

Nationwide implementation of a centralised telemedicine platform in Singapore to fight the COVID-19 pandemic

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Abstract

Introduction: This study aims to share the experience of the Ministry of Health (Singapore) in deploying a centrally managed Telemedicine service to triage, and manage COVID-19 cases in the community during the COVID-19 Omicron wave.

Material and methods: Data from the deployed telemedicine system, Telemedicine Allocation and Reconciliation System, over a 14-week period (3 January 2022–10 April 2022) was analysed to determine the safety and efficacy of both the (i) National COVID-19 sorting logic algorithm and (ii) the use of a centralised telemedicine platform with privacy protection in a pandemic.

Results: There was a total of 47,754 children (aged 1–11 years old), 75,702 adolescents and adult patients (aged 12–69 years old) and 55,774 geriatric patients (aged ≥ 70 years old) who were directly managed by this platform. Amongst them, 64,961 were from the higher-risk special populations (pregnant, end-stage renal failure and immunocompromised and geriatric population).

The total number of patients requiring escalations to public health institutions were 4212. This accounts for 1.32%, 3.00% and 2.35% of the children, teenagers and adults, and geriatric population respectively.

Keywords

Telemedicine, telehealth, covid-19, home telecare

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Introduction

COVID-19 is an infectious disease that originated from China in December 2019.¹ It quickly evolved into a global pandemic, forcing many countries into a public health lockdown. In Singapore, COVID-19 infections rapidly spread amongst its densely populated population in three waves. The first wave (April to June 2020) was concentrated within the migrant worker population, who resided in densely populated dormitories.^{2,3} The second (September to December 2020) and third waves (January–April 2021), namely the Delta wave and Omicron waves, respectively, became widespread amongst the general population.⁴

The Multi-Ministry Taskforce devised a national strategy to isolate infected individuals in their homes and quarantine facilities, in order to prevent overloading of critical secondary and tertiary hospitals.⁵ The implementation of swift contact tracing, regular mass testing and isolation of infected individuals and close contacts was meant to break the chain of COVID-19 transmission.

By the Delta and Omicron waves, majority of the isolated or quarantined individuals were managed in community isolation facilities or their own homes with no round-the-clock access to medical care. As such, the Ministry of Health (MOH) was tasked to scale limited private healthcare resources in order to extend round-the-clock medical care to such individuals through non-traditional healthcare delivery models, namely telemedicine.

Material and methods

Prior to this pandemic, the delivery of telemedicine services was not catered for by existing healthcare regulations. As

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such, telemedicine healthcare players were enrolled into a regulatory sandbox, managed by the MOH, with a view of regulating telemedicine formally via the Healthcare Services Act (2020). Telemedicine was trialled and implemented in both the private and public healthcare ecosystem in a safe and progressive manner, with data protection measures in place.⁶

Overview of the telemedicine platform deployed

Telemedicine Allocation and Reconciliation System (TMARS) is a web-based Telemedicine platform hosted on the Amazon Web Service (AWS) commercial cloud. TMARS started off as a centrally managed telemedicine software system developed and deployed by the MOH in early 2019 to extend medical care to migrant workers residing in dormitory facilities. The TMARS system was subsequently managed by the Ministry of Manpower (MOM) team, who assumed the task of providing medical care for migrant workers.⁷ TMARS was subsequently adopted and enhanced for COVID-19 pandemic purposes, in order to support the Home Recovery Program (HRP), and to reduce the strain on public healthcare resources.

Overview of teleconsultation journey on TMARS

Details of all COVID-19 patients are pulled from the National Database on a daily basis (Diagram 1). The patients are risk stratified according to the National sorting logic algorithm (Diagram 2). Patients deemed suitable for the HRP are added in the TMARS. Patients requiring a teleconsultation or who request for a teleconsultation are automatically

assigned a suitable Telemedicine provider via TMARS. The telemedicine provider will connect with the patient via a synchronous audiovisual tool (usually WhatsApp video call). The telemedicine provider will input the medical notes, prescribe medication and issue any required medical documents electronically via TMARS. In the event that the COVID-19 patient under the HRP is deemed by the telemedicine provider to require an escalation to higher echelon care, this will be flagged out by TMARS for operational staff to arrange for conveyance.

