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Research and Applications

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Implementation and impact on length of stay of a post-discharge remote patient monitoring program for acutely hospitalized COVID-19 pneumonia patients

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ABSTRACT

Objective: In order to manage COVID-19 patient population and bed capacity issues, remote patient monitoring (RPM) is a strategy used to transition patients from inpatients to home. We describe our RPM implementation process for post-acute care COVID-19 pneumonia patients. We also evaluate the impact of RPM on patient outcomes, including hospital length of stay (LOS), post-discharge Emergency Department (ED) visits, and hospital readmission.

Materials and Methods: We utilized a cloud-based RPM platform (Vivify Health) and a nurse-monitoring service (Global Medical Response) to enroll COVID-19 patients who required oxygen supplementation after hospital discharge. We evaluated patient participation, biometric alerts, and provider communication. We also assessed the program's impact by comparing RPM patient outcomes with a retrospective cohort of Control patients who similarly required oxygen supplementation after discharge but were not referred to the RPM program. Statistical analyses were performed to evaluate the 2 groups' demographic characteristics, hospital LOS, and readmission rates.

Results: The RPM program enrolled 75 patients with respondents of a post-participation survey reporting high satisfaction with the program. Compared to the Control group ($n = 150$), which had similar demographics and baseline characteristics, the RPM group was associated with shorter hospital LOS (median 4.8 vs 6.1 days; $P = .03$) without adversely impacting return to the ED or readmission.

Conclusion: We implemented a RPM program for post-acute discharged COVID-19 patients requiring oxygen supplementation. Our RPM program resulted in a shorter hospital LOS without adversely impacting quality outcomes for readmission rates and improved healthcare utilization by reducing the average LOS.

Key words: length of stay, telemedicine, hospitalist, coronavirus, mhealth

LAY SUMMARY

To improve hospital operations and bed utilization during the COVID-19 pandemic, we rapidly developed a remote patient monitoring (RPM) program as a strategy to facilitate the discharge of stable COVID-19 patients requiring supplemental oxygen and support their transition from the inpatient setting to home. We share our RPM implementation process and show that enrolled RPM patients were associated with shorter hospital length of stay (LOS) without any adverse impact on quality outcomes, such as return to the Emergency Department or readmission, compared to a cohort of control patients who were not enrolled in RPM. We also show that our RPM program had a high patient engagement rate and positive patient satisfaction. Our results demonstrate that RPM can be an essential part of the healthcare delivery model, as it could positively impact outcomes, healthcare utilization, and patient satisfaction.

INTRODUCTION

Background

In April 2020, the United States experienced an initial surge of more than 1 million confirmed cases of COVID-19 infections, accounting for one-third of all cases worldwide.[1,2] In 2021, the United States faced additional surges in COVID-19 cases across all States, which has led to more than 800 000 deaths to date. During these peaks, healthcare systems faced an influx of COVID-19 patients, which resulted in significant shortages of beds, staff, and equipment. Emergency Departments (ED), inpatient units, and post-acute care facilities were overwhelmed with COVID-19 patients. Healthcare providers were overworked, and patients experienced prolonged wait times to receive care. As a result, hospitals and healthcare systems encountered serious capacity and resource constraints from extended hospital admissions and recovery due to COVID-19.[3–6] Post-acute care settings simultaneously experienced saturation and staffing shortages, which presented an additional barrier to throughput. Additionally, patients had a low threshold for seeking medical care or returning to the ED due to anxiety about lingering symptoms and knowledge gap around COVID-19.[7] These strains ultimately affected the quality and safety of the care delivery model. Compounding this problem, healthcare organizations faced a financial burden as hospitals cancelled revenue-producing elective surgical procedures and certain ambulatory services to expand inpatient staffing and bed capacity during the COVID-19 outbreak.[8,9]

The crisis triggered a revolution of digital and technology use in healthcare and induced a transformation of the healthcare delivery model to virtual care at an exponential speed.[10] Payors have increasingly extended coverage, regulators have removed legal barriers to telehealth, and providers have expanded services through virtual programs.[11] Virtual care prevented congregation of patients and overcame the traditional physical barriers to providing medical services.[12] Digital health innovation has provided solutions and supported healthcare systems to mitigate the challenges posed by the pandemic.

RPM is a virtual care technology that digitally transmits health data to clinicians who can monitor patients outside of a traditional clinical setting.[13] During California's surge of COVID-19 cases in late 2020, hospitalizations and deaths increased at an alarming rate in Orange County.[14] University of California, Irvine Medical Center (UCIMC), the only academic medical center in the sixth largest county in the United States, made up of 3.8M people and no county hospital, rapidly developed a RPM Program for patients who were hospitalized with COVID pneumonia and respiratory failure. The goal was to optimize health care resource utilization across the continuum of care to manage patients safely at home. The RPM Program was piloted in hospitalized COVID-19 patients who required oxygen supplementation after discharge and was designed to remotely monitor real-time alarms for patients' clinical symptoms, vital signs, and oxygen saturation in the patients' home environment. In addition, the RPM technology provided patients direct access to a member of the care team. The program was developed to support the transition of hospitalized COVID-19 patients to outpatient setting, aiming to decrease patients' hospital length of stay (LOS) and prevent hospital readmission.

