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COMMENT

COVID-19 Close Contact Management: An Evolution of Operations Harnessing the Digital Edge

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Abstract
Singapore, like many other nations globally, had to contend with significant caseloads arising from the Coronavirus disease (COVID-19) pandemic. This paper focuses on using technology as an intervention for pandemic management. With scant scientific evidence on effective medications and vaccinations (i.e., pharmaceutical interventions) initially, disease containment strategies predominated during the early phases. Non-pharmaceutical interventions were critical in slowing disease transmission and preventing public healthcare institutions from being overwhelmed. Such interventions could be broadly divided into case-based interventions (e.g., contact tracing and quarantining of close contacts) and population-based measures (e.g., mask use and social distancing). The paper describes Singapore's experience in the operational implementation of contact-based interventions, and illustrates how harnessing the digital edge enabled fast, accurate, resource-efficient, and flexible execution of ground operations. Singapore applied digital technology and developed an integrated system to facilitate issuance and acknowledgement of quarantine orders, submission of COVID-19 test results, and collection of antigen rapid test kits at the population level. Data was obtained from this proprietary centralised, automated platform. The paper demonstrates how such simple, yet elegant systems could have a direct impact on disease transmission in an outbreak setting and on population health. Moving forward, it is recommended that technology and digital solutions feature prominently in work process designs beyond COVID-19 such as in the management of emerging infectious diseases and non-communicable diseases.

Keywords COVID-19 · Close contact · Pandemic management · Digitalisation · Electronic system

Introduction and Context

Singapore confirmed the first imported Coronavirus disease (COVID-19) case on 23 Jan 2020 and the first local cluster emerged on 4 Feb 2020. With local unlinked cases surfacing in quick succession, the Disease Outbreak Response System Condition (DORSCON) level was raised from Yellow to Orange on 7 Feb 2020. Travel restrictions were imposed from 1 Feb 2020 and 14-day stay-home notices were issued to Singaporean travellers returning from China beginning 17 Feb 2020. Case numbers began to climb towards the middle of March 2020 in Singapore, with a similar trend observed globally. On 11 Mar 2020, the World Health Organisation officially declared COVID-19 a pandemic.

The natural tendency during pandemic management is for significant attention and resources to be channelled towards the treatment of infected persons. However, in the case of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a proportionate amount of resources had to be directed towards the management of close contacts to prevent further spread within the population and minimise consumption of limited healthcare resources due to its transmissibility.

Non-pharmaceutical interventions (i.e., interventions not involving medications or vaccinations) were critical in slowing disease transmission and preventing public healthcare institutions from being overwhelmed initially when

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pharmaceutical interventions were not available. Such interventions could be broadly divided into case-based interventions (e.g., contact tracing and quarantining of close contacts) and population-based measures (e.g., mask use and social distancing) [1]. Reported models showed that in an outbreak context, case-based interventions can work synergistically with population-based measures to mitigate overall transmission [1, 2]. However, such interventions were extremely labour- and resource-intensive from the get-go.

This paper seeks to describe Singapore's experience in the operational implementation of contact-based interventions, and illustrate how harnessing the digital edge enabled fast, accurate, resource-efficient, and flexible execution of ground operations. To this end, we recommend that evolving pandemic response plans should incorporate or continue to retain a critical digital element within as it has been demonstrated to facilitate large-scale interventions to a significant extent.

Initial Stage – Manual Delivery of Hardcopy Quarantine Orders (QOs)

During the initial phases of pandemic management, while quarantine operations were still in its infancy, QOs were hand-delivered as hardcopy documents with in-person acknowledgements. Such a modality had considerable disadvantages in that the preparation and delivery of these official documents was extremely labour- and resource-intensive and prone to human error. A typical QO could take up to 12 to 24 h to be issued and acknowledged by its intended recipient. With progressive increments in case volume as the pandemic evolved, an electronic means of QO delivery and acknowledgement was required to match the speed and scale at which close contacts were generated.