Concept of telemedicine operations

The concept of telemedicine operations deployed for COVID-19 was developed by a centralised command centre overseeing the nationwide COVID-19 strategy. The strategy was to deploy a unified, centrally managed cloud-based system with data privacy measures in place to tackle the problem. The concept can be divided into three phases, namely pre-consultation, consultation and post-consultation.

Pre-consultation phase

1. *COVID-19-19 data gathering and aggregation:*
Personal information, individual’s COVID-19 vaccination records and swab testing results (polymerase chain reaction and antigen rapid tests) were pulled from the respective nationwide data repositories into the TMARS system (Figures 1, 2 and 3).
2. *Risk stratification framework:*
Infected patients were risk stratified based on the National COVID-19 sorting logic framework (Diagram 2).

Phase	Pre-consultation phase	Consultation phase	Post-consultation phase
Elements	<ul style="list-style-type: none"> • COVID-19 data gathering • Risk stratification framework • Telemedicine provider allocation 	<ul style="list-style-type: none"> • Telemedicine consultation • Medical records • Medication prescription and medical documents 	<ul style="list-style-type: none"> • Medication delivery • Follow-up • Escalation of care

HRP: Home Recovery Program; TMARS: Telemedicine Allocation and Reconciliation System.

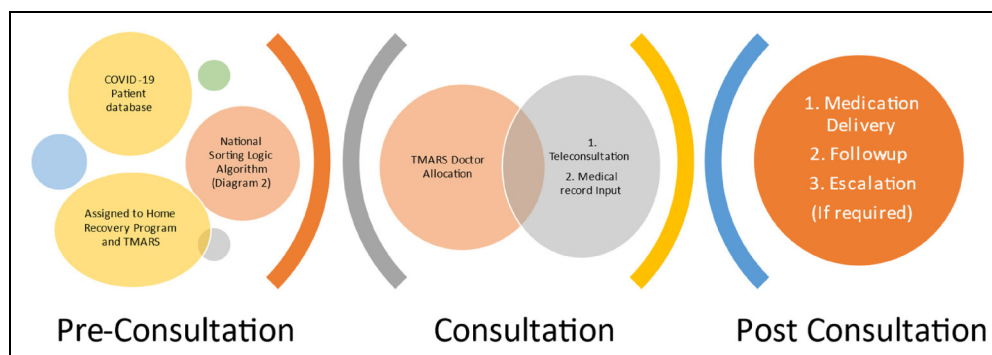


Diagram 1. Overview of teleconsultation journey via Telemedicine Allocation and Reconciliation System (TMARS).