MATERIALS AND METHODS

Study site

The study is limited to a single site, UCIMC, the teaching hospital of University of California, Irvine School of Medicine. This is the only tertiary academic medical center and Level 1 trauma center located in Orange County, California. The medical center is 1 of the 5 medical centers of University of California health system. UCIMC has 418 licensed hospital beds, of which, 68 are ICU and 223 are other acute care beds for both medical and surgical services. In December 2020, as a response to the surge of COVID-19 patients, UCIMC opened a temporary mobile field hospital that added up to 50 acute care beds.

Study population

Our study population consisted of all hospitalized COVID-19 pneumonia patients discharged to home with supplemental oxygen from January 7, 2021 to November 11, 2021. This population was sorted into 2 groups: (1) patients who were enrolled in the RPM program, and (2) patients who were not enrolled in the RPM program. Group 2 served as our Control group. Patients in the Control group were not referred for enrollment at the discretion of the discharging physician or were otherwise excluded based on the RPM program's eligibility criteria. Thirteen patients were inadvertently referred to the RPM program but excluded from enrollment based on the RPM program's exclusion criteria of language or technology. Only one eligible referred patient declined participation in the RPM program.

RPM eligibility and workflow

All patients hospitalized with COVID-19 respiratory illness were treated by hospitalists and intensivists. The treating physicians were educated about the RPM enrollment eligibility criteria (Figure 1) and were responsible for screening patients for enrollment. The inclusion criteria also utilized a validated COVID-19 Predictive Analytic Tool that was developed by the UCI Center for Artificial Intelligence in Diagnostic Medicine.[15] Simultaneously, patients were scheduled for an outpatient virtual visit to determine if disenrollment from RPM was appropriate at the date of the follow-up appointment. Patients discharged to a setting other than home, such as skilled nursing facilities, acute rehabilitation facilities, leaving against medical advice, or shelters were not eligible for the RPM program. Patients could opt out and discontinue participation in the

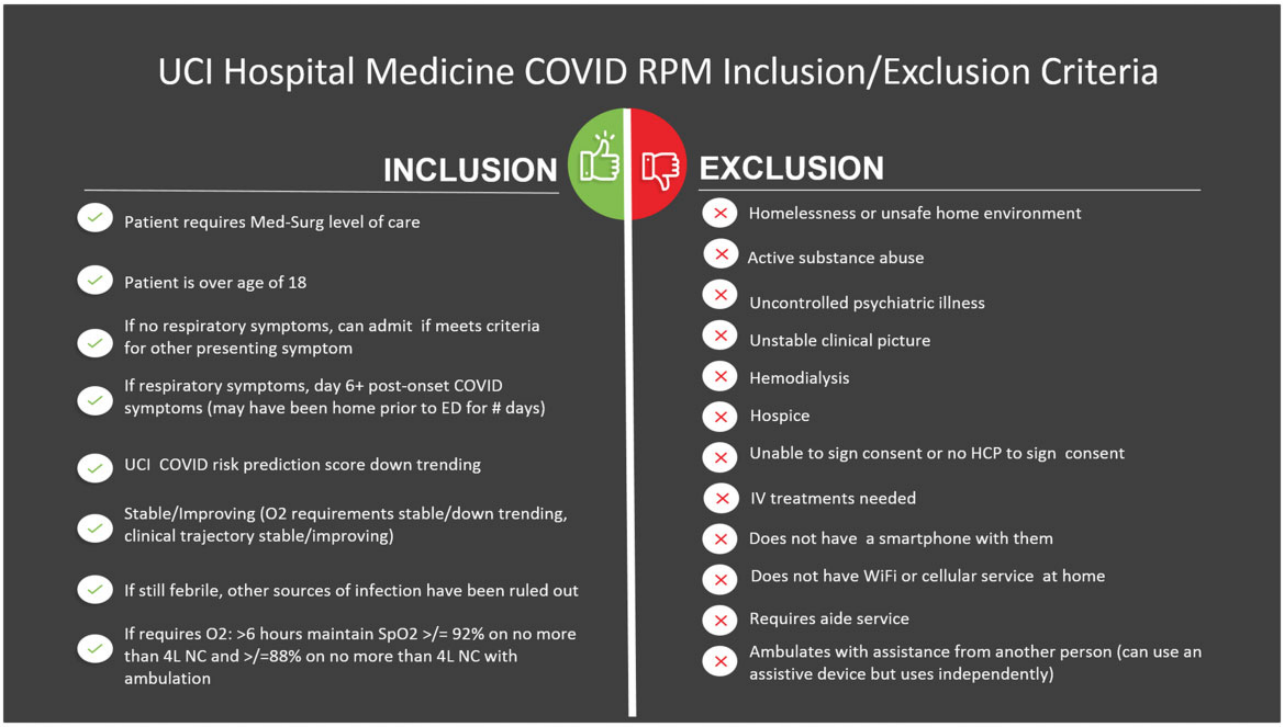

Figure 1. COVID-19 RPM inclusion and exclusion criteria. O_2: oxygen; SpO_2: oxygen saturation; NC: nasal cannula; IV: intravenous; HCP: healthcare proxy.

program at any time. There were no insurance or financial constraints to eligibility. Those who did not meet criteria could still be discharged with or without home oxygen or to other post-acute care settings without RPM.

