A prospective observational study evaluating the use of remote patient monitoring in ED discharged COVID-19 patients in NYC

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ABSTRACT

Objectives: We investigated whether continuous remote patient monitoring (RPM) could significantly reduce return Emergency Department (ED) revisits among coronavirus disease 2019 (COVID-19) patients discharged from the emergency Department.

Materials and methods: A prospective observational study was conducted from a total of 2833 COVID-19 diagnosed patients who presented to the Montefiore Medical Center ED between September 2020–March 2021. Study patients were remotely monitored through a digital platform that was supervised 24/7 by licensed healthcare professionals. Age and time-period matched controls were randomly sampled through retrospective review. The primary outcome was ED revisit rates among the two groups.

Results: In our study, 150 patients enrolled in the RPM program and 150 controls were sampled for a total of 300 patients. Overall, 59.1% of the patients identified as Hispanic/Latino. The RPM group had higher body mass index (BMI) (29 (25–35) vs. 27 (25–31) p-value 0.020) and rates of hypertension (50.7% (76) vs. 35.8% (54) p-value 0.009). There were no statistically significant differences in rates of ED revisit between the RPM group (8% (12)) and control group (9.3% (14)) (OR: 0.863; 95% CI:0.413–1.803; p- 0.695).

Discussion and conclusion: Our study explored the impact of continuous monitoring versus intermittent monitoring for reducing ED revisits in a largely underrepresented population of the Bronx. Our study demonstrated that continuous remote patient monitoring showed no significant difference in preventing ED revisits compared to non-standardized intermittent monitoring. However, potential other acute care settings where RPM may be useful for identifying high-risk patients for early interventions warrant further study.

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1. Background and significance

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged in late 2019 and continues to devastate the globe with millions of cases worldwide and unprecedented morbidity and mortality [1]. Around the world, healthcare systems have been overwhelmed and stretched beyond their limits due to the exponential growth in cases, repetitive outbreaks, and the severity of the disease [2]. Even though viral outbreaks have occurred in recent years (MERS, SARS, H1N1), the impact of the COVID-19 pandemic has demonstrated that our healthcare system was underprepared for a pandemic of such magnitude.

In April 2020, New York City was an early epicenter for the COVID-19 pandemic. Early studies found a stark variation in rates of hospitalization and deaths between the boroughs within New York City. Namely, the Bronx, which has the highest proportions of racial/ethnic minorities, persons living in poverty, and the lowest levels of educational attainment, were subjected to the highest rates of hospitalization and death of all five boroughs [3,4]. These trends pointed toward underlying comorbid illness, environmental exposures, and socioeconomic factors as drivers for the different outcomes within New York City communities [5]. Our study is unique in that our patients represent a population that (1) is traditionally underrepresented in studies, (2) is underserved with respect to both healthcare access and equity, and (3) was particularly impacted by the pandemic. As epidemics and pandemics are forecast to continue [6], and as new waves of COVID continue to stress hospitals and healthcare systems, it is crucial to test and study new strategies to

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arm our healthcare system with the necessary tools to mitigate their impact.

In recent years, with the development of various remote patient monitoring (RPM) platforms, utilization of the technology has expanded [7-11]. Remote patient monitoring can collect and share physiologic information outside of the traditional clinical setting and assist clinicians in providing care in nontraditional environments [12]. Several RPM programs launched during the COVID-19 pandemic demonstrated various levels of success [2,13,14]. However, there is limited literature regarding the utilization of an external continuous monitoring center to decrease hospital admission following a discharge from the emergency department (ED).

In this study, we tested the hypothesis that continuous remote patient monitoring could significantly reduce return ED revisits during the COVID-19 quarantine. The study's primary objective was to compare the rate of subsequent ED revisits between a continuously monitored group and a control group of COVID-19 patients who were discharged from the ED. The study's secondary objectives were to evaluate the difference in mortality and patient satisfaction between the two groups.

