Home Monitoring Programs for Patients Testing Positive for SARS-CoV-2: An Integrative Literature Review

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Abstract

Background The severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) pandemic threatened to oversaturate hospitals worldwide, necessitating rapid patient discharge to preserve capacity for the most severe cases. This need, as well as the high risk of SARS-CoV-2 transmission, led many hospitals to implement remote patient monitoring (RPM) programs for SARS-CoV-2 positive patients in an effort to provide care that was safe and preserve scarce resources.

Objective The aim of this study is to provide an integrative review of peer-reviewed literature on different RPM programs that were implemented for SARS-CoV-2 positive patients including their strengths and challenges.

Methods A search was conducted for peer reviewed literature using PubMed, CINAHL, OVID, and Google Scholar. Peer-reviewed studies written in English or Spanish and published between 2019 and 2021 on RPM of SARS-CoV-2-positive patients were considered. Information was extracted according to a qualitative content analysis method, informed by the Comparison of Mobile Patient Monitoring Systems Framework.

Results Of 57 retrieved articles, 10 publications were included. The sample sizes ranged from 75 to 48,290 and the monitoring length ranged from 7 to 30 days. Information regarding the comparison framework was summarized. Main strengths of using RPM for SARS-CoV-2 positive patients was participant acceptance, feasibility, safety, and resource conservation. Main limitations were the lack of information on patient data security measures, robust outcomes testing, and identification of the most effective biomarkers to track SARS-CoV-2 decompensation.

Conclusion Different RPM programs for SARS-CoV-2 were implemented, from sending home participants with a pulse oximeter and collecting readings via call to modifying existing mobile applications and sending holistic health questionnaires to participants. This review determined that RPM is beneficial to SARS-CoV-2 positive patients; however, its effectiveness can be improved by further research. Mainly, identifying what patient data are most effective at tracking SARS-CoV-2 decompensation by utilizing advanced technology already in the market.

Keywords

- SARS-CoV-2
- COVID-19
- coronavirus
- remote patient monitoring
- telehealth
- home quarantine
- infectious disease
- emergency medicine

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Background and Significance

Health care systems around the world were unprepared to deal with the overwhelming demand on services during the novel coronavirus disease 2019 (COVID-19) pandemic. Hospital admissions threatened to overrun entire health care systems as large numbers of patients became acutely ill.[1] Health institution leaders recognized the impact of severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2; the virus that causes COVID-19) was having on health system capacity and swiftly took action to plan for both the lack of knowledge regarding SARS-CoV-2 and the rapid, uncontrolled spread of the virus.[2] Hospitals and health care systems swiftly pivoted to different options to deliver care while responding to the pandemic, including drive-through testing sites,[3] adopting hospital incident command centers and creating the accompanying emergency leadership team,[4] delaying routine care,[5] and rapidly developing remote telehealth options in place of in-person care for both SARS-CoV-2 positive and non-SARS-CoV-2 positive care.[6]

To maximize hospital bed space, health systems adopted various methods to safely manage patients with SARS-CoV-2 while they convalesced at home including telehealth and remote patient monitoring. This decreased risk of exposure to the patient and health care team by avoiding in person visits. It was also believed that it would decrease unnecessary emergency department (ED) visits, as patient decompensation could be identified early. It is important to understand how these remote monitoring programs were designed and what they achieved. Understanding this will allow health systems to improve and appropriately deploy these remote monitoring programs.[7]

While there has been a large uptick in remote monitoring programs since the beginning of the pandemic, there are wide ranging definitions for remote patient monitoring (RPM).[8] Therefore, we settled on a broad definition that included any monitoring outside of the hospital that involved more than telehealth (phone call or video visit). The purpose of RPM is to improve patient care and outcomes via digitally transmitted health data (i.e., phone applications, internet, web-based platforms, and biosensors).[9] RPM is a rapidly growing and evolving type of patient management tool, gaining uptake as remote health care grows both in clinical and research fields.[10] A systematic review of RPM studies from the years 2000 to 2018 showed that 43% of all studies reviewed were published between 2015 and 2018 indicating an increase in recent years.[11] Additionally, of 272 articles included in the systematic review 76.8% reported positive results for using a remote patient monitoring program.[11] The ability to monitor patients in the outpatient setting is generally believed to be beneficial as it allows care to be provided earlier than without RPM.[12] Additionally, adverse events related to RPM are rare.[12] Other advantages of remote monitoring, besides early decompensation or disease detection may include reduced health care costs, faster care delivery, and allowing patients to continue to convalesce at home.[9]

It is believed that RPM will be used by 30 million patients in the United States by 2024, increasing significantly annually. RPM has been used in a multitude of diseases, with most research focusing on heart failure. Evaluations of RPM in other disease processes has been positive, negative, or neutral, leaving the question of effectiveness unresolved. As the need for high quality and efficient health care for patients with SARS CoV-2 increased rapidly, systems and providers needed to rely on safe, effective, and quality way to care for these patients.[13] In the specific case of SARS-CoV-2, patients may benefit from a remote monitoring program for multiple reasons, including potentially reducing patient anxiety, capturing early disease worsening, decreasing the risk of disease transmission as well as reducing hospital ED or inpatient costs.[14]

Objective

The objective of this paper is to provide an integrative literature review of peer-reviewed papers on RPM programs for patients that are SARS CoV2 positive, or suspected positive, and/or experiencing SARS-CoV-2 including a review of benefits and limitations of these programs.

Methods

We performed an integrative literature review guided by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA).[15] While this is an integrative review and PRISMA is intended for systematic reviews, we adopted its steps which include literature search, publication selection, quality assessment, information extraction, and descriptive synthesis. We identified international, peer-reviewed publications that described the implementation of an RPM program for SARS-CoV-2-positive and SARS-CoV-2 suspected-positive patients.

