 4 weeks from conceptualization to product.

Dashboard development utilized Microsoft Power BI and Cerner Computer Language (CCL) (6) to extract 55 pieces of data (Table 1) directly from the electronic health record (EHR) (Cerner) and to create a spreadsheet of data (Figure 1 demonstrating demo data). The output was organized in a matrix display format, reserving a row for each patient. Each row includes pertinent information, such as vital signs, oxygen requirements and mode of delivery, and a COVID-19 severity score. The severity score is the key feature of the dashboard. Using a pre-determined algorithm that accounts for age, comorbidities, laboratory results and clinical parameters, patients are assigned a number that correlates with potential risk of deterioration. A function was added to allow users to open a pop-up window, which displays the underlying patient-specific details used to calculate the severity score (Figure 2). A color-coding schema was also applied to produce a red highlight for patients whose number was increasing, whether due to increasing oxygen demand or worsening laboratory values. An additional function enables users to drill down into the patient's clinical and laboratory parameters for the past 5 days, and ultimately, to the respective patient chart for further assessment. To ensure the security of the data, only clinicians who are responsible for direct clinical care of COVID-19 patients are approved by hospital administration to access the dashboard through their unique EHR usernames and login passwords.

Throughout the development and implementation process, new ideas for elements and modifications of old elements continued to arise. A daily multidisciplinary clinical huddle was followed by a daily IT conference call that served to share feedback, discuss new protocols and approach challenges. These meetings also allowed us to quickly operationalize new guidelines by incorporating them into the EHR in almost real-time. As the pandemic progressed and demand for IT input increased, we were able to rapidly respond without jeopardizing system stability. For example, COVID-19 related IT requests were handled emergently and often implemented within 24 hours.

4. RESULTS

This dashboard creation was a combined effort of frontline clinicians and IT to increase patient safety and healthcare staff efficiency, while optimizing resources. As hospital admissions continued to increase during the COVID-19 pandemic, the ability to quickly prioritize patients clinically facilitated improved patient-centered care and appropriate allocation of healthcare resources in several major ways. First, the dashboard display guided physician rounding strategies each day to ensure that more critical patients were assessed first, allowing for expedited care for individuals at greatest risk of increased morbidity and mortality. Assessing the sickest of patients is a critical element in a time where direct patient contact is limited, in an effort to decrease healthcare worker exposure and potential infection. Second, the ability to visualize the number of patients requiring non-invasive ventilation, who were at higher risk of de-

Figure 1. Dashboard Demonstration: At-a-glance visualization of an inpatient ward (using demo data) with color-coding to indicate clinically deteriorating patients

FIN number	MRN	Nationality	Sex	Age
Unit Type	Nurse Unit	Room	Bed Number	Registration Date
Arrival Date	Admission Date	ICD-10 Diagnoses Codes	Troponin Result	Troponin Lab Date
Lymphocyte Count	Lymphocyte Lab Date	LDH Result	LDH Lab Date	CRP Result
CRP Lab Date	D-dimer Result	D-dimer Lab Date	Ferritin Result	Ferritin Lab Date
Procalcitonin Result	Procalcitonin Lab Date	ALT Result	ALT Lab Date	Creatinine Result
Creatinine Lab Date	Neutrophil Count	Neutrophil Lab Date	COVID-19 Result	COVID-19 Lab Date
Respiratory Rate	Respiratory Rate Date	Heart Rate	Heart Rate Date	SpO2 Result
SpO2 Result Date	Oxygen Flow Rate	Oxygen Flow Rate Date	Oxygen Therapy	Oxygen Therapy Date
Ventilation Type	Ventilation Type Date	Systolic Blood Pressure	Systolic Blood Pressure Date	Diastolic Blood Pressure
Diastolic Blood Pressure Date	Body Mass Index	Body Mass Index Date	Actual Weight	Actual Weight Date

Table 1. Electronic Medical Record Data for COVID-19 Dashboard. Table 1 Date indicate when the lab measurement was taken. Ventilation type refers to invasive versus non-invasive ventilation. FIN (facility identification number), MRN (medical record number), ICD-10 (International Statistical Classification of Diseases and Related Health Problems), LDH (lactate dehydrogenase), CRP (C-reactive protein), ALT (alanine transferase), SpO2 (oxygen saturation)

Figure 1. Dashboard Demonstration: At-a-glance visualization of an inpatient ward (using demo data) with color-coding to indicate clinically deteriorating patients

terioration and mechanical ventilation, helped to support large-scale level of care decisions. Comparing the 30 days before and 30 days after the implementation of the dashboard, the percentage of patients who required urgent intubation or cardiac resuscitation on the general medical ward, rather than a critical care setting, de-

clined by over 50% (8 out of 34, 33% vs. 7 out of 55, 13%; two-tailed $p < 0.05$ by Fisher's exact test; OR 3.43; CI 1.07 to 10.95). Third, the dashboard also provided at-a-glance visualization of patients who were stable enough to be transferred to non-monitored wards (Figure 1). This greatly facilitated the allocation of high dependency and

Figure 2. Pop up window with clinical details: Drill down function to view patient's specific risk factors and clinical details

Figure 2. Pop up window with clinical details: Drill down function to view patient's specific risk factors and clinical details

critical care beds. Further, stable patients who no longer required oxygen supplementation were easily identified for transfer to a lower acuity setting or discharge home. Finally, the dashboard was used to highlight complex patients to discuss during daily multidisciplinary rounds, making this meeting more efficient. Currently, IT records demonstrate that over 120 physicians in our institution utilize this dashboard on a daily basis.