2. Methods

2.1. Setting

Montefiore Medical Center (MMC) is a large not-for-profit quaternary healthcare system based in the Bronx, NY. Our study included patients who visited ED's at five different hospitals within the Montefiore network: Wakefield, Weiler, Children's Hospital at Montefiore, Moses Hospital, and Westchester Square Hospital.

2.2. Selection and screening

In this observational study, we recruited COVID-19 patients visiting EDs associated with Montefiore Medical Center from September 2020–March 2021. Inclusion criteria consisted of a first-time positive test for COVID-19 via nasopharyngeal polymerase chain reaction (PCR), ability to read and understand English or Spanish, age of at least 21 years, ED discharge without requiring inpatient admission, and ability to quarantine in one location within the greater Bronx, NY area for 14 days. Exclusion criteria consisted of patient inability to navigate a tablet or smartphone, an implanted pacemaker, hyperhidrosis, hypersensitivity to adhesive patches, or the presence of an active psychiatric or anxiety disorder.

Beginning in September 2020, a daily list of all COVID-19 positive patients discharged from MMC EDs within the last 72 h was generated using the Montefiore Epic Electronic Health Record (EHR). We reviewed each patient chart for inclusion and exclusion criteria before contacting and enrolling eligible patients. In November, we saw a dramatic rise in the number of patients on our daily list in parallel with the second wave of COVID-19 infections in New York City. For optimal utilization of resources, we enrolled high-risk patients based on CDC's published criteria [15] to maximize the benefit of remote monitoring to our patients, using a list of risk factors such as age older than 65, high-risk comorbidities, and severity of illness on presentation to the ED. Comorbidities included hypertension, diabetes, obesity, smoking, chronic lung diseases, heart conditions, chronic kidney disease, and immunocompromised states.

The control group in this study included patients who met the inclusion criteria but were not enrolled due to meeting an exclusion criterion or declining enrollment. Controls were retrospectively identified, screened for age and time of ED presentation to match those of subjects from the intervention group, and randomly sampled afterward to minimize potential bias. For our control group, a total of 150 patients were sampled from three time periods based on when we began prioritizing enrollment for high-risk patients in November 2020; 1/3 of controls were sampled from September 2020 to November 2020, 1/3 from December 2020 to January 2021, and the last 1/3 from February 2021 to March 2021.

Regarding the care given to the control patients, Montefiore ED has standardized protocols for patients discharged from the ED. All usual standard of care practices available for patients discharged from the ED were provided to patients, including telephone consultations. The study team did not interfere or dictate the care provided to the control patients.

2.3. Enrollment and device allocation

Enrollment took place each morning via phone calls. The study team informed and verbally consented patients after discussing the potential risks and benefits of the study and addressed all questions and concerns during the initial phone contact. Patients who agreed to participate were considered preliminarily enrolled. Following enrollment, we generated a unique QR code for each patient using MonitorMe's remote monitoring software (detailed description of technology below), which allowed the assignment of the monitoring device to the individual patient and shared the patient's basic demographic information with MonitorMe.

Monitoring equipment was delivered to each patient's home after enrollment. We instructed patients on how to connect to the enrollment nurse at MonitorMe using the tablet or smartphone we delivered. The nurse then completed the remote monitoring onboarding process and explained how to use the monitoring equipment. After onboarding with MonitorMe, the patient was considered to be officially enrolled, and monitoring began on day 1.

On day 10 of monitoring for each patient, we called and reassessed the patient for COVID-19 symptoms. If patients were symptom-free, we arranged to pick up the devices. If their symptoms persisted, we extended monitoring to 14 days. Following pick-ups, all monitoring equipment underwent a standardized cleaning and sterilization process before being re-distributed. We had a total of 8 monitoring packages for the entire study, and package availability was consistently our limiting factor in the number of patients we could enroll on any given day.

At the end of the monitoring period (10 or 14 days), a 14-question satisfaction survey was administered in English or Spanish via phone to all patients who had been officially enrolled in the program. This survey focused on how satisfied patients were with the program, how much help and support patients felt they had received, and how any issues with the program had affected their overall experience.