Literature Search and Selection

The literature search conducted utilized four databases: PubMed, CINAHL, OVID, and Google Scholar. Keywords in searches included: remote monitoring; COVID or COVID-19; coronavirus or 2019-ncov or SARS-CoV-2 or cov-19; wearable technology or wearable devices or wearable sensors; and telehealth or telemedicine.

Papers were screened applying the following eligibility criteria. Peer-reviewed articles published between 2019 and 2021 in English or Spanish and focusing on home/remote patient monitoring of SARS-CoV-2 positive patients were considered. To exclusively focus on RPM literature published that was centered on COVID-19, we narrowed our eligibility criteria to the following. Papers had to include data on home monitoring of SARS-CoV-2 positive or suspected SARS-CoV-2 positive participants. This review excluded articles that focused on home monitoring of participants that were monitored for non-SARS-CoV-2 diagnoses like heart failure. SARS-CoV-2, remote monitoring within a hospital or other clinical setting, and monitoring of SARS-CoV-2 transmission. Another exclusion was lack of data such as methodology papers, expert opinions, and editorials.

Titles and abstracts were screened according to the set criteria. Those who met the criteria were retrieved for a full-text review. Two authors (B.L. and A.O.) independently screened the full-text articles for inclusion criteria. Disagreements on whether to include or not were discussed with a third author (J.K.) until consensus was reached. The review process occurred from February18, 2021 to March 5, 2021.

Quality Assessment of Publications

To assess the quality of the included publications, we had two authors to independently review the articles using the National Institutes of Health (NIH) tool Study Quality Assessment Tool for Case Series Studies.[16] Given the novelty of SARS-CoV-2, there were no published randomized controlled trials, the majority were prospective case series studies or retrospective case series studies. The tool includes nine questions, all "yes" or "no" answers. Quality rating was based on the number of "yes" answers in which 7 to 9 is good, 4 to 6 is fair, and ≤3 is poor. We accepted papers into the review if they met the rating of "good." Disagreements on quality rating were resolved by discussion with a third author.

Data Extraction and Synthesis

Data from the selected studies were extracted in two stages. Stage 1 included data extraction from each study such as title, authors, country, study dates, sample size, monitoring length, and biological measures collected. Given the heterogeneity of the monitoring methodology and outcome reporting in the studies reviewed, we conducted a narrative comparison.

The second stage of data extraction was guided by the Comparison of Mobile Patient Monitoring Systems Framework.[17] This framework provides a generic architecture for comparing diverse mobile patient monitoring systems. It applies to patient monitoring systems that use mobile computing and wireless communication technologies whether the measurements are periodic or continuous.

This is a good fit for this review as the remote monitoring programs being compared vary significantly. The framework can identify key features of patient monitoring systems and how they address specific needs and challenges. The four aspects of the Comparison of Mobile Patient Monitoring Systems Framework are Patient Data, Data Transmission Method, Secure Data Server, and Alert system.[17]

Results

Literature Search and Selection

A total of 13 electronic searches using selected keywords were conducted to identify peer-reviewed articles on the topic. The electronic literature search yielded 4,792 articles.

During the screening process, 4,741 were excluded based on the title and/or abstract. After the full article review, 35 were excluded. A total of 10 articles were selected to include in this integrative review.[18–27] A PRISMA flow diagram is shown in ►Fig. 1.

Quality Assessment

The Study Quality Assessment Tool for Case Series Studies[16] was applied and all 10 publications were rated as "Good" with scores ranging from 7 to 8 out of a possible 9 (►Table 1).

Data Extraction and Synthesis

Stage 1 (Publication Characteristics)

Half of the 10 selected studies took place in the United States ($n = 5$),[18–22] the others took place in Europe ($n = 3$)[23–25] and Asia ($n = 2$).[26,27] Most of the studies ($n = 9$)[18,20–27] were case series studies and one study included a retrospective non-randomized control group[19] (►Table 2). All studies included participants who were either confirmed SARS-CoV-2 positive or suspected SARS-CoV-2 positive. Race and ethnicity were not reported across all papers, as it is often unreported or not reported in a comparable manner in European and Asian studies. Age of the study population was the most consistent demographic variable provided across all studies, as mean or median (►Table 3).

The sample sizes ranged from 75 to 48,290. Two studies specifically recruited high-risk participants,[20,24] two listed the proportion of high-risk participants in the study,[20,25] and two others listed the proportion of participants with comorbidities.[21,22] In one study 57% of patients had at least one comorbidity with the most common being obesity (27%), hypertension (26%), and diabetes (16%).[21] Another study reported 39.1% of patients having a comorbidity, with hypertension (39.1%) and diabetes (26.2%) being the most common.[22]

Half of the studies had a set monitoring length ($n = 5$)[18,21,25–27] ranging from 7 to 30 days. The other half ($n = 5$)[19,20,22–24] had varying monitoring lengths conditional on reported symptoms and/or the participant's decision to extend the monitoring length, those ranged from 1 to 21 days or until symptom free. The average monitoring length for the studies was 15 days and the median was 14 days. All studies had participants self-report data and had health care staff evaluate the need for escalation of care based on that data. The qualifications of clinical users varied by study, including registered nurses and other health professionals,[20] varied health staff with a supervising physician,[25] medical staff with clinical experience including third and fourth year medical students with an internist as a contact for care escalation.[22]

Stage 2 (Data Comparison of Mobile Patient Monitoring Systems Framework)

A detailed comparison of selected studies and their alignment with the Data Comparison of Mobile Patient Monitoring Systems Framework is shown in ►Tables 4 and 5.