Once the patient met the enrollment criteria, they were supplied with a smartphone application and disposable vital signs monitoring equipment with the capability of transferring biometric data to the smartphone RPM application via Bluetooth. The application was available for both iOS and android devices but limited to English and Spanish languages. The hospital also provided each RPM patient with a reusable Philips oxygen concentrator (maximum 5 L/min = 40% FiO_2) until home-health delivered a portable oxygen tank. Inpatient registered nurses validated eligibility for enrollment based on the defined criteria, provided patients with education on use of the RPM application and equipment, and expectations of participation in the program prior to discharge. The program was only available for enrollment on weekdays due to the availability of RPM educators/coordinators. As a result, both the study and control groups were limited to the same dates (Figure 2 for detailed enrollment workflow).

Implementation

We partnered with a cloud-based technology platform (Vivify Health) and a nurse monitoring service (Global Medical Response) for our RPM program. Together, this partnership provided the capabilities of biometric data monitoring, personalized symptom assessment care pathways, secure messaging, 24-h physician/nursing support, and HIPAA-compliant virtual video evaluation.

Monitor period and completion process

Enrolled patients were alerted twice a day by the smartphone application to complete symptom assessment questionnaires on the application. The vendor's clinical questionnaire pathways were validated by UCIMC. The RPM care team monitored the platform and contacted patients based on their Health Index score, absolute thresholds for vital sign parameters, or patient-initiated requests for support. The Health Index score is calculated using the patient's questionnaire responses and biometric data. If an alert triggered to the monitoring care team, they would triage to respond to the patient directly or escalate to the UCIMC clinician, if needed.

Patients were evaluated for follow-up during a prescheduled Hospitalist Post-Discharge Transition of Care Clinic virtual visit to determine if they could complete the RPM program or if RPM should be extended, in which case, another follow-up virtual visit would be scheduled. If patients failed to keep their appointment, the discharging Case Manager would contact them to determine disenrollment.

As a late phase of RPM implementation, we launched a post-participation satisfaction survey to assess the patients' perception of the program. After RPM program completion, patients received a notification in the smartphone application to complete the 9-question satisfaction survey.

Program analysis

We evaluated the RPM program's patient participation and satisfaction, number and frequency of biometric alerts, and provider communication. To assess the impact of the RPM program on patient outcomes and use of healthcare resources, we retrospectively reviewed the EHR data of the RPM and Control groups and compared the 2 groups' demographic data, comorbidities, hospital LOS, return to the hospital and ED within 30 days of discharge, and all-cause mortality at 30 days post-discharge. Data were analyzed using the SPSS statistical application.