2.4. Monitoring equipment and data collection

This study integrated two technologies; an FDA-approved proprietary body patch and a digital monitoring platform (Fig. 1). The body patch used in this study was the lifesignal biosensor 1AX*, which was used to monitor vital signs, including heart rate, respiratory rate, and electrocardiograms (ECGs). Additionally, a pulse oximeter and blood pressure monitor were used to measure the peripheral oxygen saturation and blood pressure.

MonitorMe used the digital monitoring platform ImagineMic for continuous digital monitoring of the physiologic measurements. The vital signs generated through the biosensor patch were continuously supervised at the Monitoring Intervention Center (MIC) by licensed nurse practitioners and physicians. These data points were monitored 24/7, and alerts were provided to patients via a telephone call from the monitoring healthcare professional in the event an intervention was required. In these cases, the appropriate medical recommendation was made, including immediate medical attention in the ED if necessary. Based on the condition of the patient, the monitoring staff facilitated ambulance support.

Fig. 1. Photo image of the remote monitoring equipment and platform.

Data collection was performed through retrospective manual chart review using Montefiore's Epic EHR system. The following data were collected during the initial ED visit: baseline demographics, clinical comorbidities, clinical symptoms, duration of the symptoms, vital signs, routine clinical laboratory values, ED revisits within 30 days of discharge, date of ED revisits, and reason for ED revisits.

Remote monitoring data were collected by MonitorMe and were available to the researchers throughout the study period. All data were shared with our institution upon completion of the study. The following data were collected: patient vitals throughout the monitoring period, daily wellness call notes including concerns shared by the patient, daily provider call notes, and telemetry notes (ECG). Whether the patients were advised to go to the ED was also noted. Additionally, the end-of-study satisfaction survey was conducted. In addition to remote monitoring, the monitoring team collected data about patients' daily clinical symptoms, including cough, myalgia, dyspnea, and any other clinically significant symptoms.

The remote patient monitoring team used established guidelines and clinical criteria for recommending ED visits. The criteria used for hospital transfer are attached to appendix 1-. The ED revisit recommendation was a shared decision made by the patient and the RPM team.

2.5. Statistical analyses

Assuming a two sided α of 0.05 and the proportion of ED revisits in the non-monitoring group as 15%, a sample size of 150 patients per group were required for an 80% power to detect a 10% difference between the two groups. At the time of study conception, as prior data was not available regarding the utilization of RPM among COVID-19 patients, the 10% difference between the groups was based on the proposed group sizes.

All continuous variables were summarized using the following descriptive statistics: mean, standard deviation, median(25th–75th percentiles). In addition, the frequency and percentages were reported for all categorical variables. No interim analyses were performed. After assessing the normality of the data, quantitative variables were compared using Mann Whitney *U* test. A Chi-square test or Fisher's exact tests was used for the comparison of categorical outcomes. Odds ratio and 95% CIs were reported for primary and secondary outcomes. All significance tests were two-tailed, and values of $p < 0.05$ were considered statistically significant.

3. Results

During the study period, 2833 COVID-19 diagnosed patients visited the Montefiore Health System ED and were discharged home. Among these patients, 1786 were eligible for participating in the study. The study team reached out to 202 patients; of those, 150 patients were enrolled in the study, and 130 patients completed the study. Among the enrolled patients, 20 patients withdrew from the study at different time points. A detailed description of patient enrollment and reasons for early withdrawal are depicted in Fig. 2.

3.1. Baseline demographics

Baseline demographics and clinical characteristics of enrolled and control patients are depicted in Table 1. Overall, 59.1% of the patients identified as Hispanic/Latino. The RPM and control groups did not differ in age, sex, or ethnicity. Additionally, no difference was observed in the occurrence of comorbid conditions such as diabetes, asthma, COPD, allergic disorders, and cardiac disorders. However, patients in the RPM group had higher BMI scores than the non-monitoring group, with the median of 29 (25–35) and 27 (25–31) in the RPM and control group, respectively. Also, more patients were diagnosed with hypertension in the RPM group than the control group, 50.7% (76) vs. 35.8% (54) (*p*-value 0.009), respectively. Finally, D-dimer was available in a subset of patients; the D-dimer value on the day of ED visit was 0.49 (0.32–0.81) and 0.74 (0.50–1.19) *p*-value 0.017 in the RPM group and control group, respectively. Lastly, the proportion of patients with a primary care doctor on file was higher in the RPM group 90% (135), than the control group, 79.5% (120), (p-value 0.011).