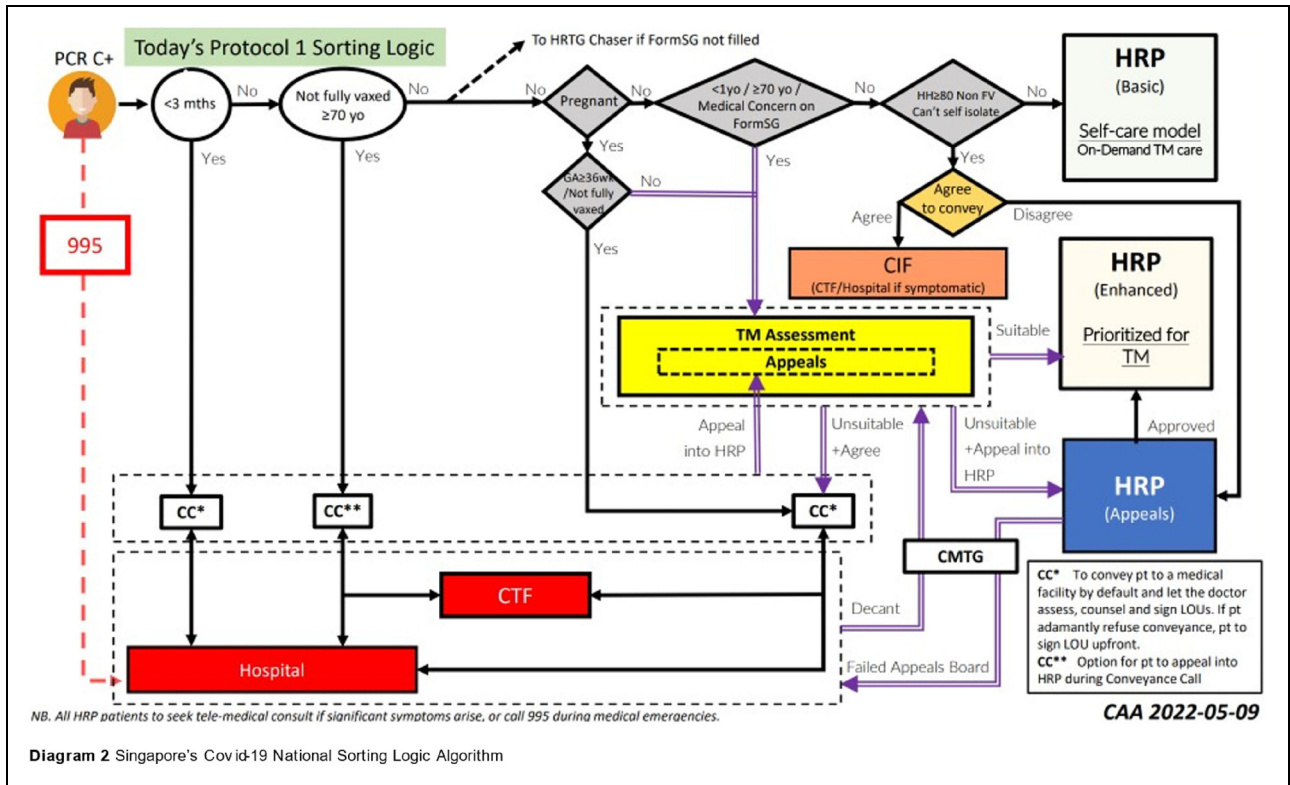


Diagram 2. Singapore's COVID-19 National sorting logic algorithm.

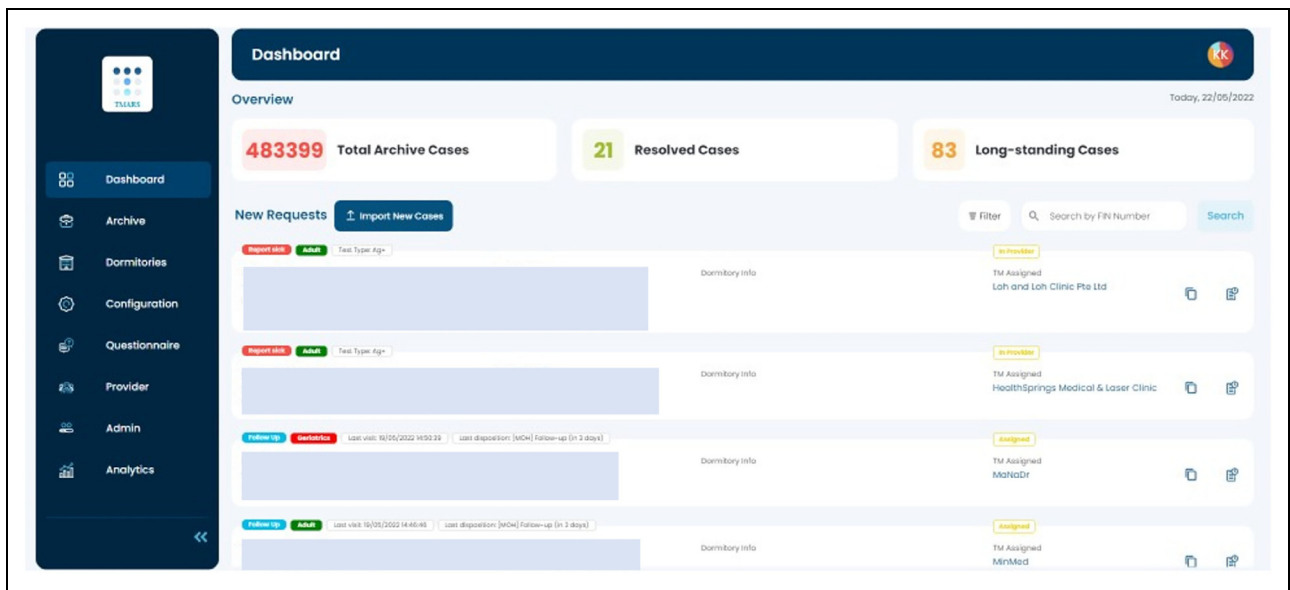


Figure 1. Dashboard of Telemedicine Allocation and Reconciliation System (TMARS).