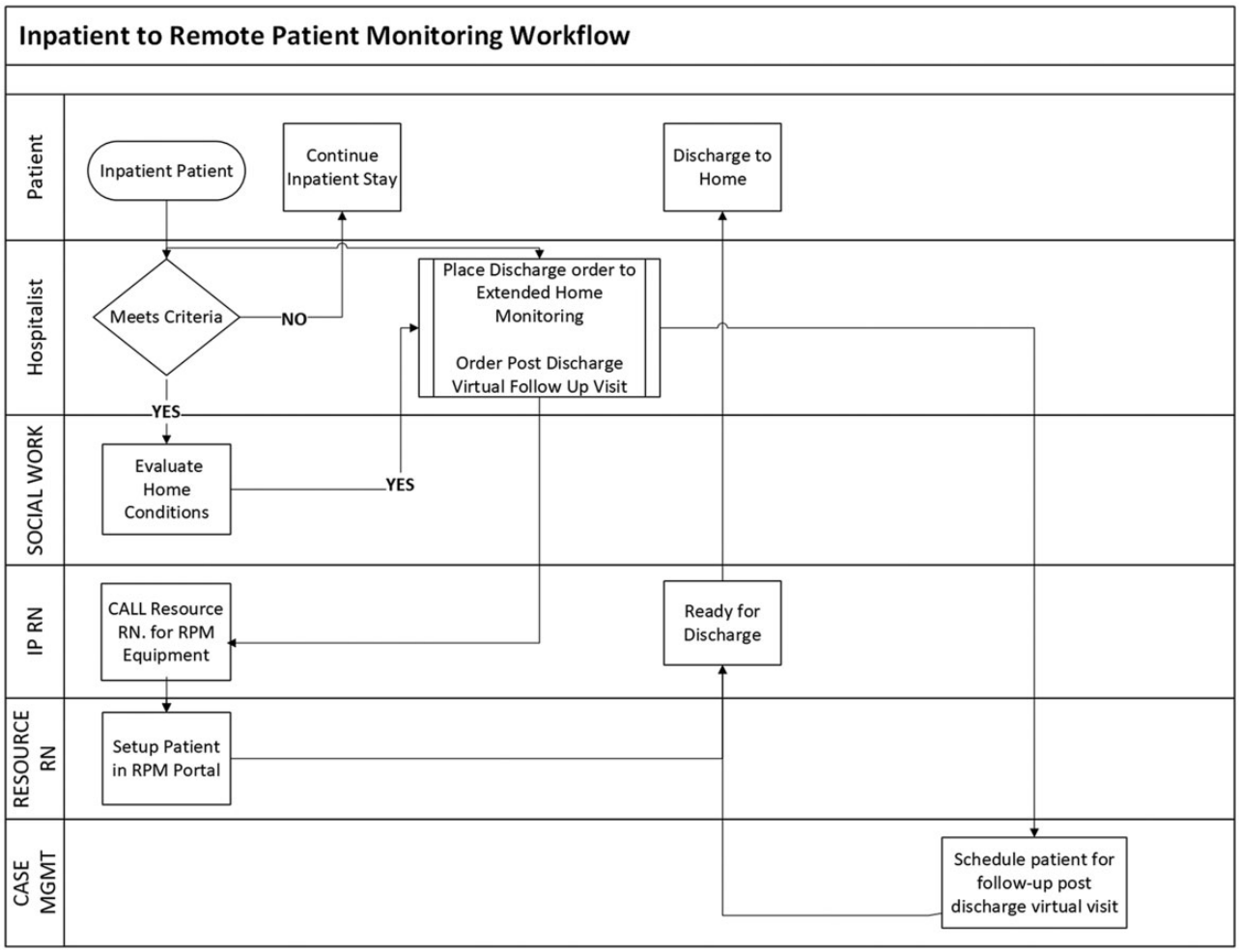

Figure 2. Detailed RPM enrollment workflow. IP: inpatient; RN: registered nurse.

IRB approval/ethical issues

Our implementation and retrospective analysis of the RPM program constituted a quality assessment of a pilot program and did not require our Institutional Review Board's approval.

RESULTS

Between January and November 2021, 75/76 referred eligible patients enrolled in the RPM program (Table 1). The median age for the RPM group was 56 years (Interquartile Range, IQR: 51–68), 67% (50/75) of patients were male, and 59% (44/75) were Hispanic. Enrolled patients spent a median of 35 days (IQR: 26–56) on the RPM program and completed a median of 43 application questionnaire pathways per patient (Table 2). Patient engagement was high, with 96% (72/75) of enrolled RPM patients completing at least 1 pathway. No patients asked to be removed from the program prior to scheduled disenrollment, and among patients who were eligible to enroll, only 1 declined participation.

Monitoring was performed by 40 care team members, composed of registered, licensed vocational, and licensed practical nurses, who reviewed a total of 1556 biometric alerts that were triggered during the study period. The median turnaround time for a care team member to review an alert was 24 minutes. The most common alerts reviewed were for abnormal blood pressure (which triggered an alert in 88% [66/75] of enrolled patients) and oxygen saturation (which triggered an alert in 85% [64/75] of patients). The oxygen saturation alert frequency peaked at day 2 and became minimal after day 21 (Figure 3). Fewer than 1% (8/1556) of biometric alerts required escalation to the on-call clinician.

A post-participation survey was deployed 8 months into RPM program implementation. Of the 31 RPM participants that received the survey invite, 52% (16/31) completed the post-participation survey and reported high satisfaction with the program (Figure 4). Most RPM survey respondents strongly agreed that: (1) the remote monitoring technology was easy to use; (2) learning to take care of their health condition with the remote monitoring program did not take too much time; (3) they had no privacy concerns when using the remote monitoring technology; (4) they felt more comfortable knowing a nurse was checking their health every day; and (5) they were satisfied with the remote monitoring program experience. All (100%) of respondents indicated they would recommend the remote monitoring program to others. Additional patient comments about their experience with the RPM Program were also positive, and responses included "it was great," "it was very helpful," "highly recommend," "very beneficial," and "I am pleased with the program." There were no negative patient comments.

Our retrospective analysis included a total of 225 patients (150 Control and the 75 RPM patients). Demographics and baseline

Table 1. Patient demographics and baseline characteristics of remote patient monitoring (RPM) and control groups

Characteristic	RPM group, $n = 75$	Control, $n = 150$	P value
Gender			.69
Male, *n* (%)	50 (67)	96 (64)	
Female, *n* (%)	25 (33)	54 (36)	
Age, median (IQR)	56 (51–68)	59 (47–68)	.53
Race			.12
Asian, *n* (%)	16 (21)	24 (16)	
Black, *n* (%)	2 (3)	0 (0)	
White, *n* (%)	42 (56)	85 (57)	
Not available/other, *n* (%)	15 (20)	41 (27)	
Ethnicity			.63
Hispanic, *n* (%)	44 (59)	93 (62)	
Non-Hispanic, *n* (%)	31 (41)	57 (38)	
Diabetes, *n* (%)	15 (20)	46 (31)	.09
Hypertension, *n* (%)	16 (21)	40 (27)	.38
Obesity, *n* (%)	32 (43)	72 (48)	.45
COPD, *n* (%)	2 (3)	5 (3)	.79
CKD, *n* (%)	5 (7)	7 (5)	.53
Required ICU, *n* (%)	11 (15)	36 (24)	.10
Received Remdesivir, *n* (%)	52 (69)	87 (58)	.10
LACE+ score			.13
Low risk [0–28], *n* (%)	0 (0)	3 (2)	
Moderate risk [29–58], *n* (%)	49 (65)	82 (55)	
High risk [59–90], *n* (%)	26 (35)	65 (43)	

Note: Data presented as numbers (*n*) and percentages (%). Non-normally distributed data presented as medians and interquartile range (IQR). Statistical tests performed: Mann–Whitney test or Pearson chi-square test.

