


# BMJ Open Remote COVID-19 patient monitoring system: a qualitative evaluation

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## ABSTRACT

**Background** Many COVID-19 patients are discharged home from hospital with instructions to self-isolate. This reduces the burden on potentially overwhelmed hospitals. The Royal Melbourne Hospital (RMH) Home Monitoring Programme (HMP) is a model of care for COVID-19 patients which chiefly tracks pulse oximetry and body temperature readings.

**Objective** To evaluate the feasibility and acceptability of the HMP from a patient perspective.

**Design, settings and participants** Of 46 COVID-19 patients who used the HMP through RMH during April to August 2020, 16 were invited to participate in this qualitative evaluation study; all accepted, including 6 healthcare workers. Attempts were made to recruit a gender-balanced sample across a range of COVID-19 severities and comorbidities. Participants completed a brief semistructured phone interview discussing their experience of using the HMP.

**Outcome measures and analysis** A thematic analysis of interview data was conducted. Feasibility was defined as the HMP's reported ease of use. Acceptability was considered holistically by reviewing themes in the interview data.

**Results** The HMP allowed clinical deterioration to be recognised as it occurred enabling prompt intervention. All participants reported a positive opinion of the HMP, stating it was highly acceptable and easy to use. Almost all participants said they found using it reassuring. Patients frequently mentioned the importance of the monitoring clinicians as an information conduit. The most suggested improvement was to monitor a broader set of symptoms.

**Conclusions** The HMP is highly feasible and acceptable to patients. This model of care could potentially be implemented on a mass-scale to reduce the burden of COVID-19 on hospitals. A key benefit of the HMP is the ability to reassure patients they will receive suitable intervention should they deteriorate while isolating outside of hospital settings.

## INTRODUCTION

Hospitals and intensive care departments, have, at times, become overwhelmed in areas severely affected by the COVID-19 pandemic.<sup>1</sup> In Australia, community and healthcare-associated transmission has occurred. As at 6 December 2021, there are currently over 18 700 active COVID-19 cases in Australia and Melbourne, Victoria experienced the

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The Royal Melbourne Hospital Home Monitoring Programme (HMP) is a new, scalable, automated model of care for COVID-19 patients which chiefly tracks pulse oximetry and body temperature readings.
- ⇒ As well as describing the HMP, we provide one of the first qualitative descriptions of patients' experiences of using the HMP.
- ⇒ Attempts were made to recruit a gender-balanced sample across a range of COVID-19 severities and comorbidities.
- ⇒ Interviews, transcription and thematic analysis were performed by a single researcher, who identified when thematic saturation had occurred and when recruitment should therefore cease.
- ⇒ The reliance on a single researcher's perception and clinician-led recruitment introduces the possibility of bias, however, thematic saturation was noted.

highest disease burden of any Australian city.<sup>2,3</sup> COVID-19 symptoms range from mild to severe. In patients with severe COVID-19, the mean time from symptom onset to severe symptoms presenting is, on average, 8–10 days. COVID-19 complications may require hospitalisation to treat and may become life threatening.<sup>4</sup>

Due to the variable clinical course, there are several models of care available for monitoring COVID-19 patients. Many patients who present to emergency services may be diagnosed and discharged home with instructions to self-isolate, monitor symptoms and to return to hospital only if significantly unwell. For some patients, the clinical course remains mild, with further medical intervention not required. However, a subset of patients who do not require urgent inpatient hospital admission at the initial clinical review may deteriorate or die during their illness. These patients may develop rapid hypoxaemia and silent hypoxia, which can potentially be detected through a monitoring system.<sup>5</sup> COVID-19 patients considered by assessing clinicians to not require hospitalisation may be offered a home-based monitoring system

while self-isolating. Home-based monitoring systems track signs and symptoms, particularly blood oxygen saturation, to identify if a patient deteriorates and requires hospitalisation. Systems described in the literature include phone or video based clinical assessment/s of isolating patients, email links to surveys collecting biometric and symptom data, and mobile phone-based web applications. At a minimum, symptom data, pulse oximetry and body temperature readings are generally included, in addition to providing a mechanism enabling patients to discuss concerns with a clinician. When certain thresholds are met, further follow-up, including emergency department (ED) referrals are triggered.<sup>6–11</sup> Previous reports indicate home-based monitoring can avoid unnecessary hospitalisations, reducing the likelihood of overwhelming hospitals and reducing the risk of nosocomial transmission, as well as providing a much more cost-effective alternative to inpatient care.<sup>6–10 12–15</sup> A number of evaluations report high levels of user satisfaction (67%–100%).<sup>7–9</sup> Despite these advantages, concerns regarding home-based monitoring systems have been raised in regards to patient safety and privacy.<sup>16</sup>

The aim of this study was to evaluate the feasibility and acceptability of the Royal Melbourne Hospital (RMH) Home Monitoring Programme (HMP) from a patient perspective. This information will ultimately inform refinements to this new model of care for COVID-19 patient management, with an eye to maximising acceptability to patients.