Eight of 10 studies[18–20,22,24–27] used both subjective (symptom reporting) and objective data (vital sign data) to remotely gather patient data. The most common data collected were oxygen saturation (8/10)[18–24,26] and temperature (7/10).[19,20,22,24–27]

All 10 studies either used a smart phone application, a phone call, or a combination of both methods to transmit participant data. Six studies used a smart phone application.[18–20,25–27] Five

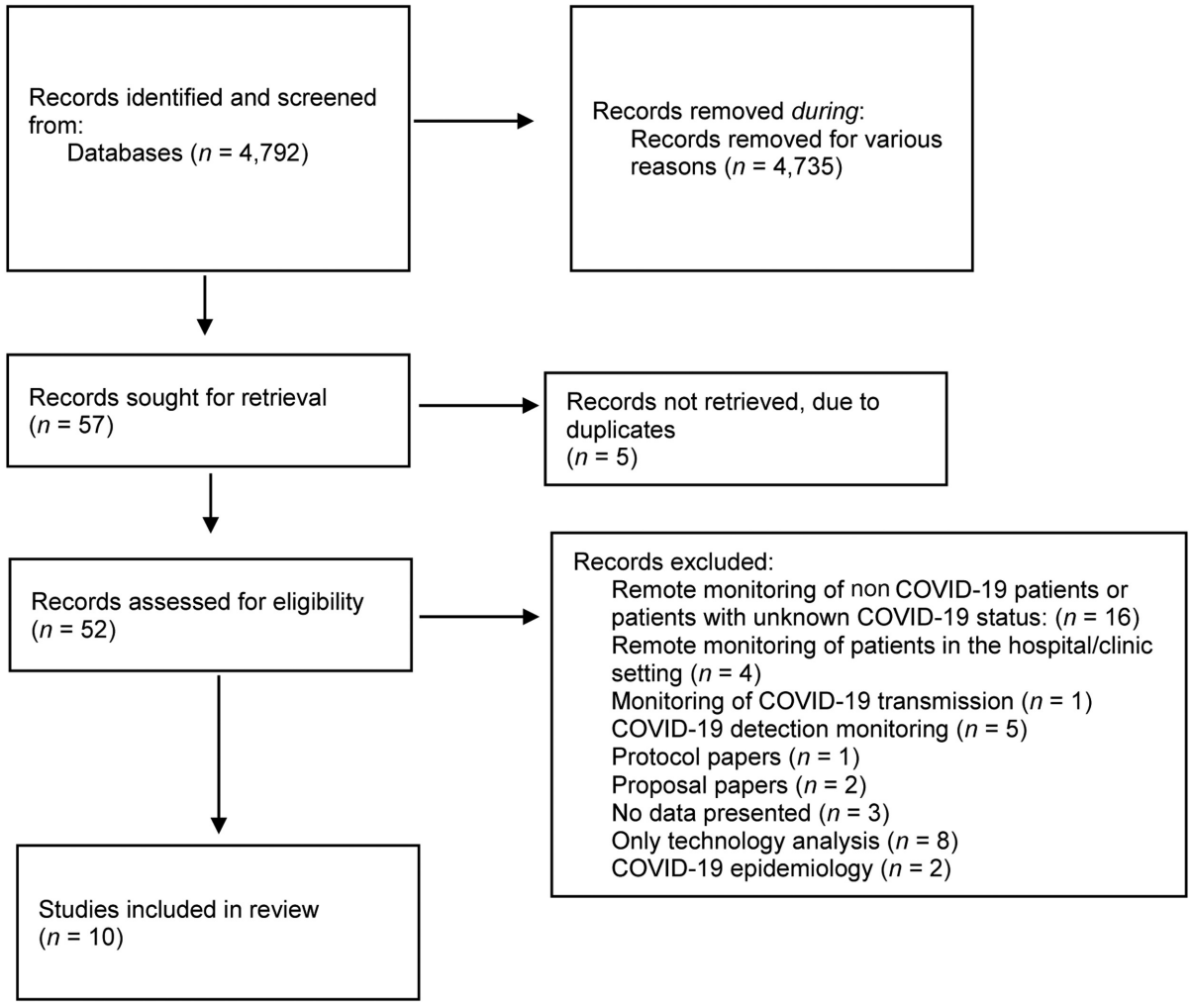

Fig. 1 A preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

studies used a daily phone call for participants to report symptoms and objective data if applicable.[20–22,24,25] None of the studies specifically addressed data security.[18–27]

Seven studies utilized an alert system that triggered a response from clinicians.[18–20,22,25–27] Most alerts came from abnormal temperature, oxygen saturation, and/or worsening symptoms. Four of the seven studies that used an alert system had specific thresholds that triggered an alert.[19,25–27] The remaining three studies did not have an alert system.[21,23,24] The clinical team evaluated the need for escalation of care based on the participant's data. The number of alerts generated per study and the number of participants who were identified for escalation of care across studies is shown in ►Table 2.

Discussion

Findings

The objective of this integrative literature review was to provide an overview of peer-reviewed literature about RPM programs for SARS-CoV-2-positive and suspected-positive participants including benefits and limitations. A variety of RPM programs for SARS-CoV-2 positive and suspected-positive participants were implemented worldwide.[18–27] The studies reviewed used a wide range of participant data to evaluate the need for escalation of care, from basic objective data such as pulse oximetry[19] to questionnaires including patient reporting of vital signs and psychological symptoms.[23] All studies used either a web application and/or a phone call to receive data. Some studies had sophisticated systems with programed data thresholds that would produce an alert when reported data exceeded the threshold,[16–18,20,23–25] while the others relied on the medical staff's judgement of the reported data to contact the participant and escalate care if needed. Most studies focused on the following outcomes which we detail below: participant acceptance, feasibility, safety, and resource conservation (►Table 6). Additionally, we discuss the RPM programs reviewed.