Criteria for the evaluation of any dashboard has been classified into 7 main categories, specifically user customization, knowledge discovery, security, information delivery, alerting, visual design, and integration and system connectivity (2). We believe that through our collaborative, iterative process, our COVID-19 dashboard has met all elements of effective dashboard design.

5. DISCUSSION

The physician-IT collaboration helped to coordinate clinical and operational needs and was essential in establishing systems and structures to respond to COVID-19, whilst ensuring appropriate allocation of valuable healthcare resources during the pandemic. The teamwork enabled seamless communication to rapidly change IT policies and infrastructure as new priorities evolved. The utility and sustainability of the clinical intelligence dashboard was increased through incorporating feedback from the end-users as a means of continuous process improvement. The dashboard provided valid and clinically relevant data that was easily accessible and actionable.

Despite the benefits, dashboards can pose their own unique set of challenges and difficulties, ranging from the technical (coding expertise and integration limitations) to the financial challenges. Dashboard development can be costly, depending on the provider's requirements and its purpose (7). Our greatest challenge was the time constraint. Collaboration across departments involves developing a shared mental model, which can involve a significant time investment. In the midst of an infectious disease outbreak that limited group meetings and physical interaction, it was difficult to assemble a

team of people to map and refine the requirements, especially given the physicians' heavy clinical loads. Frequent and open communication, as well as a common goal to optimize scarce resources, ultimately facilitated the collaborative process.

In addition to the dashboard, our clinician-IT collaboration helped to create COVID-19 specific order sets and standardized documentation templates, which were continually updated to ensure that physicians had access to the most relevant and accurate information. The IT team also expedited procedures for granting access to the EHR and enabled tracking of patients located in non-clinical areas. Finally, when the hospital reached maximum capacity and nearby hotels were converted to inpatient COVID-19 areas, the IT team was able to quickly extend the network to all new treatment areas. These modifications substantially enhanced the ability of the frontline physicians to access information and provide seamless patient care, regardless of location.

Although the dashboard has been critical in clinician decision-making during the pandemic, it is not without limitation. First, our dashboard initially required manual updates that occurred every 2-3 hours during the daytime and physicians were not able to perform an ad-hoc display refresh when needed, which substantially limited its use, particularly after working hours. Currently, automatic updates occur hourly and the IT team is working on enabling more frequent updates, as well as an auto-refresh function. Further, the EHR does not have radiology reading capability, which precludes the inclusion of important chest x-ray or CT scan results in calculating the severity score.

As the first wave of the pandemic starts to subside, formal feedback from all clinicians regarding dashboard performance is currently underway. Including the diverse perspectives of all key stakeholders will help to optimize dashboard efficacy. Further, more studies are needed to assess the predictive validity of the clinical parameters that informed our COVID-19 severity score, which was used to clinically predict the probability of morbidity and mortality amongst the COVID-19 infected

patients. Validation of this scoring system, specifically the reliability of its use in predicting adverse outcomes, is necessary and currently underway.

6. CONCLUSION

While dashboards are used by hospital administrators worldwide to make macro-level manpower and resource allocation decisions, they are not routinely incorporated into the daily work of frontline clinicians in the UAE. In an effort to improve the efficiency and quality of care delivered to COVID-19 patients, an in-house clinical intelligence dashboard was designed and produced in our institution to aid on-the-ground physicians in their daily triaging and management decisions. We recommend the use of such dashboards as a streamlined approach to process large quantities of hospital and clinical data to prioritize and improve day-to-day patient care during this time of overwhelming healthcare demands imposed by the COVID-19 pandemic. As the needs of our clinicians can evolve over time, ongoing revision of the dashboard will likely be required. To our knowledge, this is the first emergency response clinical intelligence dashboard developed in the UAE. We have shared our experience regionally through webinars and expect to launch the dashboard in other government hospitals. We anticipate that the dashboard will be useful for public and private hospitals in the UAE and other countries that are grappling with the pandemic.

- **Ethical approval:** The patient outcomes data was obtained as part of a larger study approved by the Department of Health COVID-19 Institutional Review Board (DOH/CVDC/2020/978).

- **Authors contribution:** All authors were involved in all steps for preparation this article. Final proof reading was made by the first author.
- **Competing interests:** The authors declare no conflicts of interest
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