COPD: chronic obstructive pulmonary disease; CKD: chronic kidney disease; ICU: intensive care unit; LACE+: scoring index that predicts the risk of post-discharge death or urgent readmission.

characteristics of the 2 groups are summarized in Table 1, where we found no differences in the baseline characteristics of the Control and RPM groups. However, median LOS for the Control group was 6.1 days (IQR: 3–10) while the median LOS for the RPM group was 4.8 days (IQR: 2–10), representing a statistically significant ($P = .03$) difference (Figure 5).

The 30-day all-cause hospital readmission rates were 14.7% (22/150) and 9.3% (7/75) for the Control and RPM groups, respectively, and the 30-day all-cause ED visit rates were 4.0% (6/150) for the Control group and 6.7% (5/75) for the RPM group (Figure 6). These differences in all-cause hospital readmissions and ED visits were not statistically significant ($P = .26$ and $P = .38$, respectively). To determine if a clinically related readmission measure would differ between the 2 groups, we analyzed the 30-day readmission rates for respiratory-related complaints and found that the 30-day respiratory-related return hospital admission rates were 8.7% (13/150) and 8.0% (6/75) for the Control and RPM groups, respectively. The 30-day respiratory-related ED visit rates were 0.7% (1/150) and 1.3% (1/75) for the Control and RPM groups, respectively. These respiratory-related measures were not statistically different between the Control and RPM groups ($P = .87$ for hospital readmission and $P = .62$ for ED visits). No deaths occurred within 30 days of discharge among RPM patients compared to 2 in the Control group. Total readmissions, respiratory-related hospital measures, and deaths trended in favor of RPM, even though these categories were not statistically significant.

Table 2. Remote patient monitoring (RPM) program characteristics

Patient participation		
Patients enrolled, *n*	75	
Days on program per patient, median (IQR)	35	(26–56)
Completed pathways per patient, median (IQR)	43	(7–84)
Patients that completed at least 1 pathway, *n* (%)	72	(96%)
Vital sign tracking		
Patients that triggered BP alert, *n* (%)	66	(88%)
Patients that triggered O_2 alert, *n* (%)	64	(85%)
Patients that triggered Temp alert, *n* (%)	14	(19%)
Patients that triggered Pulse alert, *n* (%)	15	(20%)
Patients that triggered Steps alert, *n* (%)	1	(1%)
Provider communication		
Care team reviewers, *n*	40	
Registered nurse, *n* (%)	22	(55%)
Licensed vocational nurse, *n* (%)	15	(38%)
Licensed practical nurse, *n* (%)	3	(7%)
Biometric alerts reviewed, *n*	1556	
Turnaround time for alert review, median (IQR)	0:24	(0:08–1:17)
Biometric alerts requiring MD attention, *n*	8	(0.5%)

Note: Data presented as numbers (*n*) and percentages (%). Non-normally distributed data presented as medians and interquartile range (IQR).

BP: blood pressure; O_2: oxygen; Temp: temperature; MD: Doctor of Medicine.

DISCUSSION

The COVID-19 pandemic has forced an expansion in the use of virtual care and radically accelerated a shift in healthcare delivery. Development of the RPM program complemented our existing virtual services and further augmented our ability to efficiently use health care resources while providing personal support and delivering enhanced quality of care to patients at home. Some important results were obtained to inform how to safely and rapidly implement a RPM program that can be further developed into a more robust RPM strategy. We were able to deploy the RPM program within 14 days from concept to patient enrollment by leveraging existing infrastructure, creating new internal workflows, and partnering with vendors. This allowed us to create a monitoring care team while preserving the already stretched UCIMC nursing resources.

Our retrospective cohort study shows that the RPM program had a statistically significant reduction in the hospital LOS for COVID-19 pneumonia patients that were discharged to home with supplemental oxygen, compared to patients who received usual care, without adversely impacting quality, return to ED, or all-cause readmission. While no deaths occurred within 30 days of discharge among RPM patients, there were 2 in the Control group. Prior studies[10,16] offered no guidance on the optimal duration for home monitoring. For our study group, the alerts for RPM low oxygen saturation were minimal and plateaued after day 21. Based on the experience with our alert frequency, it may be reasonable to limit RPM for 21 days post-discharge for similar patients. In addition, patients returning to the ED or readmission for respiratory symptoms occurred within the first 21-day window post-discharge, and most were within 7 days.