Participant Acceptance

Most studies (90%)[18–26] specifically listed participant engagement/satisfaction as an outcome of the remote monitoring program. Because all but one study aimed to evaluate patient satisfaction it underscores the importance of acceptability to the patient in the success of the program. Sekhon et al wrote that "from the patient's perspective, the content,

Table 1 Quality ratings of included studies according to NIH quality assessment tool for case series studies

	Study									
	Annis et al[18]	Gordon et al[19]	Medina et al[20]	Shah et al[21]	Ye et al[22]	Bell et al[23]	Martínez-García et al[24]	Yordanov et al[25]	Ko et al[26]	Xu et al[27]
1. Was the study question or objective clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the study population clearly and fully described, including a case definition?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Were the cases consecutive?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Were the subjects comparable?[a]	CD	CD	Yes	Yes	Yes	No (73% likely did not have COVID-19)	CD	CD	Yes	Yes
5. Was the intervention clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6. Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No (assessment scales were modified as more information was learned)
7. Was the length of follow-up adequate?[b]	CD	CD	CD	CD	CD	CD	CD	CD	CD	CD
8. Were the statistical methods well-described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Were the results well-described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quality rating consensus (GOOD, FAIR, POOR)	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

Abbreviations: CD, cannot determine; COVID-19, novel coronavirus 2019; NA, not applicable; NIH, National Institutes of Health; NR, not reported.
[a]If marked CD the percentage of confirmed severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2)-positive patients was not reported. Both confirmed positive and likely positive were reported together.
[b]Given the novelty of SARS-CoV-2, there is not enough validated research that demonstrates what length of follow-up is adequate for this patient population.

Table 2 Study design, interventions, results, and conclusions of the reviewed SARS-CoV-2 remote monitoring programs by publication

Study (year and country)	Design	Sample size	Monitoring length	Intervention	Results	Study conclusions
Annis et al (2020 and the United States)[18]	Pilot study without control group	2,255 suspected or confirmed SARS-CoV-2+ pts (vast majority were suspected)	16 days	Pts were sent daily questionnaires to report symptoms with the option to leave questions and comments for providers. Concerning symptoms were flagged as either red or yellow alerts and sent to a dashboard where a member of the first- responder team would take action	2,304 alerts and 4613 messages were generated which resulted in 91 ED visits and 13 hospital admissions. Each pt had an average of 1 alert and 2 comments during monitoring	A remote pt monitoring program can be quickly adapted and implemented with existing resources. This type of program is well accepted by pts
Bell et al (2021 and England)[23]	Case series	192 pts total: 83 confirmed or probable SARS-CoV-2+ pts, 109 unlikely or uncertain SARS-CoV-2 status	1–6, median = 1	Call within 36 hours after discharge from the ED for a Follow-up assessment via phone call. Confirmed or probable SARS-CoV-2+ pts were categorized as low or high risk of deterioration, and follow up calls were scheduled as necessary	23 pts were called back for face to face assessments, of which 5 resulted in hospital admissions. 49.4% of the SARS-CoV-2 confirmed/likely group was referred to a respiratory clinic to follow-up. The study cohort compared with a retrospective analysis of a cohort from April 2020 showed unplanned ED visits were 17.9% lower in the study cohort	The proposed framework for remote follow-up of SARS-CoV-2 positive/suspected pts is a robust mechanism for hospitals to manage Pts following discharge. Sharing the results of this type of programs can be useful to prepare for other future pandemic waves
Gordon et al (2020 And the United States)[19]	Retrospective case series	225 confirmed SARS-CoV-2+ pts or pts who were presumed SARS-CoV-2+	14 days, pts had the option of 7 additional days of monitoring. Median length was 12 days	Pts were discharged home with MyChart companion, a thermometer, and a pulse oximeter. Pts self-reported symptoms app. A message was sent to a pooled EHR inbox under certain conditions. Nurses contacted the pt, performed a clinical assessment, and then determined an appropriate plan	2,161 questionnaires were completed which generated 315 alerts and 868 calls to pts. 11 pts were readmitted to the ED, and 3 were readmitted to the hospital	The RPM reduced the risk of readmission to the hospital. The majority of pts can be passively monitored which can conserve human resources in the postacute setting
Ko et al (2020 and Singapore)[26]	Retrospective case series	800 confirmed SARS-CoV-2+ pts	14 days	Pts were given a pulse oximeter and thermometer. A Chatbot was used to report symptoms twice per day. All vital sign information was sent to a	12,511 discrete vital sign data were reported. 372 abnormal readings led to 96 telehealth. 7 were escalated to emergency services after the telehealth visit, and	Cost effective telemedicine solutions can be implemented to increase access to healthcare for marginalized populations. Challenges imposed by

Table 2 (*Continued*)