## METHODS

### Study design

This was a prospective cohort study with a qualitative evaluation component which used a constructivist approach.

This study is reported in accordance with the consolidated criteria for reporting qualitative research (COREQ) guidelines.<sup>17</sup>

### Study setting and population

This study was undertaken at the RMH, a quaternary care hospital in Melbourne, Victoria, Australia. More than 80 000 adults present at the ED per annum and around half require hospital admission.<sup>18</sup>

All patients attending the ED or COVID-19 assessment clinic at RMH were screened for HMP eligibility. Eligible patients were adults aged over 17 years-old who were self-isolating in Victoria and had laboratory confirmed SARS-CoV-2 infection. Patients who were considered well enough to be sent home were assessed for risk of deterioration, with low-risk, moderate-risk and high-risk patients identified. Low-risk patients who were well at discharge and were considered unlikely to deteriorate were advised to follow-up with their usual general practitioner or return to hospital as needed. Moderate-risk and high-risk patients were offered enrolment in the HMP. This risk assessment was conducted by clinicians using the matrix

presented in online supplemental appendix 1, which considered patient age, comorbidities and supports.

### HMP intervention

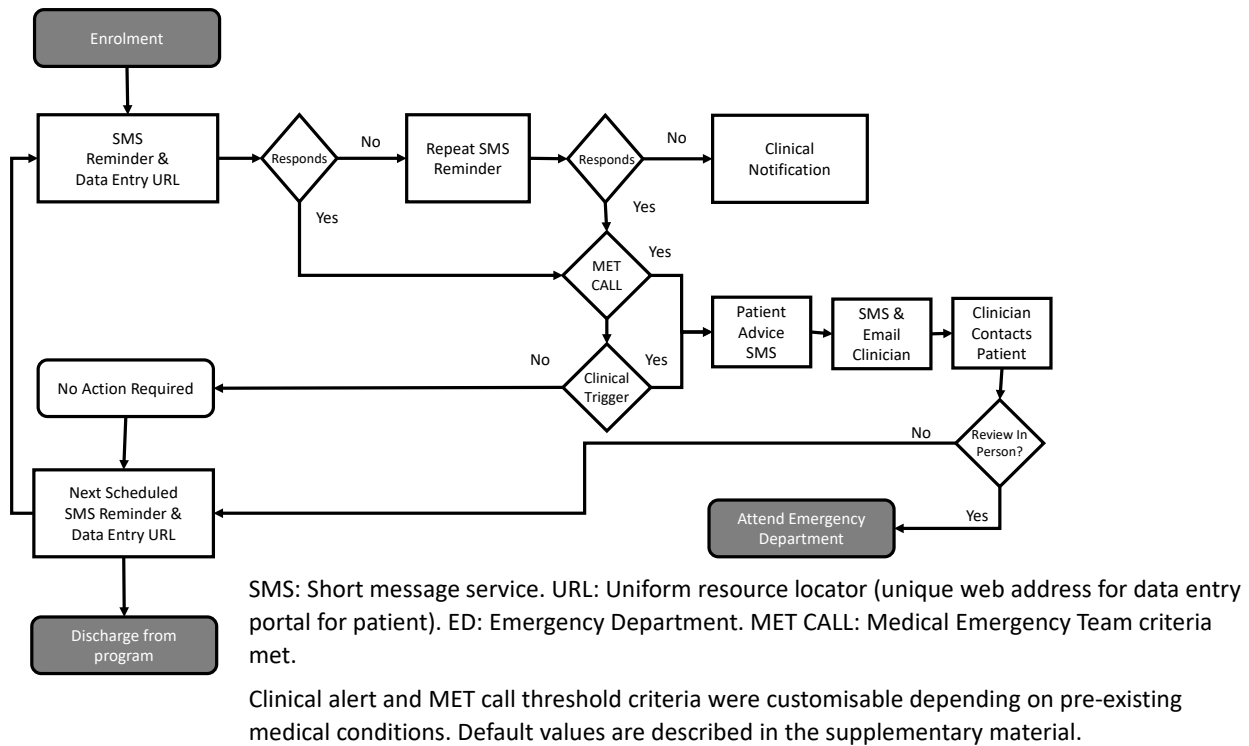
The HMP was established de novo and used pre-existing hospital information technology infrastructure, finger-tip pulse oximeters (inHealth: ARTG ID: 321974) and personal-use oral digital thermometers (MT-518). A bespoke open-source mobile-health software solution was built to facilitate the HMP via mobile phone and wireless technologies. In summary, patients were enrolled into the programme via a hyperlink to a REDCap form. The form captured demographic and clinical data. After enrolment, patients were given monitoring packs. During the monitoring period, patients received twice daily automated prompts via short message service reminders to measure and report symptoms, pulse rate, temperature and oxygen saturation (termed ‘observations’). Abnormal vital signs triggered automated clinical advice to be sent to patients and flagged the supervising clinician, who provided e-health services and arranged transfer for hospital admission if required (figure 1).