The improved healthcare resource utilization demonstrated by our RPM program may also translate to lower costs associated with hospitalization. This is consistent with Schmier et al's findings on the cost-effectiveness of remote monitoring.[17] The average daily expense for a nonprofit hospital in the United States in 2019 was $2738 and in California was $4128.[18] The costs of hospitalization for a COVID-19 patient were even higher. Although the cost of

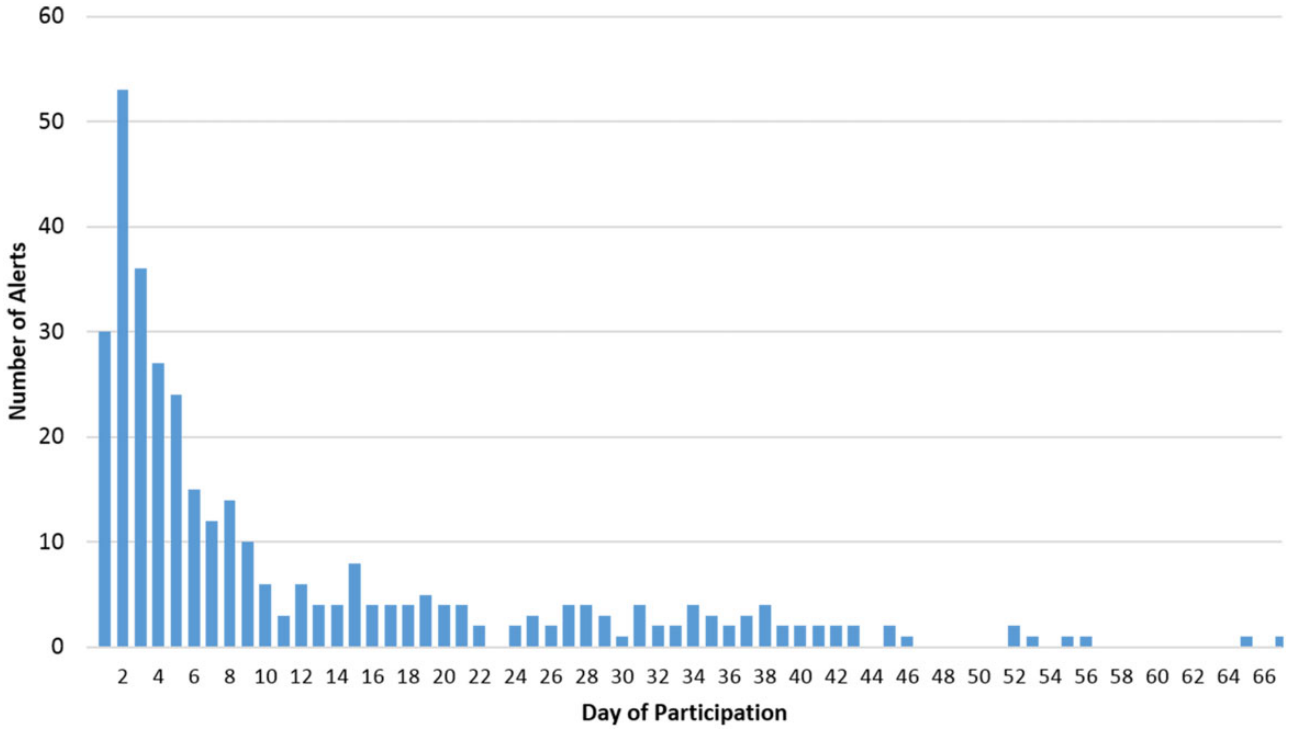

Figure 3. Frequency of oxygen alerts by day of participation in the remote patient monitoring program.