Development and Mainstreaming of Electronic QOs

Consequently, electronic QOs were operationalised and seamlessly integrated into Singapore's COVID-19 Management System, a centralised platform commissioned in March 2021 to handle and store all COVID-19-related information of individual patients. Such integration provided for a single source of truth and ensured that quarantine workflows were streamlined from the time of close contact identification to QO issuance. When this concept was first mooted, engineering for system compatibility and workflow integration were key considerations.

Electronic QOs were mainstreamed and designated as the default modality of QO issuance following the arrival of the Delta variant in April 2021. Singapore's experience following this transition was dramatically different, and was one marked by speed, efficiency, accuracy, and manpower savings. The litmus test for this system was during surges fuelled by local clusters in April and July 2021. The quarantine caseload multiplied by more than ten, alongside a steep rise in daily confirmed COVID-19-positive cases. As visualised in Fig. 1, the system could handle more than 3,000 close contacts by July 2021. This provided the necessary reassurance when Singapore eventually faced the peak of the Delta wave in October 2021, which saw close to 6,000 electronic QOs issued daily.

Transition to Health Risk Warning (HRW) and Health Risk Alert (HRA)

The issuance of QOs upended lives and disrupted livelihoods significantly as individuals had to observe a period of complete isolation from others for seven to ten days. It meant that they could only work if they had means of working remotely and had to source for alternative caregivers for their dependents. Persons under QO also had to undergo mandatory polymerase chain reaction (PCR) tests at the start and end of their isolation period. Furthermore, given high daily case numbers under surge circumstances in densely populated Singapore, there was the possibility for one unique individual to receive consecutive QOs due to successive exposures after the preceding period of isolation. At the national level, accommodating individuals whose household was unsuitable for quarantine also strained capacities and resources at government quarantine facilities. A more sustainable approach to close contact management was required in order to ensure that public inconvenience was minimised.

In a bid to further stratify transmission risks and probability of infection, and commensurate public health measures to risk levels, HRW and HRA were conceptualised [3]. This was in the context of better knowledge of virus characteristics and substantial vaccination uptake amongst the larger population. HRWs replaced QOs and were issued to persons who had been close to a COVID-19 case for an extended period or identified as close contacts based on TraceTogether (Bluetooth-enabled contact tracing application) and SafeEntry (location entry/ exit recording system) data. In contrast to QOs, persons issued a HRW only had to undergo a mandatory PCR test and remain isolated until a negative result was confirmed. After which, they were strongly recommended but not required to remain isolated. The individual had to undergo another mandatory PCR test