Clinical alert and Medical Emergency Team (MET) call threshold criteria were customisable depending on pre-existing medical conditions. Default values are described in the online supplemental table. Detailed technical specifications for this software, and all associated documentation have previously been published.<sup>19 20</sup>

### Interview guide content and administration

Patients were recruited into a formal evaluation of the programme following their routine 60-day post-HMP discharge phone consultation with a clinician. When recruiting, the clinician requested the patient’s verbal consent for the interviewer to phone them and invite them to participate. Recruitment was conducted at this point to coincide with routine recontacting and allow patients time to recover and reflect on their experiences. Which patients were invited was at the clinician’s discretion, but when recruiting, attempts were made to achieve a gender balance, and include patients across a range of COVID-19 severities, age groups and comorbidities.

Qualitative HMP evaluation data were collected during semistructured one-on-one phone interviews. Invited participants were interviewed once. A pilot study was not conducted. All interviews were conducted by JO (PhD—Public Health; female; postdoctoral fellow—University of Melbourne). Participants had no prior knowledge of, or relationship with, the interviewer. Interviews were conducted via a phone call from the interviewer’s office. Participants were informed that the interviewer had no prior involvement with the HMP and was independent from RMH. Informed verbal consent to participate was provided. Interview questions were planned a priori. The semistructured interview guide (online supplemental appendix 2) was created by the interviewer using suggestions from two clinicians experienced in treating COVID-19. Both clinicians and the interviewer had



**Figure 1** Home Monitoring Programme flow diagram. Clinical alert and MET call threshold criteria were customisable depending on pre-existing medical conditions. Default values are described in the supplemental material. ED, emergency department; MET call, medical emergency team call; SMS, Short message services; URL, uniform resource locator (unique web address for data entry portal for patient).

experience in qualitative research and interviewing for health systems research. The interviewer sought to cover each participant's overall experience of the HMP, its ease of use, positive and negative aspects, potential improvements and whether participants would recommend the HMP to someone with COVID-19 in a similar situation to their own. Participants were free to comment in other areas. Participants were able to speak until they indicated they had nothing further to add. Interview times varied according to the speed at which participants volunteered information, the amount of information volunteered, and participants' time restraints. Interviews were recorded using a Dictaphone. Any notes made during the interview were not included in the analysis.

We aimed to interview 10–20 people across a range of demographic and clinical characteristics. This sample size was practical given the study team's time frames and resources. Recruitment ceased when the interviewer felt that thematic saturation had occurred.

### Data analysis

Quantitative data for all patients enrolled in the HMP were extracted from the RMH REDCap database, aggregated, and reported using descriptive statistical analysis. These data included the patient's age, gender, comorbidities, clinical course during COVID-19, reason for HMP discharge and outcome at the routine clinical assessment 60-day post HMP discharge.

A inductive thematic analysis was used to analyse interview data.<sup>21</sup> Interviews were transcribed by the interviewer using Trint with automated transcriptions manually edited with reference to the audio recording.<sup>22</sup> Participants did not review the interview transcripts or provide feedback on findings. Interview transcripts were holistically analysed on NVivo by the interviewer.<sup>23</sup> The interviewer assigned codes and subcodes to data, and grouped these according to perceived themes. A virtual whiteboard (miro.com) was used to identify unique and common themes. A saturation point was reached when no new codes were generated while reviewing the transcripts. A single registry of codes was created. Illustrative quotes, corrected for grammar, are provided.