COVID-19 risk factors such as age, vaccination status and relevant co-morbidities were taken into consideration to determine the risk of poorer outcomes.

High-risk individuals were treated at dedicated hospital facilities. While low-to-moderate risk individuals

were managed at either community isolation facilities or at home via the HRP (Figure 4).

3. *Telemedicine provider allocation:*

Infected individuals deemed as low to moderate risk and managed in either community isolation facilities

Case Detail

Patient Name: [Redacted] Work permit Number: [Redacted] WhatsApp no.: [Redacted] Language: english

Postal Code: [Redacted] Case reference no.: [Redacted] Address: [Redacted]

Case Type: Follow Up Patient Type: Pregnant Residential Name: No Data Residential Type: No Data

Test Type: C+ Did a doctor tell you that you are COVID-19 positive? No Data

Timestamp: 22/05/2022 07:22:56 Swabbing Available? No Data

Age: 37 year(s) old Gender: F

Alternative contact number: [Redacted] DOB: 01/07/1984

Vaccination status: VP Day 1 of PCR positive: 19/05/2022

Age: 37 Remarks: Pregnant 10 Wk vaccinated

Past Medical History Consultation Notes Diagnosis **Disposition & Prescription** MC & Memo Others

Disposition
Case Resolved

Prescription

History

Figure 2. Pre-consultation details captured on Telemedicine Allocation and Reconciliation System (TMARS).

or HRP will be algorithmically assigned a telemedicine provider.

The telemedicine provider may be tasked to do any of the following:

- Assessment: To assess if the patient is suitable for community isolation or home recovery;
- Appeal: For medical appeals relating to an infected individual's appeal against their designated isolation facility;
- Ad hoc consultation: Individual will register via a dedicated web browser-based registration page;
- Follow-up consultation: Automatically triggered by the TMARS system based on the initial assessment and/or medical policy.

The telemedicine providers are assigned patients based on their respective capabilities such as age, specific medical features and operational capabilities.

(a) *Patient age or co-morbidities:*

- Age: Paediatric and geriatrics and
- Medical condition: pregnant, end-stage renal failure on dialysis and immunocompromised.

(b) *Operational capabilities:*

- Operating hours,
- Operational capacity,
- Geographical location and
- Ability to handle appeal or assessment cases.

Consultation phase

1. *Telemedicine consultation:*

Telemedicine providers are provided with a restricted web browser-based user account for the purposes of telemedicine consultation. They are only able to view the relevant patient information of patients assigned to them.

During the initial stages of TMARS implementation, the telemedicine provider had to contact the patient via social video conferencing tools (e.g. WhatsApp video calls). Subsequently, TMARS was enhanced to allow a seamless and synchronous audio-visual experience via the platform.

Video Call A Doctor Now

Name
Name

I do not have a Singapore-issued NRIC/FIN/UID.

NRIC/FIN
Input NRIC/FIN

Date of Birth
DD/MM/YYYY

I am pregnant

Mobile Phone Number
+65 Phone Number

Alternative Contact
+65 Alternative Contact

Postal Code
Postal Code

Are you currently on Dialysis?
No

Are you on chemotherapy or/and medications that will cause you to be immunosuppressed?
No

Figure 3. Ad hoc consultation request form for patients on Telemedicine Allocation and Reconciliation System (TMARS).

Vulnerable groups not suitable for telemedicine were assigned a mobile medical team that provided in-person healthcare assessment and management in the comforts of their own home or isolation facility.

Patients who were socially vulnerable or uncontactable via telemedicine means were escalated to a mobile team of healthcare personnel (**'Chaser Team'**). They were deployed to the patient's doorstep to physically establish contact with the uncontactable patients. This team (which is physically present at the patient's home) was able to use digital means to connect with existing telemedical resources or to escalate healthcare to public healthcare resources without unnecessary delay.