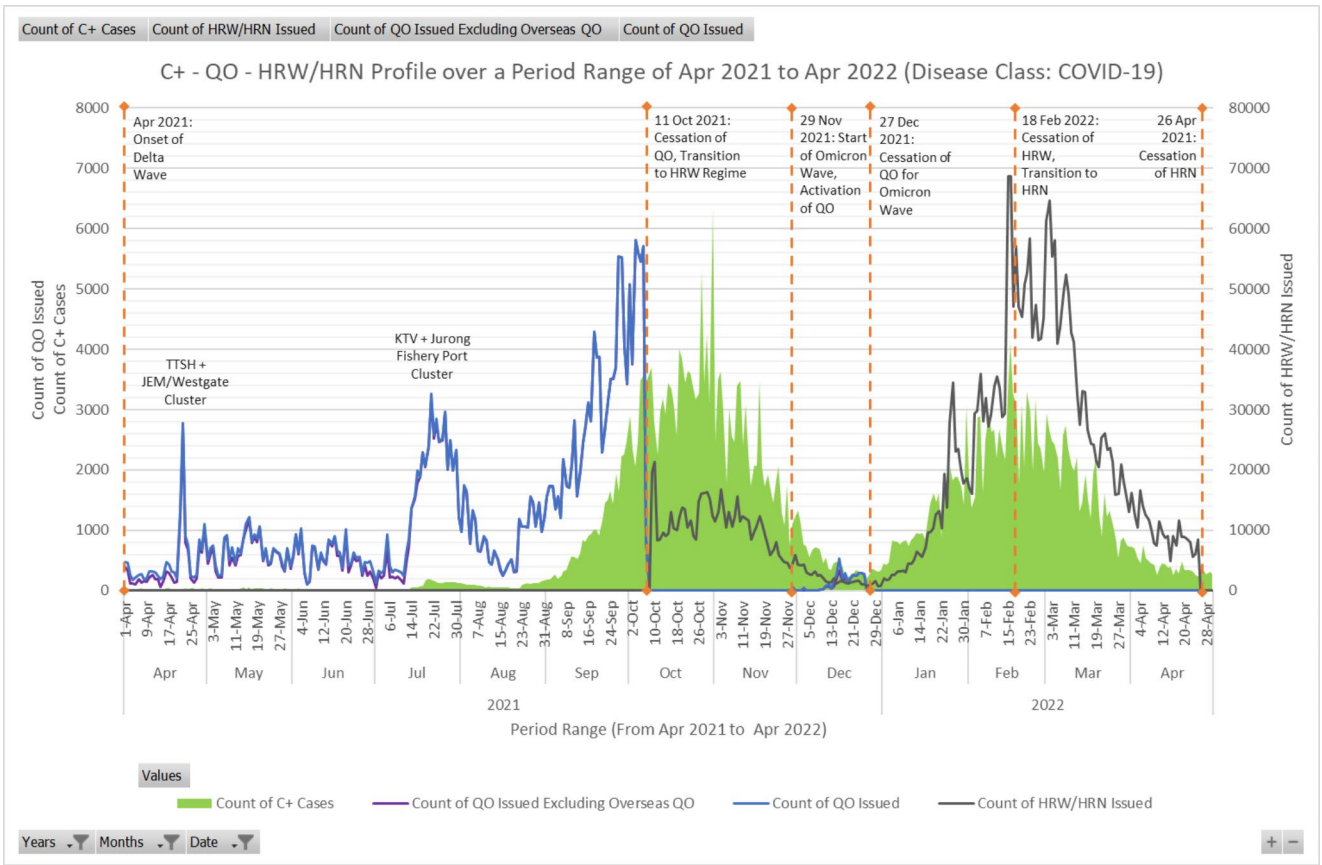

Fig. 1 Chart of COVID-19-positive (C+) Cases, Quarantine Orders (QOs) Issued, and Health Risk Warnings (HRWs) and Health Risk Alerts (HRAs) Issued

at the end of the HRW period, with self-administered antigen rapid tests (ARTs) during the intervening period, to confirm a non-infected status.

HRAs were issued to persons whose location data for the past 14 days overlapped with those of a COVID-19 case. Such persons had to undergo self-administered ARTs upon receipt of the notification and at regular periods during the prescribed period. Again, these individuals were not required to remain isolated if the initial self-administered ART returned negative.

Overall, the cessation of QOs and introduction of HRWs and HRAs represented a policy shift from state governance/enforcement to individual social responsibility. This pivot complemented the simplified COVID-19 management strategy which broadly segregated individuals into unwell patients (Protocol 1), those assessed to have mild illness or were well (Protocol 2), and close contacts (Protocol 3) [4]. Following the commencement of HRW and HRA issuance on 11 Oct 2021, daily transaction volumes increased further and ranged from ten to twenty thousand (see Fig. 1). Similar to electronic QOs, the issuance of HRWs and HRAs relied heavily on a completely digitalised process, including an automated centralised processing platform receiving inputs via digital forms and generating Short Message Service (SMS) notification outputs with internet links to electronic forms to identified recipients.

