Automating triage and monitoring of 7578 COVID-19 migrant workers in the community: A Narrative Review

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Abstract

Background: The COVID-19 pandemic unmasked how quickly healthcare systems could be overwhelmed. One of the most pressing issues was the lack of hospital and intensive care beds. Attempts to mitigate these addresses both ends of the equation: admissions and bed creation. While it is relatively straightforward to utilize resources in generating more facilities, we were in unchartered waters with regards to refining triage criteria for admission to hospital for patients in the setting of community primary care.
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Methods: This narrative review shares our journey in determination and revision of triage criteria and effecting a robust self-monitored and reported automated vital sign system in a cohort of 7578 COVID-19 patients managed out-of-hospital.
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Results: We present descriptive statistics on our patient cohort’s vital signs, compliance rate to monitoring, percentage of patients triggering medical review, percentage of patients transferred out to hospital and adverse events incidence.
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Conclusions: We believe there are lessons and potential applications for the international community from our experience.

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MANUSCRIPT

Introduction

At the peak of Singapore's COVID-19 pandemic, a novel community quarantine facility (named Community Care Facility, CCF) was deployed in response to the swell of COVID-19 cases amongst our migrant-worker population[1]. To conserve limited manpower and healthcare resources while minimizing the risk of transmission, a strategy of low healthcare worker-patient ratio aided by technology was intentionally employed in the CCF. The facility was meant as a temporary stop-gap measure, hence with declining number of patients, it ceased operations after 3 months.

The overarching goal of CCF was to enhance patient safety while reducing exposure risk by minimizing the dwell-time of healthcare workers among patients. One challenge arising from this goal was how we would monitor and triage patients effectively within the CCF. The ideal system ensures high compliance, low false negatives and false positives in triggering transfer out of CCF to hospital and has safeguards to ensure every resident was accounted for. The facility we managed comprised of 4 halls, each with the capacity to admit 800 patients. We leveraged on an automated Vital Signs Monitoring (VSM) system: a shared-responsibility system where patients were trained to measure their own vital signs on 15 self-monitoring stations located throughout each hall, and then recorded the measurements via an app on electronic tablets provided. This uploaded data was monitored remotely by a dedicated medical team. The VSM detects pre-determined "out-of-range" vital signs ascribed as "triggers", as well as patients who did not submit recorded vital signs for the day. The system flags these up for downstream intervention and triage. We present the set-up, refinement process, outcomes, and safety profile of using such an automated system as an adjunct to managing a large number patients with a low healthcare worker to patient ratio.

Method

The selection criteria of patients tested positive for Sars-CoV2 on polymerase chain reaction testing admitted to CCF was determined by the Ministry of Health, Singapore and comprised Category 1 and 2 patients[2]. Patients were classified by duration since onset of symptoms or testing positive (whichever earlier), and age. Patients additionally had to be independent in their activities of daily living, not require supplemental oxygen, afebrile for at least 3 days, and have no comorbidities requiring inpatient care. Category 2 patients had to be 45 years or younger and not obese. Table 1 shows the baseline characteristics of our patient population.

- Hardware

Fifteen VSM stations were set up per hall; each station was equipped with two sets of digital sphygmomanometers, pulse oximeters, digital thermometers, and electronic tablets. A digital dashboard displayed aggregated VSM data via a web-based app accessible to authorized users. A desktop displaying the VSM dashboard was installed outside the halls, where values out of pre-determined ranges were highlighted.

Wi-fi was available in the CCF for the electronic tablets as well as for patients' mobile phones. SIM cards and mobile phones were sourced for those patients who did not have one. This ensured that the medical team could contact patients.

- Training

On admission, patients were given orientation booklets in their preferred language (8 languages available), instructing them how to record and submit their vital signs. They also received practical teaching from healthcare workers. Other measures instituted to boost compliance were having multi-language posters, Telegram and SMS phone reminders, and empowering existing patients who voluntarily taught newly admitted patients. Dedicated staff were trained to interpret the alerts highlighted on the digital dashboard and followed a protocolized workflow in response.

- VSM and Transfer Workflow

Patients were instructed to take and record a full set of vital signs at breakfast each day. Only Phase 2A+ patients required thrice daily monitoring, so they were instructed to measure their vital signs at lunch and dinner too. We synced the measurements to mealtimes as we postulated it would increase compliance as well as avoid crowding up meal areas. A patient was deemed compliant if he entered the requisite number of VSM entries per day.

At 1 - 2 AM, a non-compliance report was generated for the preceding day. An automated text message was sent at 6 AM to all patients on this list, prompting them to perform the task. These patients were also contacted by phone. At 9 -10 AM and 3 - 4 PM, medical staff review the dashboard. All patients with triggers were contacted via phone. They would be asked if they were feeling well and told to repeat vital signs measurement. Should the recheck parameters be out-of-range, they had to attend the sickbay situated in the hall.

During day shift, we had a roving team of healthcare workers within the halls tasked to locate patients if they were uncontactable. This served several purposes: to troubleshoot difficulties patients had with equipment, re-educate and correct errors in measurement techniques, and direct patients to sickbay if necessary.