2. Medical records:

The Telemedicine provider is able to simultaneously input the medical consultation notes of the patient. This is recorded in the patient's respective cloud ledger which is accessible to other providers who are directly involved in the patient's medical care.

The telemedicine provider is able to prescribe medications (based on a templated pharmacy inventory) and also the relevant medical documents via the platform.

3. Medication prescription and medical documents:

Medications prescribed by the telemedicine provider is fulfilled by the respective Clinic entities, who will prepare the medications and call the patient to counsel them regarding medication usage.

Medical documents are downloadable electronically via a secured access link sent to the patient's mobile post telemedicine consultation.

Form SG Triage Criteria

1. Age ≥ 70 or Child < 1 yo
2. Weight above 100kg
3. BOTH Diabetes Mellitus AND history of heart attack / stroke / laser therapy for diabetic eye disease / amputations
4. Immunocompromised (ANY)
 - i. Have you had any organ transplant surgery performed before?
 - ii. Any disease or medication that weakens the immune system
 - iii. Have you ever been diagnosed with cancer before (including blood cancers)?
 - iv. Are you on dialysis?
 - v. Have you ever been diagnosed with HIV/AIDS?
5. Having a disease affecting the heart, lung, kidneys, liver or brain, requiring admission to a hospital **at least once in the past 6 months.**
6. Pregnant
7. Unable to self-isolate
8. Living with a household member who is not fully vaccinated and 80 years or older?
9. Under 12 years old AND has a congenital or chronic condition that affects the heart, lung, brain, nerves or muscles
10. Under 12 years old AND has either Diabetes Mellitus or Hypertension

Figure 4. Singapore's COVID-19 triage criteria.

Post-consultation phase

1. Medication delivery:

The prescribed medication will be delivered to the patient within the same day through third party logistics providers.

2. Follow-up:

TMARS system generated follow-up consultation will be triggered via the platform to the assigned doctor on the assigned date.

3. Escalation of care:

Patients who are deemed to require an escalation care to the relevant higher echelon care facilities will be flagged up by the TMARS system to the MOH's COVID-19 operations team, who will arrange the necessary resources for convincing via dedicated logistic assets or emergency medical services.

Evaluation of key outcomes

Data from TMARS were collected and analysed on a regular basis throughout the pandemic in order to refine the National COVID-19 sorting logic and also the nation's COVID-19 management policy.

For the purposes of this study, data from the period of 3 January 2022 to 10 April 2022 (14 weeks period) was analysed. This time period co-relates with the third wave of COVID-19 infections (Omicron wave).

This study aims to provide a breakdown of patient demographics who were infected with COVID-19 and assigned to TMARS during the Omicron COVID-19 wave, and also to determine the safety and efficacy of both the (i) National COVID-19 sorting logic algorithm and (ii) the use of a centralised telemedicine platform in a pandemic.

Data such as patient's demographics, special risk groups, assignment logic (assessment, follow-up and ad hoc requests) and care escalation were used to determine the safety and efficacy (i) and (ii). (Table 1)

Results

During the period of 3 January 2022 to 10 April 2022 (14 weeks period), a total of 179,230 COVID-19-related

telemedicine consultations were completed via TMARS. There was a total of 47,754 children (aged 1–11 years old), 75,702 adolescents and adult patients (aged 12–69 years old) and 55,774 geriatric patients (aged ≥ 70 years old). Amongst them, 64,961 were from the higher-risk special populations (pregnant, end-stage renal failure and immunocompromised and geriatric population).

The total number of patients requiring escalations was 4212. This accounts for 1.32%, 3.00% and 2.35% of the children, teenagers and adults, and geriatric population respectively (Table 2).

To assess the adequacy of the National sorting logic algorithm, based upon age, vaccination status and high-risk co-morbidities, the percentage of patients escalated amongst the case types (ad hoc, assessment, and follow-up) was used as a surrogate measure. The percentage of patients escalated amongst the various case types are 6.70%, 3.80% and 0.14% for the ad hoc, assessment and follow-up cases, respectively (Table 3).

Interesting to note, the drop-call rates (i.e. number of TMARS assigned patients who were not contactable) was less than 1.00%. This demonstrated the effectiveness of the mobile medical team and Chaser team in reaching out to socially vulnerable or uncontactable patients.