In the RPM group, 71% of the patients were English speaking. The remaining patients were Spanish language speaking except for two patients who spoke Bengali (with English-speaking caregivers). During the study period, 39% (59) patients were monitored for 10 or more days. Additionally, 37% (56) patients were monitored between 7 and 9 days, and 10% of patients (15) were monitored between 3 and 6 days. Among the patients who completed the monitoring, 31% (56/130) requested not to call them from 10 pm to 7 am. Additionally, 124 patients used the proprietary patch at least once. Among the enrolled patients, 18 patients refused to use the patch for daily monitoring, and in 8 patients, technical issues prevented continuous monitoring.

3.2. ED presentation

Regarding initial ED presentation symptoms, there were no statistically significant differences between the two groups. However, more patients experienced shortness of breath, chest congestion, and diarrhea in the RPM group. In agreement with the ED symptom presentations, the lowest oxygen saturation recorded in the ED was 97 (96–99) and 98 (97–100) (*p*-value 0.023) in the RPM and control group, respectively. Detailed ED presentation of symptoms is depicted in Table 2.

3.3. Primary and secondary outcomes

The primary endpoint of the study, ED revisit during the monitoring period, was not significantly different between the two groups with 8% (12) and 9.3% (14) in the RPM and control group, respectively (OR: 0.863; 95% CI:0.413–1. 803; p- 0.695). However, among the patients who revisited the ED, 65.4% (17/26) were admitted to the hospital. Furthermore, the rate of ED visits resulting in an inpatient admission was higher in the RPM group 75% (9/12) versus 57% (8/14) in the control group, an absolute difference of 18% (95% CI: −0.17-0.47), (OR:2.25; 95% CI:0.419–12.091; p- 0.172) between the two groups. Additionally, among the admitted patients, the median length of stay (25th–75th percentile) was 7 (4.5–9.5) and 7 (1–14) days (p- value0.05) in the RPM and control group, respectively. Overall, three patients died after
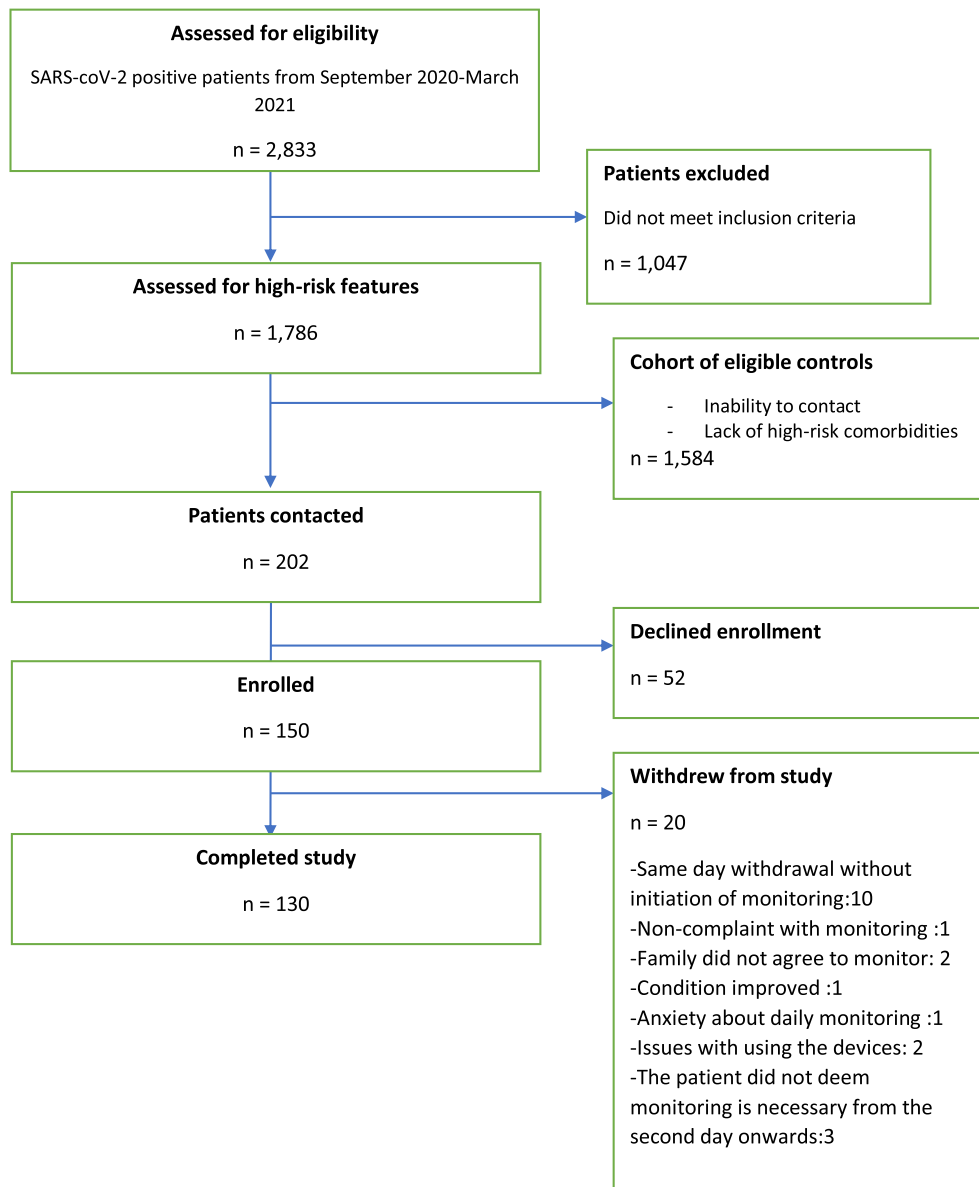
Assessed for eligibility