Successes

The digitalisation of QO issuance and acknowledgement gave the task group the capability and flexibility to react to the fluid ground situation. For a sudden change in isolation location or personal particulars, whereas the conventional pen-and-paper modality would have necessitated the operators to go through laborious and layered processes for a simple amendment to be effected, all the electronic system required was for a service request to be raised for the recipient to receive the revised text within the hour. The additional capacity created enabled the task group to focus efforts on (1) rapid notification and ring-fencing of close contacts, (2) education on the requisite health-related measures and follow-up actions to be adhered to, and (3) enforcing compliance with the quarantine orders issued. If not for the speed, reach and coverage through electronic QOs, transmission containment efforts would have been

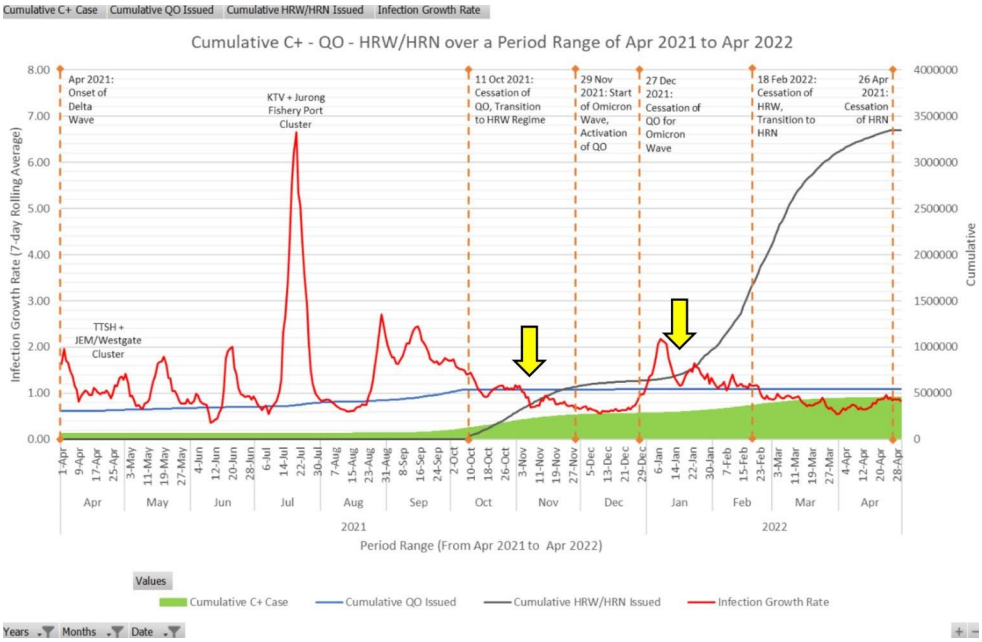

Fig. 2 Chart of Cumulative HRWs and HRAs Issued and Infection Growth Rate

significantly hampered, with the possible end result of much higher peaks observed and healthcare facilities being inundated and overwhelmed by cases.

The end-to-end digitalisation of processes, incorporating case identification, notification, acknowledgement, and subsequent closure, enabled automated triggering of downstream workflows once prerequisite actions were completed and registered electronically. As human intervention was kept to a bare minimum, coupled with automation driving key processes, turnaround time for each close contact was rapid and the system demonstrated robustness in handling large case volumes. During the ensuing Omicron wave in February 2022, total daily transactions came close to seventy thousand (see Fig. 1). This further reinforced the utility of an electronic platform and the importance of harnessing the digital edge for close contact management in a pandemic setting.

Figure 2 clearly demonstrates the suppressive effect that the HRWs and HRAs had on the national infection growth rate, as evidenced by the divergent curves each time there was an increase in HRWs and HRAs issued (see **yellow arrows**). The success of such a public health measure could be attributed to (1) contact tracing capabilities, (2) ability for the relevant warnings and alerts to be triggered and dispatched rapidly, and (3) general cooperativeness of the local population when it came to exercising social and personal responsibility.

As the pandemic continued to evolve with successive variants causing less severe disease overall, HRWs and HRAs were consolidated as Health Risk Notices (HRNs) on 18 Feb 2022. This represented a transition towards normalcy with further shortening of the recommended isolation period and the use of self-administered ARTs for de-isolation.