Discussion

The COVID-19 pandemic brought about a unique public health crisis. Economies were brought to a standstill, with many countries adopting swift contact tracing, mass testing and close contact isolation to break the chain of transmission. To manage surges in infections, many countries adopted a strict lock-down approach in order to preserve and prioritise existing healthcare resources.⁸

With the advent of smartphone devices, affordable telecommunication tools and cloud computing technology (Web 2.0), developed countries have a high mobile penetration and technology adoption rate.⁹ This created a perfect platform for telemedicine to be piloted trialled and scaled on a nationwide basis to support the public health infrastructure.

Table 1. Overview of consultations on TMARS from 3 January 2022 to 10 April 2022.

Age group	Unique consultations				Escalations				% escalated
	Ad hoc	Assessment	Follow-up	Total	Ad hoc	Assessment	Follow-up	Total	
Children (1–11 years old)	5142	24,166	18,446	47,754	233	339	59	631	1.32%
Adolescent and adults (12–69 years old)	38218	19,769	17,715	75,702	772	1449	49	2270	3.00%
Geriatric ≥ 70 years old	2100	28,143	25,531	55,774	146	1134	31	1311	2.35%
Total	45,460	72,078	61,692	179,230	1151	2922	139	4212	2.35%

TMARS: Telemedicine Allocation and Reconciliation System.

Table 2. Breakdown of consultation types for high-risk population groups on TMARS from 3 January 2022 to 10 April 2022.

Special populations	High-risk population											
	Ad hoc consultations	Ad hoc escalations	% escalated	Assessment consultations	Assessment escalations	% escalated	Follow-up consultations	Follow-up escalations	% escalated	Total consultations	Total escalations	% escalated
Pregnant	456	25	5.48%	4379	103	2.35%	4242	11	0.26%	9077	139	1.53%
Geriatric (>= 70 years old)	2100	146	6.95%	28,143	1134	4.03%	25,531	31	0.12%	55,774	1311	2.35%
Immunocompromised	81	5	6.17%	0	0	NA	2	0	0.00%	83	5	6.02%
End-stage renal failure	21	2	9.52%	1	0	0.00%	5	0	0.00%	27	2	7.41%
Total	2658	178	6.70%	32,523	1237	3.80%	29,780	42	0.14%	64,961	1457	2.24%

TMARS: Telemedicine Allocation and Reconciliation System.

Table 3. Breakdown of consultation types for low and moderate-risk patients on TMARS from 3 January 2022 to 10 April 2022.

Age group	Low risk (HRP basic + P2PC)						Moderate risk (HRP enhanced)					
	Ad hoc consultations	Ad hoc escalations	% escalated	Assessment consultations	Assessment escalations	% escalated	Follow-up consultations	Follow-up escalations	% escalated	Total consultations	Total escalations	% escalated
Children (1–11 years old)	5142	233	4.53%	24,166	339	1.40%	18446	59	0.32%	339	59	0.32%
Adolescent and adults (12–69 years old)	38,218	772	2.02%	19,769	1449	7.33%	17715	49	0.28%	1449	49	0.28%
Geriatric >= 70 years old	2100	146	6.95%	28,143	1134	4.03%	25531	31	0.12%	1134	31	0.12%
Total	45,460	1151	2.53%	72,078	2922	4.05%	61,692	139	0.23%	2922	139	0.23%

Traditionally, telemedicine was used to provide healthcare to remote areas, whereby the value proposition was to solve for geographical barriers.¹⁰ In Singapore, healthcare was readily accessible and therefore, telemedicine was used to solve for healthcare convenience and resource prioritisation. However, the COVID-19 pandemic brought about an artificial geographical barrier to healthcare, brought about by the isolation and lockdown measures.