Study (year and country)	Design	Sample size	Monitoring length	Intervention	Results	Study conclusions
				dashboard. Abnormal results were sent via text message to healthcare providers and escalation of care was done if necessary. Alerts were sent if reported data was concerning	were 18 triaged to a physical exam performed onsite- of the 18, four were sent to the hospital	SARS-CoV-2, language barriers, and tech literacy can be overcome
Martínez-García M, Bal-Alvarado, et al (2020 and Spain)[24]	Case series	313 confirmed SARS-CoV-2+ pts	11.64 days on average (SD 3.58). Monitoring ends when the Pt meets certain criteria	Pts were given a username and password to access a web page that allows them to answer a health questionnaire and input vital signs. They were given a pulse oximeter and a thermometer. The nursing team checked the pt submitted data periodically and called the pt at least once per day. Calls were more frequent for those with concerning data	38 pts were sent to the ED and 18 were admitted. 2 died after admission. Those that died were admitted on day 1 and 3 of remote monitoring. A total of 224 participants were discharged from monitoring and 78 pts continued to monitor. The majority of discharges were between days 6–15 of the remote monitoring	Remote monitoring used in a proactive way allows for useful and safe follow-up of high-risk pts with SARS-CoV-2
Medina et al (2020 and the United States)[20]	Case series	1,924 confirmed SARS-CoV-2+ pts	Hospitalized pts 7 days after discharge. Ambulatory pts 14 days after symptom onset. Option to continue If symptoms persisted	Pts used a self-monitoring app, to report symptoms. In addition, Pts received a daily phone call. If new or worsening symptoms were reported, the app forwarded those symptoms to a clinician. The clinician would then escalate care if needed	10% of Pts reported symptoms that required escalation to a telehealth visit, 2% were admitted, and 3% were readmitted due to SARS-CoV-2 or other underlying condition. In total, 9 Pts have died. The median time to escalation was 7–8 days into the monitoring program	A novel remote Pt monitoring program for SARS-CoV-2 Pts is presented. Its effectiveness is pending as the study is still in progress at time of publication
Shah et al (2020 and the United States)[21]	Case series	77 confirmed SARS-CoV-2+ pts	7 days	Three self-reported pulse oximeter readings. Researchers called Pts daily to collect oxygen saturation data. Pts were instructed to present to the ED if oxygen saturation was below 92%, with a confirmation reading ten minutes later	19 of 77 pts reported oxygen saturation <92%. 17 presented to the ED, and 16 were hospitalized. Half of those pts did not report worsening symptoms. 58 of 77 Pts reported oxygen saturation >92%. 11 of those pts presented to the ED and 6 were hospitalized. Of the 8 Pts admitted to the ICU, 6 of them reported oxygen saturation <92%	Home pulse oximetry monitoring is a useful tool in identifying need for hospitalization in initially non-severe SARS-CoV-2 pts. With 92% serving as a useful threshold

(*Continued*)

Table 2 (*Continued*)

Study (year and country)	Design	Sample size	Monitoring length	Intervention	Results	Study conclusions
Xu et al (2020 and China)[27]	Retrospective case series	75 confirmed SARS-CoV-2+ pts	14 days	Pts used WeChat to complete a telemedicine form. The app allowed two-way communication. If a red alert was generated, an ambulance was called and the pt was admitted. If a yellow alert was generated, the Pt filled out the questionnaire twice daily and was closely monitored by a nurse. Anything besides the above responses generated a green alert	Six pts were readmitted, one of whom was on ECMO. Data regarding alerts was not provided	Continuous monitoring of home quarantined pts via telemedicine reduced the risk of delayed hospitalization. Medical staff can identify changes in key symptoms to track disease progression
Ye et al (2021 and the United States)[22]	Retrospective case series	409 confirmed SARS-CoV-2+ pts	7–14 days; pts had the option to complete at day 7 if asymptomatic. Median monitoring length 5 days, average of 10 days	Pts were called daily and asked about their symptoms. Flags were triggered for pts with abnormal symptoms. Physician followed up with flagged pts to see if they should return to the hospital	1,406 calls were made and 28.1% of pts had at least one flag throughout monitoring. 45 pts returned to the ED and 31 of those were readmitted. Of the admitted, 7 expired. The median days to readmission was 4 days. Pts who were readmitted were significantly older and more likely to have chronic kidney disease, coronary artery disease, and heart failure	Lenient discharge criteria for SARS-CoV-2 pts with post-discharge remote monitoring is linked to low rate of readmissions. This proved to be well accepted by pts and can be particularly useful when pt volume surges threatening hospital capacity
Yordanov et a (2020 and France)[25]	Case series	48,290 suspected or confirmed SARS-CoV-2+ pts	30 days; 72% of participants monitored for the entire duration of the program	Pts used an app to fill out a ten-question survey. High risk Pts completed the survey twice daily. The responses were classified by an algorithm as red, orange, or gray	21,873 red alerts and 211,160 orange alerts were triggered. Red alerts were answered with a median time of 2.3 minutes, and orange alerts were answered with a median time of 10.5 minutes	Remote monitoring solutions like Covidom could increase health care systems' capacities by allowing them to promptly identify worsening symptoms, while limiting the need for in person care

Abbreviations: ED, emergency department; Pt, patient; Pts, patients; RPM, remote patient monitoring; SARS-CoV-2; severe acute respiratory syndrome-coronavirus-2.

Table 3 Participant demographics of included publications

Study	Age in years	Sex	Race	Ethnicity	Language
Annis et al[18]	38 median	62% F, 38% M	N/A	N/A	N/A
Gordon et al[19][16]	54 mean	51% F, 49% M	22% Black, 38% White, 40% other	36% Hispanic, 56% Not Hispanic, 8% other	63% English, 29% Spanish, 8% Other
Medina et al[20]	25% older than 60, 3.5% younger than 18	N/A	N/A	N/A	N/A
Shah et al[21]	44 median	44% F, 56% M	27% Asian, 8% Caucasian, 8% Black	57% Hispanic	N/A
Ye et al[22]	57.3 mean	40.1% F, 59.9 M	19.6% White, 23.2% Black, 34.0% Other, 23.2% unknown	51.1% Hispanic, 22.7% non-Hispanic, 26.2% unknown	N/A
Bell et al[23]	43 median	50% F, 50 M	N/A	N/A	N/A
Martínez-García et al[24]	60.9 mean	52.4% F, 47.6 M	N/A	N/A	N/A
Yordanov et al[25]	43.7 mean	58.8% F, 41.2% M	N/A	N/A	N/A
Ko et al[26]	33 mean	0% F, 100% M	N/A	N/A	N/A
Xu et al[27]	37 median	73% F, 27% M	N/A	N/A	N/A

Abbreviations: F, female; M, male; N/A, not available.

context, and quality of care received may all have implications for acceptability."[28] If remote monitoring is considered acceptable, patients are more likely to participate in a program and possibly benefit from improved outcomes.[9,10]

The results of these papers indicate acceptability of RPM. Nonetheless, interpreting these results remain a challenge as methods of assessing acceptability and satisfaction varied greatly. Measures varied from low participant withdrawal to informal questionnaires on satisfaction. The importance of participant engagement is critically important in RPM programs for a variety of reasons including transmitting consistently and accurately. This is especially challenging as all the studies relied on participants to self-reported data, no studies used passive monitoring through biosensors. One could assume that the fewer demands on the patient might result in greater compliance, engagement, and acceptability.