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans for our research.

## RESULTS

### HMP enrolment, events and outcome

Forty-six patients were enrolled in the HMP from 7 April 2020 to 21 August 2020. The evaluation component recruited from a population with a significant burden of comorbid diseases (table 1).

The median number of self-reported observations submitted by patients through the HMP was 16 (equating to 8 days of observation) with a range of 1–28 observations.

**Table 1** Home monitoring Programme population enrolled from 7 April to 21 August 2020, Royal Melbourne Hospital, Victoria, Australia

Characteristics	Median	IQR
Age (years)	45.8	36.8–61.6
	No. of Home Monitoring Programme patients (N)	Proportion (%)
Sex		
Male	20	43.5
Female	26	56.5
Comorbidity burden		
Single comorbidity	19	41.3
2 comorbidities	6	13.0
3 comorbidities	3	6.5
4 comorbidities	1	2.2
Any comorbidity	29	63.0
Comorbidity frequency by type		
Diabetes	10	21.7
Pulmonary disease	9	19.6
Hypertension	8	17.4
Ischaemic heart disease	3	6.5
Immunosuppression	3	6.5
Smoker	3	6.5
Pregnancy	2	4.3
Obesity	2	4.3
Other	8	17.4
Total patients	46	100.0

Over one-third of patients had an episode of documented oxygen desaturation, however significant episodes of hypoxia were less common. Automated fever management advice was generated for just under 10% of patients (table 2).

Clinical events resulted in supervising clinician notification and planned ED attendance for 10/46 (22%) patients. No patients had ED attendances that were not facilitated through the HMP. Following ED presentation, one patient required general ward admission, and two patients were admitted to the Intensive Care Unit (ICU). Following discharge from the HMP period, one patient deteriorated and died following re-hospitalisation with COVID-19 complications.

#### Programme evaluation: description of participants

Sixteen of 32 patients who completed the 60-day follow-up were invited to be interviewed and all consented with no withdrawals. Interviews ranged from 4 to 13 min. The median duration was 7.5 min.

Nine of the 16 participants were female and seven were male. The median age was 44 years (range: 26–68 years).

**Table 2** Summary of clinical deterioration events occurring among the home monitoring population, Royal Melbourne Hospital, Victoria, Australia

	Patients		Total triggers for clinical review
	Number (N)	Proportion (%)	Number (N)
Pulse rate			
Clinical review*	2	4.3	2
MET call†	4	8.7	6
Oxygen saturation			
Clinical review*	16	34.8	39
MET call†	3	6.5	5
Body temperature			
Automated advice	4	8.7	6
Clinical review: Modest physiological derangement. MET Call: Medical emergency team call. Marked physiological derangement. *Clinical Review: Modest physiological derangement. †MET Call: Medical emergency team call. Marked physiological derangement.			

Six participants self-identified as healthcare workers when asked by the interviewer.

Four participants were assessed at ED while they were using the HMP, all of whom resumed using the HMP once discharged.

Nine participants (56%) had no comorbidities. The most common comorbid state was pulmonary disease/moderate-to-severe asthma. One participant had four separate comorbid conditions. Two participants were pregnant while using the HMP.

All 16 participants praised the HMP, despite many also mentioning very unpleasant experiences of having COVID-19. All participants recommended using the HMP, with almost all (N=14; 88%) saying they would recommend it to someone in their situation with COVID-19.

#### Key themes

##### Theme 1: 'it gave a complete peace of mind'

Almost all of the participants mentioned they felt reassured knowing that medical staff were monitoring their health remotely while they were isolating with COVID-19. Participants described having peace of mind knowing that if they deteriorated, help would be provided. This theme was particularly strong among patients with severe COVID-19, those with serious comorbidities, and those who were pregnant. Participants who required hospitalisation while isolating frequently discussed perceptions of harm averted through using the HMP. Around half the participants described being contacted by a HMP clinician following data entry in the HMP app. In a small minority of cases, the participant had entered data incorrectly and this contact was not warranted, but in other cases, HMP clinicians facilitated a transfer to hospital,

with participants saying they were extremely grateful to have received this help.

It [the HMP] probably saved my life. It was quite frightening knowing how sick I was getting. It showed me when I de-stated and needed help.

HMP013, female, aged 45 years, hospitalised twice using HMP.

Participants discussed feeling comforted by seeing their temperature readings and oxygen saturation results. They used this information to assess the severity of their illness.

It gave a complete peace of mind and reassurance that I could follow where my body was. It was my comfort actually.