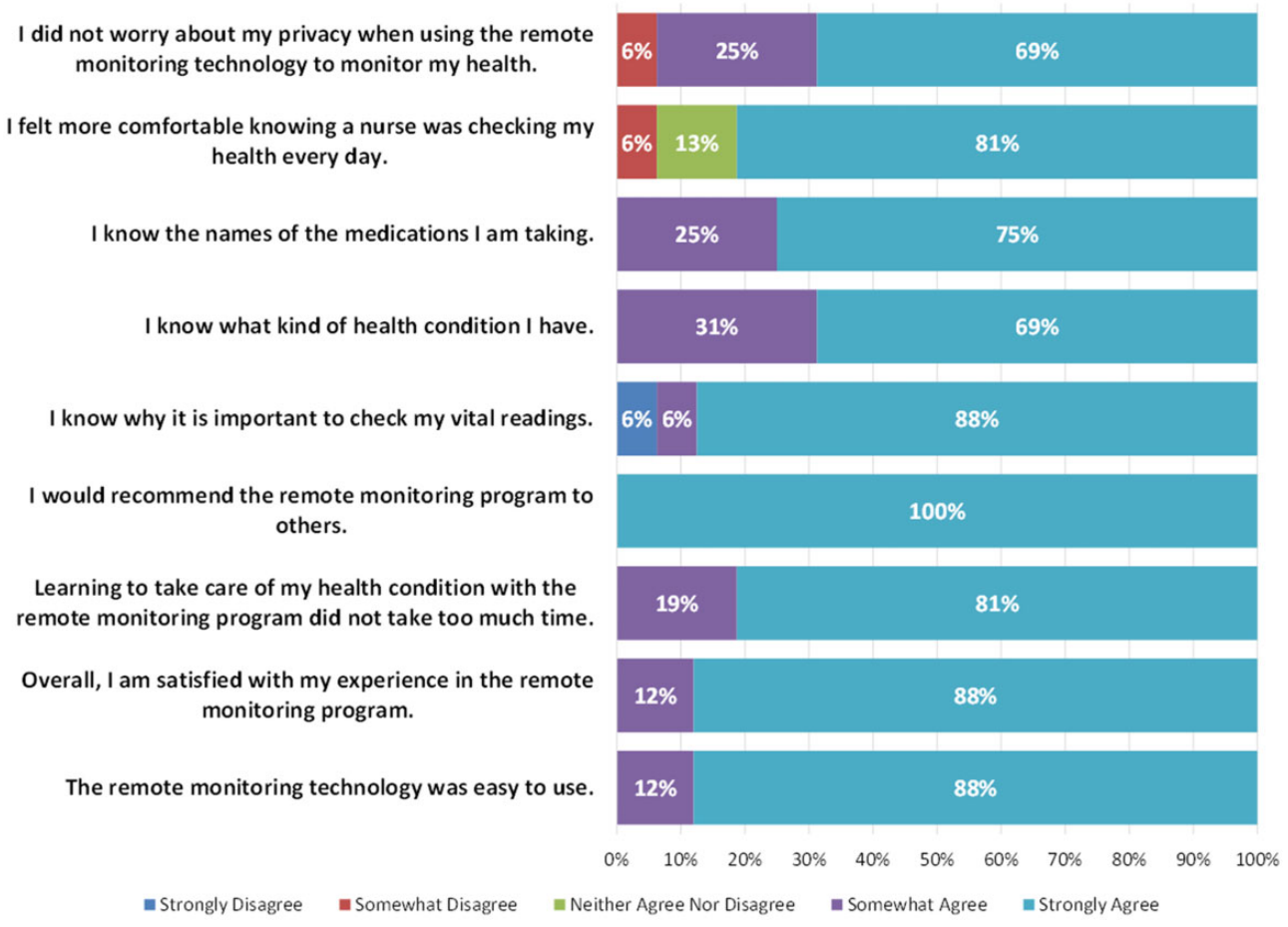

Figure 4. Satisfaction survey responses ($n = 16$) from the remote patient monitoring participants.

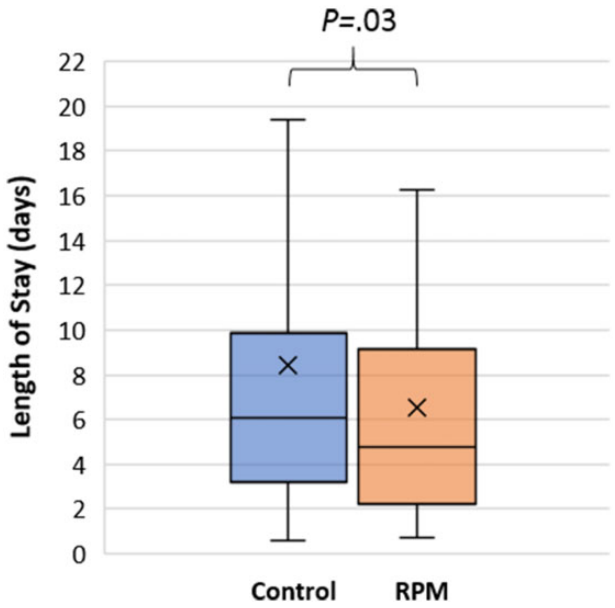

Figure 5. Boxplot of lengths of stay from the control and remote patient monitoring (RPM) groups. The box represents the interquartile range (IQR), with the top and bottom of box corresponding to the upper (third) and lower (first) quartiles, respectively. The horizontal line inside the box marks the median and the X marks the mean. Lines extending out from the box (whiskers) represent values within 1.5 times the IQR. Data beyond the whiskers are outliers and not plotted for simplicity.

COVID-19 care can vary widely due to many factors, such as hospital location, patient's illness severity, comorbidities, demographics, complexity of care, and payer mix, reports indicate that the average cost per day for a hospitalized COVID-19 patient in the United States was $11 700.[19] For our study, the average daily cost of disposable equipment and all contracted services, including nursing monitoring services, was approximately $11 per patient per day, although regional variation is expected. Shortening LOS may also provide the hospital with increased capacity to care for more patients. Thus, the median reduction of 1.3 days in the hospital that we observed in our study may represent direct savings and revenue opportunity of hundreds of thousands of dollars in healthcare costs annually. We estimate that 97 bed days per year were opened as a result of this program. Thus, the implementation of a RPM program could allow a healthcare system to be more efficient without compromising the quality of care it provides.

In addition, there are other benefits such as enhanced physician confidence to discharge patients sooner and improved patient confidence for willingness to go home with the RPM program. We received positive feedback from RPM patients that completed the post-participation satisfaction survey. The majority of respondents felt more comfortable knowing a nurse was monitoring their health daily, which is similar to the patient feedback described by Annis et al.[20] The survey revealed that the technology was well received and accepted by participants and that privacy was not a concern for them while being enrolled in the RPM program. Despite the positive comments, further education on digital literacy may be necessary to enhance patients' experience on virtual care since patients who are less familiar with technology may doubt the reliability of virtual care.[21]

Although we piloted our RPM program in COVID-19 patients, this technology will have utility beyond the current pandemic and can be applicable to other chronic conditions, such as heart failure, COPD, or other diseases associated with high hospital readmissions. Our pilot study and other RPM models support that real-time and regular tracking of patient data with RPM offers healthcare providers the opportunity to quickly address changes in patients' health status, improving the management of their condition, and potentially reducing unnecessary health care utilization such as ED visits and inpatient hospitalizations. As the world transitions to a post-pandemic phase, we believe virtual care services such as RPM will continue to be an important part of the healthcare delivery model.