Feasibility

Most studies mentioned that RPM of SARS-CoV-2 participants is feasible (80%).[18–20,23,25–27] In research, feasibility looks at the practicality of a study intervention being implemented within a specific setting.[29] This is promising for the wide implementation of RPM of SARS-CoV-2 patients. It demonstrates that it is feasible for many health institutions worldwide. However, it is important to note that many authors listed a smaller sample size of SARS-CoV-2-positive patients which has the capability to skew feasibility results.[18–21,27]

Safety

The majority of studies demonstrated that RPM of SARS-CoV-2 participants is safe (70%).[19–27] Overall these studies found that even though patients were acutely ill, the criteria created to qualify for RPM maintained a safe environment for effective and urgent patient care if needed while recovering at home. This was especially important during the COVID-19 pandemic where patients may have acute decompensation or subjectively be unaware of the acuity of their illness. For healthcare providers, providing remote patient care while a patient may be suffering from an acute illness can be anxiety provoking, especially for a not as well-known disease such as a SARS-CoV-2 infection. Ultimately, these studies show that the quality and amount of care in these RPM programs are sufficient in curating a safe healthcare model for both clinicians and patients.

Conservation of Resources

A majority of studies (7/10) mentioned that RPM of SARS-CoV-2 participants can conserve resources such as hospital capacity, health care staff, and/or PPE.[19,20,23,24,27] This is especially helpful in the case of SARS-CoV-2 since it threatened to overrun hospital capacity and in many places it did overrun hospital capacity during major outbreaks. The infection rate and novelty of the virus delivered a shock to health care systems and production lines affecting availability of hospital beds, health staff, and personal protective equipment available. However, definite measurable impact on conservation of resources could not be determined given the lack of randomized controlled groups. Given the early phenotyping of SARS-CoV-2, the majority of the studies were pilot/prospective observational studies.

Program Types

Five of the programs consisted of symptom reporting via an application,[18,19,25–27] three consisted of data reporting via

Table 4 Comparison of publications by the aspects of the comparison of mobile patient monitoring systems framework

Framework components	Reviewed publications
Patient data	• Out of eight studies that collected both objective and subjective data, three stated that a pulse oximeter and thermometer were given to participants upon discharge.[19,24,26] The remaining five studies either did not specify if those devices were given, or stated that the information was reported if those devices were owned by the participant.[18,20,22,25,27] • The questionnaires deployed to participants included questions about new or worsening symptoms. Objective data collected from participants included temperature, oxygen saturation, heart rate and blood pressure. • Used only objective data for monitoring. Participants were given a pulse oximeter and reported three readings per day via phone call.[21] • Did not specify what data was collected from participants.[23] • Four studies inquired about the participant's mental health in the symptom questionnaire using several techniques.[20,22,25,27] • Used existing validated instruments for the subjective data, the General Anxiety Disorder 2 item (GAD-2) and the Patient Health Questionnaire 2-item (PHQ-2) instrument.[22] • Created their own subjective assessment instrument and validated it by sending it to 34 medical experts.[27] • Two created their own subjective assessment instrument but did not specify validation methods.[20,25]
Data transmission method	• Six of the programs consisted of symptom reporting via an application.[18–20,25–27] All five asked about worsening symptoms, the most common being cough, dyspnea, diarrhea, weakness, and vomiting. • Used WeChat, a social media and messaging platform. Participants were able to respond to symptom questionnaires and enter objective data using the app. Required the participants to submit the questionnaire twice daily.[26,27] • Used MyChart companion, a self-monitoring app that participants used to respond to questionnaires and enter objective data.[19] Asked the participants to report on oxygen saturation and temperature in addition to new or worsening symptoms.[20] Used an online platform and a daily call to collect temperature and oxygen saturation readings. • Used GetWell Loop, where participants were enrolled in a loop specific for SARS-CoV-2. Participants were given education information in a newsfeed and daily questionnaires to report symptoms and objective data with the option of sending messages to providers.[18] • Developed their own app to provide education about SARS-CoV-2 and to send daily questionnaires for participants to report symptoms. It required low risk participants to submit the questionnaire daily and high-risk participants to submit it twice daily.[25] • Three of the programs consisted of data reporting via phone.[21–23] • Called participants 3 times per day to collect oxygen saturation and anyone with a level below 92% was instructed to go to the ED.[18] • Called participants daily to inquire about symptoms (dyspnea, cough, emotional, stress) and collect temperature, oxygen saturation, and pulse readings.[22] • Called participants during enrollment, evaluated their health status, and based on their determined risk status, scheduled follow-up calls.[23]
Secure data server	• The studies reviewed did not specifically address data security.[18–27] • The majority of studies mentioned how the data was collected without mentioning security measures of the platform.
Alert system	• Four studies forwarded concerning symptoms via message or text to a clinician.[19,20,22,26] • Three studies created specific alert types that corresponded to different thresholds.[18,25,27] The colors indicated how severe or urgent the alert was. • The remaining three studies did not have a formal alert system.[21,23,24]

Abbreviations: ED, emergency department; SARS-CoV-2; severe acute respiratory syndrome-coronavirus-2.

phone,[21–23] and two of the programs used both an online platform and a daily phone call.[20,24] All data were reported by the participants themselves.