Our study demonstrated that a centralised unified telemedicine platform with data safety measures in place is highly effective to not only provide telemedicine consultation for simple acute illnesses, but also as a triaging tool to identify moderate and high-risk patients who require urgent or early escalation of care. Amongst the moderate and high-risk patient groups, the escalation rate across all age groups for assessment cases is 4.05% and 3.80%, respectively, while the escalation rate for follow-up cases is only 0.23% and 0.14%, respectively. This data demonstrates that:

1. *National sorting logic algorithm is effective in triaging high-risk populations:*

The low rate of escalations amongst assessment and triaging cases amongst the moderate and high-risk population groups shows that higher risk cases have been appropriately triaged and managed at condition appropriate public health facilities, and that those deemed by the algorithm to be suitable for the HRP are appropriately categorised.

The National sorting logic algorithm is an evolving algorithm and is refined over time, reflecting the latest disease-specific scientific studies and country-specific utilisation data. The data extracted from the TMARS system is regularly analysed and fed into the National sorting logic algorithm as part of the machine learning process. The evolved National sorting logic algorithm used during the 14-week period of this study is a product of this learning process. (Diagram 2) more detailed discussion of this algorithm will be published in a separate scientific paper. To conclude, this destruction-renewal cycle can be used to effectively manage any pandemic in the future.

2. *Telemedicine is a safe and effective digital tool to scale healthcare provision in a pandemic:*

Telemedicine can be a safe and effective care tool in a pandemic. It can be used in providing appropriate care to patients, yet protecting healthcare providers.^{11,12} Two meta-analysis by Snoswell et al. have demonstrated that telemedicine is clinically effective and did not detrimentally affect the mortality rates for patients.^{13,14}

In our deployment of telemedicine, it proved to be an effective safety net, layered on top of a dynamic monitoring and conveyance system was able to scale and managed large numbers of patients during the peak of the Delta and Omicron waves. In addition, it was able

to help identify high-risk cases which may have fallen through the cracks, and convey them to suitable public healthcare institutions with the appropriate level of care.

The reduction of escalation case rates from assessment to follow-up demonstrates that patients that remain in the HRP are cases that can be managed in the community, thus preserving public health medical resources for high-risk patients.

As a digital tool, telemedicine is ineffective as a stand-alone. Internal and external resources are required to support the telemedicine service. Internally, having adequate training of healthcare providers, an operations support team to support the doctors, and an operations team to coordinate external resources (escalation logistics and public health resources).

Within a short notice, TMARS was able to on board more than 40 different medical entities and more than 100 medical doctors in the private sector. At the peak of the pandemic, TMARS ecosystem was able to handle more than 5000 teleconsultation cases in a single day, when the daily COVID-19 case count was over a 7-day moving average was more than 20,000 cases. This demonstrates the scalability of a centrally managed telemedicine platform.

Moving beyond this pandemic, there are four key areas requiring change, in order for telemedicine to remain relevant, current and effective on a healthcare system level^{15,16}:

1. Healthcare professionals need to be adequately trained and comfortable in its use.
2. Clinical delivery models need to be refreshed to include Telemedicine.
3. Healthcare reimbursement models need to be adjusted
4. Healthcare digital systems need to be interoperable.

This may seem like an up-hill task, but after the COVID-19 pandemic experience, it is definitely not impossible. All these transformation needs to happen now, in order to benefit the healthcare ecosystem in the long term, and to make it viable to stand up for future pandemics.

Limitations

The TMARS system scaled in response to the pandemic lacked objective tools to remotely record patients' vitals and perform physical examinations.¹⁷ As such, escalations were based on the doctors' subjective assessments available using a synchronous audiovisual platform. This led to non-uniformity amongst doctors with different experiences and trainings.

We acknowledge that the escalation rate may not be an accurate surrogate measure of the safety and efficacy of deploying a telemedicine system. Data like hospitalisation records, hospital emergency visit records and community primary healthcare records should ideally be matched to accurately reflect the patient's COVID-19 journey to determine the safety and efficacy of the telemedicine system. However, in view of the limited accessible data, we have chosen to adopt the escalation rate as the benchmark for comparison.

Conclusions

A centrally managed telemedicine system is a safe and effective tool to scale medical services in the community during a pandemic. It can be used both as a triaging tool and a medical consultation service. A successfully deployed telemedicine system is able to help right site higher-risk patients while preserving existing tertiary healthcare resources for the high-risk and vulnerable groups.

The telemedicine system cannot be deployed as a stand-alone, and has to be plugged in with both internal and external healthcare resources to ensure the patient safety is not compromised.

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