At the sickbay, patients are tagged “abnormal VSM” to distinguish them from other sickbay patients, and a nurse rechecks their vital signs. Patients with values still beyond the cut-offs would undergo consultation by the sickbay doctor. The process to transfer a patient to an acute hospital by ambulance is initiated by the doctor. The logistics of transfer was designed for minimal personnel to be exposed to the patient during the physical route out of the CCF, and a no-contact medical handover to the receiving doctor ensured continuity of care.

Results

A total of 337,681 recordings from 7578 patients were collected from May to July 2020. Descriptive statistics of this cohort' shock index, pulse oximetry, heart rate, systolic and diastolic blood pressure, and temperature are shown in Table 2.

Patient compliance of ≥95% was attained by day 9 and maintained largely above 99% till the closure of CCF. Compliance rates tailed down towards 95% in the last 3 days due to a small population denominator.

There were 4773 sickbay visits. VSM abnormalities accounted for 118 (2.4%) of these. Other reasons for sickbay visits were medication refills and requests, or subjectively feeling unwell. Diagnoses from sickbay visits were categorized as dermatological/rash, gastroenteritis, abdominal issues, cardiac issues, respiratory issues, headache, psychological and others. Of all sickbay visits, 182 patients were transferred to acute hospitals for further management, of which 38 (20.9%) were due to VSM abnormalities. Twenty-four (63.2%) were admitted to general ward while the rest were assessed, investigated, observed, and discharged at the Emergency Department. Of the other 144 transfers, 71 (49.3%) were admitted.

Figure 1 shows the causes of VSM abnormalities in patients referred to the sickbay for evaluation and reasons for acute hospital transfers out of CCF. Hypertension was the most common vital sign anomaly triggering a sickbay review, followed by tachycardia. However, most acute hospital transfers triggered by VSM abnormalities were due to tachycardia (87%). The other reasons for transfers were hypertension and bradycardia.

Figure 2 details the composition of VSM triggers over time, and the overall composition of VSM abnormalities. Tachycardia was the commonest cause of VSM abnormality, followed by low saturation, hypotension, hypertension, and lastly bradycardia.

There were no adverse events such as cardiorespiratory collapse or mortality on site, and no patient-to-staff COVID-19 transmission for the entire duration of CCF operation.

Discussion

At the time when CCF was launched, there was paucity of studies on the use of predictive scoring systems for monitoring and triaging, specifically in COVID-19 patients, whether in-hospital or in the community. There was no guidance on stratification of patients into different risk levels based on baseline characteristics. The first iteration of the National Early Warning Score[3] was developed retrospectively and pragmatically, based on a logistic regression model incorporating 24-hours set of vital signs by the Royal College of Physicians in 2012, aiming to improve in-hospital recognition and escalation of care of unwell patients. This was revised to NEWS2[4] in 2017 but a recent single center study described that NEWS2 did not seem to be more predictive than its predecessor. One Chinese study[5] proposed an early warning score for COVID-19 patients adapted from NEWS2. A recent systematic review concluded that the value of NEWS2 in COVID-19 primary care is unknown and reliance on it was possibly premature. The NICE guidelines for management of COVID-19 in a primary care setting reflected lack of direct evidence on the value of NEWS2 and did not recommend face-to-face consultation to solely calculate NEWS2.

Without precedent data in a rapidly evolving pandemic, “pre-selection” criterion was applied, described above, to cohort COVID-19 patients deemed as likely low-risk patients for admission to the CCF. In this selected group of well patients, we then applied our VSM cut-offs, influenced by the above iterations of the NEWS scoring, to determine which patients required intervention. Our original cut-off values were: Heart Rate ≥100 or ≤50, Shock Index ≥0.8, Systolic Blood Pressure ≥180 or ≤90 mmHg and SpO2 ≤ 94%. Shock Index was automatically derived from the dataset.

$$Shock\ Index = \frac{Heart\ Rate}{Sysolic\ Blood\ Pressure}$$

It acts as a gauge of the extent of hypovolemia in infectious shock states[6], with 0.5 to 0.7 defined as normal.

The original cut-offs generated many triggers, peaking at 56.2% of patients on day 6. Our core committee held daily meetings to feedback and discuss how we to improve processes, including the VSM. We noticed majority of the triggers were from shock index, followed by heart rate. However, there was no commensurate large number of patients being transferred out. Most patients were asymptomatic and anxious; accounting for the tachycardia between 100 to 110. We redefined the cut-off values as: Heart Rate ≥110 or ≤50, Shock Index ≥0.9, Systolic Blood Pressure ≥180 or ≤90 mmHg and SpO2 ≤ 94%. We also addressed the issue of erroneous measurements and data entry described in Methodology. Figure 3 shows the percentage of admitted patients with VSM triggers over time.