The programs were successful in obtaining health data from participants. However, the usefulness of the data collected was not rigorously tested. Additionally, none of the studies reviewed used continuous data collection. At most, data were reported three times per day by the participant.[21,24] None of the studies used biosensors to collect participant data even though the technology is available. Using biosensors to continuously obtain participant data would ease the burden on participants and would allow for more information to be collected that in turn can more effectively and accurately predict decompensation.

Population

Three studies included high proportions of Hispanic/Latinx, identifying individuals: 36,[19] 57,[21] and 51.1%.[22] Several studies included information about patients' comorbidities. COVID-19 monitoring programming should be generalized to meet the needs for most of the population it serves. This includes making interventional adjustments for racial or socioeconomic differences that may interfere with the equality of the monitoring program. The inclusion of participants of Hispanic/Latinx

Table 5 Objective and subjective measures studied in included publications

	Study									
	Annis et al[18]	Gordon et al[19]	Medina et al[20]	Shah et al[21]	Ye et al[22]	Bell et al[23]	Martínez-García et al[24]	Yordanov et al[25]	Ko et al[26]	Xu et al[27]
Objective measures										
Temperature		X	X		X		X	X	X	X
Oxygen saturation	X	X	X	X	X	X	X		X	
BP										X
Heart rate								X	X	
Subjective measures										
Shortness of Breath					X			X	X	
Cough			X							X
Appetite			X							
Nausea/vomiting			X					X		
Diarrhea			X				X			X
Dyspnea			X				X			
Weakness			X				X			X
Muscle soreness							X			X
Psychological distress					X			X		X
Subjective measures not specified	X	X				X				

Abbreviation: BP, blood pressure.

Table 6 Overview of study outcomes for included publications

Outcomes listed	Reviewed publications
Patient acceptance	• Nine studies listed this as an outcome.[18–26] • Stated participants reported feeling safe and cared for while at home, and they liked how COVID-19 specific information was easily accessible.[18] • Reported only 2 withdrawals out of 77 participants.[21] • 86.7% of patients would recommend the program to friends and family.[22] • 99% of eligible patients consented to the study and only 1 out of 304 participants chose to withdraw from the study.[24] • 70.6% of participants answered questionnaires for more than 7 days.[25]
Feasibility	• Another study was able to use residents and medical students to staff the study, this group would have been sidelined otherwise but instead was very useful.[18] • Showed RPM was possible for this population even with a very large sample.[25] • Eight studies listed this as an outcome.[18–20,23–27] • Stated that successful remote patient monitoring is possible at low cost.[26] • Translated the questionnaires into several languages which allowed participants of various backgrounds to be included in monitoring. • Reported that only seven staff members were needed to manage their large patient cohort.[27] • Demonstrated collecting participant health data remotely is possible even in rural areas with predominantly marginalized populations with a variety of languages.[27]
Safe	• Seven studies listed this as an outcome.[19,22–27] • Noted that RPM could limit the spread of COVID-19 by keeping patients at home and out of the hospital.[19,24–27] • Participants reported feeling supported without needing in-person visits that could risk virus spread.[24] • Two studies sent abnormal vitals or new symptoms directly to healthcare providers, allowing prompt intervention if participants were decompensating.[26,27]
Conserves health staff capacity	• Five listed this as an outcome.[19–21,23,24,27] • Concluded that patients with mild symptoms did not require much communication time, thus freeing providers to focus on unwell patients who need in-person care.[19] • Reported that only seven staff members were needed to manage their large patient cohort.[27]
Conserves hospital capacity	• Five listed this as an outcome.[19,20,23,24,27] • Had a retrospective case control group. Gordon et al used a multivariate model to compare participants enrolled in the remote monitoring versus patients that were referred to the program but did not enroll and reported that those being monitored had a decreased chance of presenting to the ED or being readmitted.[21] • Stated that one third of participants reported that they stayed home due to reassuring oxygen saturation levels, and if they did not have this information, they would have gone to the hospital. This, in turn, reduced ED utilization.[23] • Looked at past medical records to identify a retrospective cohort to compare with the pilot cohort. They reported that 4.7% of their participant cohort had unplanned re-attendances to the ED, while a historical cohort from the same hospital had 22.6% unplanned re-attendances.[24] • Reported that only seven staff members were needed to manage their large patient cohort. Additionally, they recruited medical staff on COVID-19 isolation to help with monitoring which allowed those unable to work in-person the ability to work remotely.[27]
Reduces ED visits	• Four listed this as an outcome.[19,20,22,23] • See above for listed evidence on this outcomes.
Conserves PPE	• Two listed this as an outcome.[21,27]
Generalizability	• One this as an outcome.[24]
Rapidly track decompensation	• Seven listed this as an outcome.[19,21,23,27] • Two studies sent abnormal vitals or new symptoms directly to health care providers, allowing prompt intervention if participants were decompensating.
Limit SARS-CoV-2 spread	• Five listed this as an outcome.[19,24–27] • Noted that RPM could limit the spread of COVID-19 by keeping patients at home and out of the hospital.[19,24–27] • Participants reported feeling supported without needing in-person visits that could risk virus spread.[24]

Abbreviations: COVID-19, novel coronavirus disease; ED, emergency department; SARS-CoV-2; severe acute respiratory syndrome-coronavirus-2

ethnicity is important due to their overrepresentation in COVID-19 cases in the United States. The reporting of comorbidities is also important as we have seen that patients with certain comorbidities are more likely to require hospitalization. There is an inverse relationship between patients with certain comorbidities and negative COVID-19 outcomes.[30] This stratifies those patients with certain comorbid conditions at high-risk of poor COVID-19. Understanding whether or not RPM is

also safe for high-risk patients is an important contribution to the literature. Expanding RPM methodologies can make monitoring programming more accessible to those at highest risk for poor COVID-19 outcomes.