Lesson Learnt – System Integration and the Use of Smart Vending Machines for Distribution of ARTs

Central to the success of the socially driven HRW/ HRA/ HRN public health measures were availability of ARTs for self-testing. When test kits became commercially available, 100 smart vending machines which were accessible round-the-clock were sited at accessible locations across the island from 17 Sep 2021 (see Fig. 3) [5]. As described, because information of all close contacts was centrally processed on a common platform, this permitted simultaneous whitelisting of close contacts to self-retrieve free testing kits from any of the internet-connected vending machines situated island-wide at their own convenience in real-time.

System integration and technology (1) eliminated the need for tedious backend processing of close contact information on a separate platform, (2) minimised the time lag to obtain ARTs for self-testing, (3) obviated the need to physically man collection booths or stations round-the-clock, and (4) prioritised user-centricity and ensured that the pleasant user-experience facilitated individuals in exercising social responsibility.

To further improve accessibility and ART availability, the total number of smart vending machines deployed across Singapore was scaled according to weekly projected demands based on the trajectory of the local epidemiological curve. At the peak of the Omicron wave, 250 vending

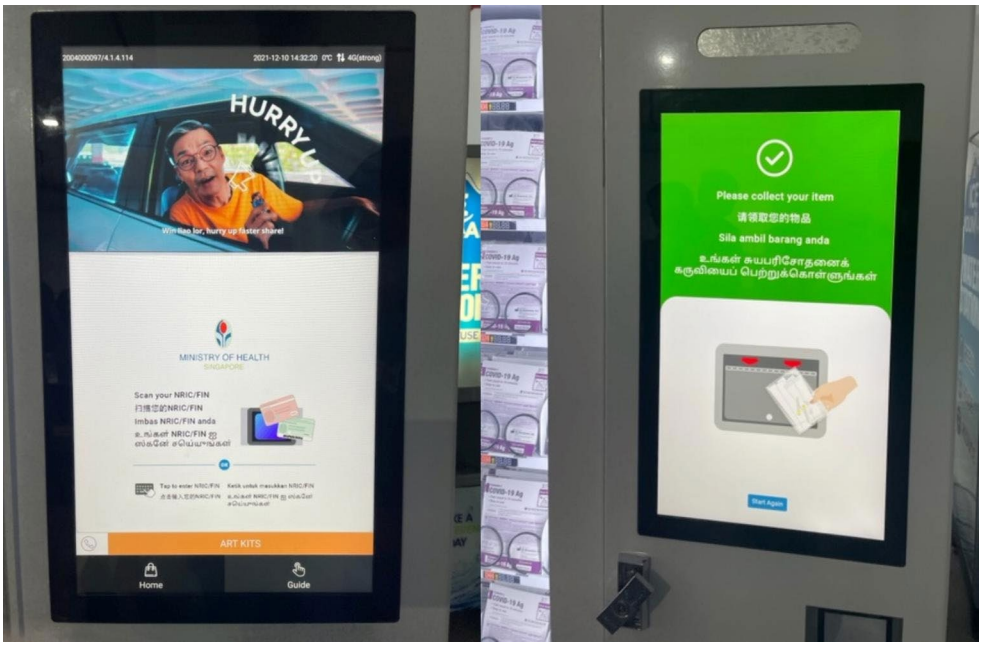