HMP001, female, aged 35, not hospitalised using HMP.

Five participants spoke about the HMP facilitating contact with clinicians when they were concerned about symptoms that were not monitored using with the pulse oximeter or thermometer, such as severe pain, and receiving help.

I added a note [to the HMP] saying I was in a lot of pain and that was when [the clinician] contacted me and said, 'We'll get you an ambulance'. So you can deteriorate on it but... there is a safety net.

HMP003, female, aged 65 years, hospitalised once using HMP.

As well as feeling reassured themselves, two participants spoke about how their loved ones felt reassured knowing they were using the HMP.

The greatest value... was for other people in my life to know... I wasn't an invisible and isolated person who may die and not be found for days. ...they found it very reassuring knowing that I was being monitored...

HMP005, male, aged 45 years, not hospitalised using HMP.

### Theme 2: HMP clinicians as an important information conduit

The benefits of having good communication with the HMP clinicians while isolating were often raised. In addition to appreciating their ability to answer clinical questions, the HMP clinicians were identified as an important information conduit outside of their clinical role. Participants discussed feeling distressed while experiencing having great difficulty contacting public health authorities to receive advice. In this absence, HMP clinicians provided advice about when participants might be released from mandatory isolation and provided updates on the COVID-19 situation and the Victorian public health response.

I live by myself so I was in isolation for that whole period and their [the Health Department's] lack of communication was distressing. What I was able to do was call the [HMP clinicians]... get some kind of

prediction about when I might get a release and how many days of food I needed to plan.

HMP005, male, aged 45 years, not hospitalised using HMP.

### Theme 3: a highly acceptable supplement to clinical care

Considerable suffering due to COVID-19 symptoms and aggravating comorbidities were often mentioned. Many participants discussed the HMP supplementing their clinical care and enabling them to isolate outside of hospital settings. A strong theme around participants not wanting to present to hospital unless they really had to in order to avoid burdening the healthcare system and posing a transmission risk to staff was noted.

It's good to see that people have been looking at creative ways to... prevent potentially overwhelming the health system, it [the HMP] was a good idea.

HMP007, male, aged 68 years, not hospitalised using HMP.

One participant felt there was an overreliance on the HMP and they had not received a full clinical assessment at RMH ED. They indicated they felt the seriousness of their illness had been trivialised.

It [HMP] was excellent... but I feel the service at Emergency ended up lacking because I was sent straight into the monitoring system and sent home. [Laughing] If we can control COVID like this, why can't we just produce lots of oximeters and monitor it this way?

HMP011, female, aged 33 years, not hospitalised using HMP.

All participants reported they felt using the HMP was highly acceptable. None said they found the multiple daily data entry prompts intrusive at all, even when feeling very unwell as they understood the importance of regular data entry. This came in spite of feeling overwhelmed having to report to multiple systems, often while unwell, such as to the Department of Health and to their workplace. All participants said they found the HMP extremely easy to use. No issues with the pulse oximeters were noted, and all thought inputting data were extremely easy, except one participant who reported difficulty using the sliding scales on multiple electronic devices.

Many participants highly praised the quality of clinical care they had received while at RMH and from the RMH HMP clinicians.

I thought every aspect of my visit there from the first day to the ward was just absolutely phenomenal. I sent them a complimentary feedback afterwards.

HMP001, female, aged 35, not hospitalised using HMP.

### Theme 4: criticisms and potential improvements

About half the participants indicated that they could not think of any possible improvements to the HMP.

The most common criticism was that only a few signs (temperature and blood oxygen) were formally monitored. Monitoring a greater number and breadth of symptoms and signs was the most commonly suggested improvement, including respiratory rate, pain levels, neurological and gastrointestinal symptoms. Concerns that people with atypical, or more severe symptoms, could be missed by the HMP were expressed. Four participants mentioned that incorporating monitoring for comorbid conditions would have been an improvement. One participant suggested modifying the HMP and applying it to other conditions besides COVID-19.

One participant was frustrated by a lack of quality internet connection in her isolation facility which made it harder for her to use the HMP. Another emphasised the need for HMP clinicians to understand their importance as an information conduit when public health authorities are unresponsive.

It would be great to put that [communication role] a little bit more in the foreground so that the people who are running it are aware that they actually might be the most important health professional reference point that's available.

HMP005, male, aged 45 years, not hospitalised using HMP.