Applying the revised cut-offs to the day 6 of CCF operations, the percentage of patients with triggers dropped to 40.6%. During the first 6 days of CCF operation managing 1120 patients, we found that patients with shock index triggers were clinically well and did not warrant escalation to a sickbay review or transfer out to an acute hospital for further evaluation. Thus, the committee agreed to further exclude shock index from criteria. With shock index excluded, the percentage of patients with triggers on day 6 drops to 33.5%. The percentage of patients with triggers fell to 11.1% by day 13 and remained below 10%. Our patient base was dynamic, but most admissions were within the first 12 days. We postulate that as patients become more familiar with the VSM, the percentage of patients fulfilling criteria for VSM triggers fell. This likely reflects correction of data entry and measurement technique errors.

We consider VSM triggers leading to sickbay visits a more accurate indicator of clinically significant vital sign abnormality than VSM triggers alone, as this cohort would have had their parameters rechecked and data collection verified or corrected by a member of the healthcare team. For example, the composite of VSM triggers due to desaturation was 29%, yet none were eventually referred to the sickbay for evaluation. This suggests with correction of measurement technique and data entry, no patient triaged from VSM was truly hypoxic with SpO_2 of 94% and below. Additionally, even though we had approximately 10% of patients meeting VSM trigger criteria daily, the actual percentage of patients visiting the sickbay or transferring out to an acute hospital was even lower.

Hypertension was the commonest VSM trigger requiring a sickbay visit, while tachycardia and hypotension made up the majority of VSM triggers. We perceived that anxiety from the stress of being in a new environment, facing uncertainty, and dehydration contributed to tachycardia and hypotension. Measures were taken to reassure patients, meet their psychological needs and address their concerns in a holistic manner. We engaged with patients on the ground and found, for example, that they were hesitant to hydrate adequately due to concerns on the cleanliness of shared toilets. We increased water points and frequency of interval cleaning of toilets, and repeatedly emphasized the importance of hydration. Progressively, the incidence of hypotension reduced but tachycardia continued to make up the bulk of VSM triggers. It is unclear if COVID-19 inherently results in tachycardia due to the disease process; furthermore, patients were afebrile.

Anxiety, undiagnosed existing hypertension and lack of access to medication were factors likely accounting for hypertension being the commonest VSM trigger for sickbay review. Patients were started on or obtained refills of antihypertensive medications at the sickbay, and we can see that their hypertension was effectively managed, since a low proportion of patients were transferred out for hypertension.

The mean shock index was 0.7, which sits at the upper limit of normal range. Yet, we found a large proportion of patients would meet VSM trigger criteria of shock index ≥0.9 (Figure 6) on any given day. We are uncertain of the utility of this score in the triaging of COVID-19 patients in the community as it might generate too many false positives for the purpose of identifying patients requiring escalation to an acute care facility.

Limitations

Our report is limited by observational descriptive data and retrospective analysis, as we had not intended to embark on an observational study prospectively. This model of care was applied to a cohort of patients who were low risk males of Asian ethnicity – generalizability to other patient populations is not assured. However, there has been no strong evidence to suggest the COVID-19 in-vivo biological disease process is significantly different in either gender or ethnicity. There is some suggestion that males tend toward higher risk of severe infection and mortality related to COVID-19[7], and that socioeconomic status may be a confounder for ethnicity influencing the incidence of hospitalization and mortality in COVID-19. Vital signs fluctuate throughout the day even in well, non-COVID adults, and measuring them once or thrice a day at random time-points may not reflect the true overall physiological state. What mitigates this is that we have collected many data points from a large cohort of patients, and the descriptive statistics reflect a normal distribution of data. Patient population numbered less than 200 daily in the last 4 days of CCF operation, hence we would consider these last few days of data to be skewed for compliance.

Conclusion

Using VSM, we were able to safely monitor 7578 patients over 3 months with a staffing ratio of 3 to 4 doctors and 8 to 14 nurses or allied staff per 800 patients in the day shift (8 AM to 8 PM). During night shift (8 PM to 8 AM), this ratio is reduced to 1 doctor and 2 nurses or allied staff. This aided in minimizing manpower decanted from our main institution, such that routine hospital function was not impacted.

The VSM model is modifiable, scalable, and potentially applicable to a non-CCF setting. With multiple new burgeoning clusters of COVID-19 patients a distinct possibility across the world, a similar but customized model for out-of-hospital monitoring and triaging may help to rationalize and reduce hospital admissions in low-risk patients. This helps to preserve hospital capacity for COVID-19 patients who truly require that level of care, and patients with non-COVID-19 illnesses who require treatment in hospital. Even though we ceased operation after 3 months because concomitant public health measures effectively reduced community transmission, we would have been able to continue operating long-term without adverse impact on routine hospital functioning. The model should be adapted to specific local needs and healthcare delivery characteristics. We believe this has potential applicability in future novel pandemics.

We emphasize that VSM triaging should not be used in isolation. Patient safety was achieved through multiple prongs of care and safeguards. Other aspects of care of COVID-19 patients in the community importantly include availability of primary healthcare, access to medical assessment, access to medications, software and hardware for data collection and communications, and a reliable system for escalation and transfer to an acute care facility while minimizing risk of infection to healthcare personnel.

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