Fig. 3a and 3b: ART Vending Machine

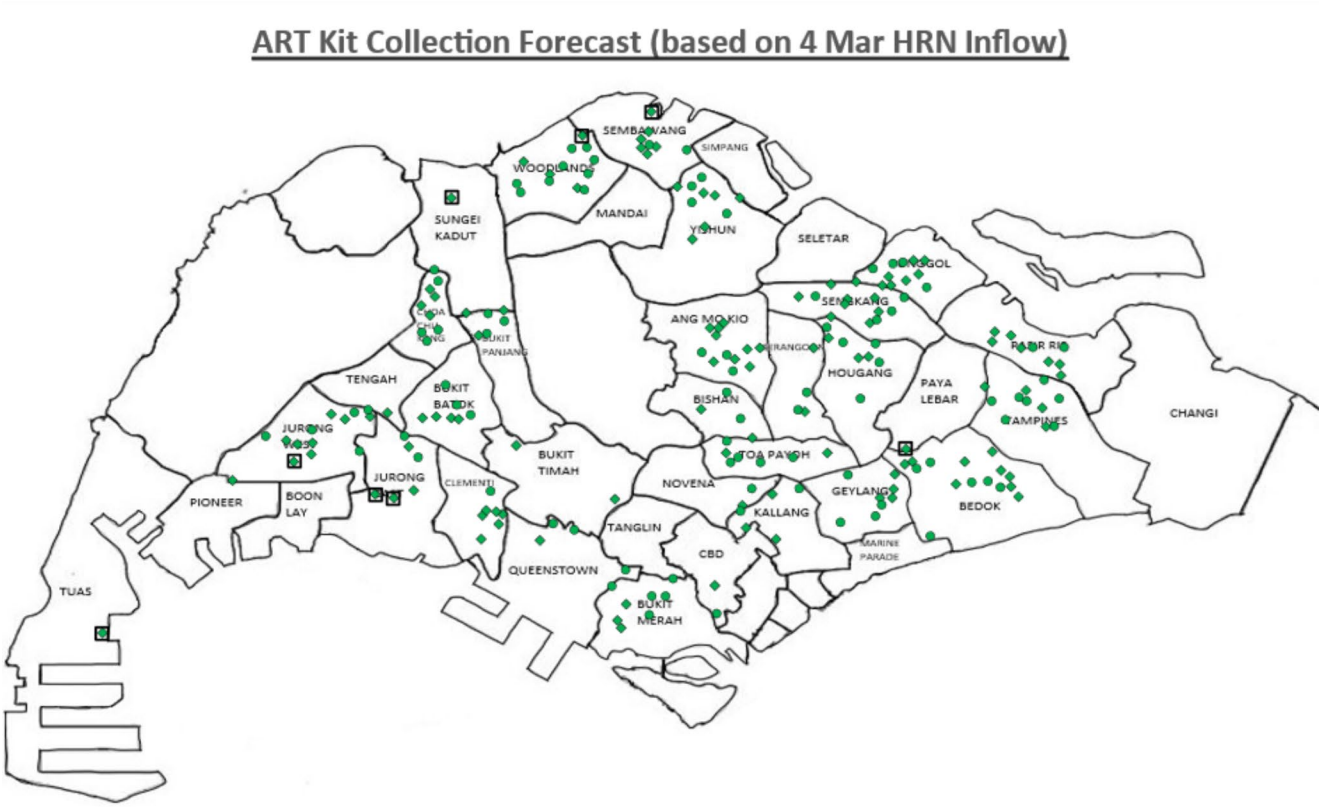

Fig. 4 Island-wide Distribution of ART Vending Machines

machines were deployed across Singapore near dormitories, residential precincts, and transportation hubs (see Fig. 4).

Conclusion

The development of a completely digitalised end-to-end close contact management workflow integrated with a centralised, automated platform enabled large volumes of

information to be collected, processed, and actioned upon in real-time. Capitalising on digital technology thus enabled physical resource constraints to be overcome and high accuracy rates to be achieved where non-pharmaceutical interventions were concerned. Although such a development was spurred primarily by pandemic needs, potential applications beyond COVID-19 to other emerging infectious diseases and non-communicable diseases should be considered. Leveraging technology to improve existing processes should not be an afterthought but an ongoing consideration. Re-thinking and re-designing existing workstreams using technology and integrated systems as an enabler would facilitate ground operations and free up capacity to focus on more critical tasks. Therefore, we strongly advocate that such digital solutions be suitably incorporated into future pandemic response plans and daily work processes.

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Declarations

Ethical Approval Not Applicable.

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