## DISCUSSION

We report the successful rapid development, implementation and evaluation of a COVID-19 home monitoring system in Melbourne, Australia, during the global COVID-19 pandemic. The HMP demonstrated episodes of hypoxia were relatively common in our cohort. Clinical deterioration was recognised as it occurred, with patients recalled to hospital for assessment and/or admission. This model of care harnessed existing health information-technology infrastructure and has potential to be implemented on a mass-scale to protect hospital capacity. Important design considerations inbuilt into the HMP set a low technical hurdle for participants to engage with, met requirements for cybersecurity, and were sufficiently agile and capable of a short concept to implementation cycle. When developing the HMP, consideration was given to the need to minimise face-to-face contact between healthcare workers and patients.

The HMP was developed extremely quickly over approximately 2 weeks in February 2020 in response to reports of COVID-19 community transmission internationally. It used readily available, configurable software such as REDCap, which enabled prompt implementation once ethical and administrative requirements were met. The HMP was highly acceptable and feasible from the perspective of a patient isolating outside of hospital settings, and it provided them with an important source of reassurance. An unexpected finding identified the importance of the monitoring clinicians as information conduits in the absence of accessible public health

authorities (who themselves were overwhelmed by the outbreak). Any mass-implemented HMP should ensure that the staff involved are able to answer questions about COVID-19 and the public health response. Such a HMP might incorporate routine monitoring of other signs and symptoms, including heart rate and peak expiratory flow as implemented by a similar Brazilian system. However, increasing data entry may make it more difficult for patients to comply with the system.<sup>7</sup> The HMP provided a low-cost patient care solution, which only required the use of the patient's smartphone, an internet connection and the cost of posting the oximeter and thermometer back to RMH. The HMP was similar to several home-based monitoring systems developed in other countries that successfully facilitated early assessment of deteriorating patients and reported high levels ( $\geq 67\%$ ) of user satisfaction.<sup>7-9</sup> A HMP should be routinely evaluated from a clinician and a patient perspective, with refinements implemented promptly—including refinements to help meet the needs of less typical patients.

Children and youth aged less than 18 years were excluded, and no adults aged over 68 years participated. It should be noted that participation required some proficiency in using a smartphone and reasonable English language skills. Interviews, transcription and analysis were all performed by a single researcher, who identified when thematic saturation had occurred and when recruitment should therefore cease. This reliance on a single researcher's perception introduces the possibility of bias. A thematic analysis with multiple contributors was not possible due to the time constraints of the study team, however preliminary themes were discussed in regular study team meetings and were refined based on feedback. A further source of potential bias occurred when the monitoring clinicians identified patients to recruit, however, it was made clear to participants that the interviews were confidential and the interviewer had no involvement in HMP development or implementation, or in patient care. Including more participants may have led to the identification of new themes, however, thematic saturation was noted. The brevity of some interviews limited the depth and richness of the data generated (especially for the briefest interview which was only 4 min), however, participants were allowed to speak until they indicated they had nothing more to say. Patient recruitment into the HMP was halted due to practical elimination of community transmission of COVID-19 within Victoria, Australia. This limited our ability to report on the relationship between subjective and objective markers of clinical deterioration, however, our findings highlight a high frequency of desaturation episodes.

Next steps include scalability assessments for mass-scale roll out of a HMP, should this become useful, and larger studies to assess economic and clinical outcomes. Refining a HMP to meet the needs of culturally and linguistically diverse patients and elderly patients is important as they may be less comfortable using an internet-based electronic system.

## Conclusions

Currently stable patients at moderate-risk and high-risk of COVID-19 complications may benefit from a HMP if they are discharged home to isolate. The HMP was highly feasible and acceptable to participants. This model of care could be implemented on a mass-scale to reduce the COVID-19 burden on hospitals. Key benefits of the HMP were its ability to reassure patients that they would receive suitable intervention should their health deteriorate while in isolation, and the ability of the monitoring clinicians to provide information and advice to isolating patients.

**Contributors** JO drafted the study protocol and the manuscript and refined these documents following several rounds of feedback from coauthors. JO collected data, performed the analysis and write up findings. JO is responsible for the overall content as the guarantor. AR critically reviewed successive versions of the manuscript and guidance on the interpretation of data. MD performed recruitment, critically reviewed successive versions of the manuscript and provided guidance on the interpretation of data. MP critically reviewed successive versions of the manuscript provided guidance on the interpretation of data. JCK conceived of the study, performed recruitment, critically reviewed successive versions of the manuscript and study protocol and provided guidance on the interpretation of data.

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