Strengths and Challenges

Each article reviewed exhibited different strengths that could be incorporated in future monitoring programs. One of which included possibly decreasing hospital or emergency room readmission rates.[19,23] Creating a well-rounded, easily accessible monitoring program would be the best to ensure a monitoring system as such would be adopted by a broad range of patients, without limitations to age, technology savviness, or socioeconomic factors. Creating alternatives for communication to report vital signs, symptomology, or contact tracing will help mitigate socioeconomic, language, and technology barriers amongst a broad patient population.[25] This can include ensuring multiple language options to choose from on the software or through interpreter services[19,26]; utilizing a familiar interface (i.e., patient portal)[19,26]; or even, finding alternative methods to reporting symptoms, including simply via phone call.[20] Putting an infrastructure in place with definitive methodology for escalating patient care due to abnormalities in clinical statuses is one of the most significant ways to safely monitor patients remotely.[25]

Various monitoring challenges have presented themselves in the reviewed literature. While participant data was successfully collected, information on how the data was viewed by clinical users and information on data security and storage was lacking.[18–27] These two elements are critical for those looking to design a RPM platform. Additionally, patients must perceive the transmission of their data as being safe and secure to maximize patient engagement and satisfaction.

The data collected were also not robustly tested via randomized control groups to differentiate between data that is noise and data that signals decompensation. This is very important as without this key component, collecting patient data remotely can create more work (false positives and false negatives) for health care staff and will not support a measurable impact on patient care.

It is necessary to identify a set of data that signal SARS-CoV-2 decompensation and a workflow around those data points. This would also inform what measurement instruments must be provided to the participants. For example, determination of type of biosensor, selecting the method of contact, processing algorithm, and communication network.[12] Frequency of "alerting" and threshold for alerts should be reported and reviewed for quality assurance. Which level of health care staff (MD, APRN, RN, and others) is needed to determine escalation of care and how much staff is needed.

Overcoming these adversities will make a significant difference in creating a sustainable digital monitoring program. Some solutions to the challenges noted include the following: (1) expanding a study population in both size and characteristics so it is not too niche can allow research findings to be more broadly utilized; (2) ensuring proper data security for a monitoring program, thus all patients' data are protected; (3) attempting continuous remote patient monitoring with wearable devices which may improve the amount and quality of data collected; and (4) including literature at a higher level of evidence, such as reviews, meta-analyses, and randomized control trials, to solidify and build upon concrete findings from various COVID-19 monitoring programs.

Further Direction

Recent disseminated literature regarding the technological advancements in RPM include the uses of artificial intelligence (AI) and continuous wearable devices (i.e., fitness trackers, watches, or heart monitors).[31–33] Published articles have highlighted the various acute illnesses and chronic diseases that RPM can help manage in both the outpatient and inpatient settings. Benefits of AI may include the following: (1) automating workflows and increasing the efficiency of health care delivery models, (2) identifying potential deterioration and recommending intervention, (3) analyzing physiologic rhythms and obtaining treatment/therapy earlier, and, lastly, (4) giving patients the power to manage their health.[31] The benefits of AI, along with the concept of continuous physiologic data stream, can help gain insight for patients' current health status in real time which ultimately can potentially disrupt the current health care models for the better.[34] These advances can likely be incorporated to RPM of SARS-CoV-2. It would be beneficial for future studies testing RPM of SARS-CoV-2 to incorporate these new approaches to RPM.

Conclusion

The novelty of SARS-CoV-2, in addition to its lethality, placed a spotlight on health care systems and required innovative approaches to patient care that could be quickly and effectively deployed. Telemedicine continues to demonstrate value in health care and position itself as a permanent care delivery avenue. Remote patient monitoring also is becoming a pillar in the health care infrastructure. This review found that the deployed RPM programs were well accepted by participants, feasible to deploy, safe, and were able to track SARS-CoV-2, in some cases reducing ED attendances. However, the incorporation of a remote monitoring program requires different considerations in its deployment.

Clinical Relevance Statement

This review shows that remote patient monitoring for severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2)-positive patients is feasible in a variety of institutions worldwide. This synthesis can help researchers understand the methodologies that have been used to date in remote patient monitoring (RPM) for this patient population. It demonstrates that RPM is well accepted by participants, safe, and can help identify the need for escalation of care while SARS-CoV-2-positive patients are at home. Additionally, it highlights the need for research in specific areas to further develop existing RPM programs for SARS-CoV-2-positive patients.

Multiple Choice Questions

1. In the remote monitoring programs for patients with severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2), what was the average length of time the participants were monitored?
   a. 1 day
   b. 5 days
   c. 15 days
   d. 30 days

   Correct Answer: The correct answer is option c. While the monitoring length ranged from 1 to 30 days and varied from a set timeframe to a conditional time frame per study, the average length participants were monitored for was 15 days.

2. Why would remote patient monitoring be beneficial for SARS-CoV-2 positive patients?
   a. allows for early detection of worsening symptoms
   b. allows for a shorter quarantine time
   c. eliminates the need to ever attend a hospital
   d. eliminates the need to ever attend a primary care physician

   Correct Answer: The correct answer is option a. Remote patient monitoring programs for SARS-CoV-2-positive patients aim to detect worsening symptoms via patient self-reported data.

Protection of Human and Animal Subjects

This review did not require human subjects research approval. However, the studies reviewed obtained human subjects research approval.

Conflict of Interest

None declared.

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