As we believe virtual care will continue to be an essential part of the healthcare delivery model beyond the current pandemic, we will use the analysis of this pilot experience to improve the next phase of our RPM program. We plan to supply all eligible patients with a reusable smartphone and RPM equipment, implement instructions for self-titration off oxygen, broaden to other languages, and expand to other respiratory disease RPM pathways like COPD, pneumonia, and heart failure. Lastly, we plan to fully integrate the RPM data into our EHR for a seamless provider experience.

Limitations

The study has a few limitations including: (1) availability to only English and Spanish-speaking patients with a stable home setting; (2) enrollment limited to weekdays; (3) requirement for a patient-supplied smartphone with either iOS/Android operating systems; and (4) late addition of patient satisfaction surveys, resulting in completed surveys for only a portion of the study group; Additionally, the data retrieval was limited to our EHR and HIE (Epic, Providence, Oregon Health Sciences, OCPRHIO, and the CDPH death registry), so we were not able to obtain patient health information outside of these data sources. Because of the small study size and limitation to 1 medical center, the findings may not be generalizable to other populations and the observed benefits may not translate to a wider adoption of RPM. Additionally, there may be an inherent bias of equity based on the eligibility criteria for this program since lower socioeconomic groups may have been more selectively excluded because of homelessness or inability to own a smartphone. There may also be unidentified bias related to selection of patients for participation since referral to the RPM program was at the discretion of the discharging physician's clinical judgment. Lastly, technology-averse patients may be less willing to participate in this program, although that was not our experience.

CONCLUSION

We described our successful rapid implementation of a RPM program for post-discharged COVID-19 patients requiring supplemental oxygen. Our RPM program was associated with shorter hospital LOS without any adverse impact on quality outcomes such as all-cause ED visits and readmission rates with a nonstatistically significant trend towards improved mortality, which led to improved healthcare utilization. Our program had a high patient engagement rate and positive patient satisfaction. This small pilot study suggests that further investigation is warranted to fully assess the impact of RPM technology on hospital throughput and quality.

FUNDING

There is no funding source for this work. We did not receive any donation or funding from any third-party partner vendors to conduct this study.

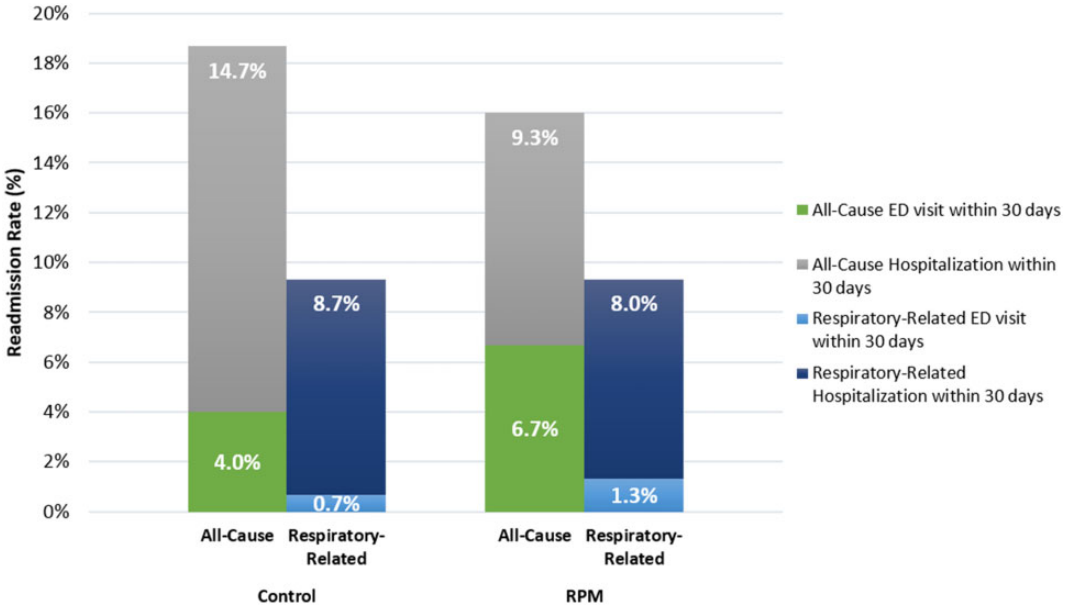

Figure 6. Readmission rates for control and remote patient monitoring (RPM) groups.

AUTHOR CONTRIBUTIONS

SK and AA conceived the study, acquired the data, designed the analysis plan, drafted the manuscript, and participated in the critical revisions process. RO acquired the data and participated in the critical revisions process. SR conceived the study and participated in the critical revisions process. AAD and ANA conceived the study, designed the analysis plan, drafted the manuscript, participated in the critical revisions process, and contributed equally as cosenior authors. All authors reviewed and refined the draft and finalized the article.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

The data underlying this article cannot be shared publicly for the privacy of the individuals who participated in the study. Data may be shared upon reasonable request to the corresponding author.

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