SARS-coV-2 positive patients from September 2020-March 2021

n = 2,833

Patients excluded

Did not meet inclusion criteria

n = 1,047

Assessed for high-risk features

n = 1,786

Cohort of eligible controls

- Inability to contact
- Lack of high-risk comorbidities

n = 1,584

Patients contacted

n = 202

Declined enrollment

n = 52

Enrolled

n = 150

Withdrew from study

n = 20

-Same day withdrawal without initiation of monitoring:10
-Non-complaint with monitoring :1
-Family did not agree to monitor: 2
-Condition improved :1
-Anxiety about daily monitoring :1
-Issues with using the devices: 2
-The patient did not deem monitoring is necessary from the second day onwards:3

Completed study

n = 130

Fig. 2. Flow diagram of patient enrollment and reasons for withdrawal.

being admitted to the hospital; two of the patients were from the control group and one from the RPM group. The one patient in the RPM group was instructed to go to the hospital immediately after initiating continuous monitoring. The patient was discharged from the ED on a Saturday morning and was reached by the study team on Monday (device delivered Monday evening). However, due to the patient's condition, the monitoring team was only able to initiate monitoring when a family member visited the patient on Tuesday morning. On monitoring initiation, the patient's saturation was 68%, prompting immediate transportation of the patient to the hospital, who then died on the 17th day of admission.

Among the patients who visited the revisited ED during the monitoring period in the RPM group, 75% (9/12) were instructed to visit the hospital by the monitoring team. Additionally, two patients visited the ED due to anxiety and COVID-19 related symptoms. One patient visited for high blood pressure. On average, patients were monitored for 5 (1–12) days before they were instructed to go to the ED. In the control group, 57% (8/14) of patients visited the ED for serious COVID-19 symptoms such as breathlessness and a pneumonia diagnosis. Additionally,

two patients were called to the ED for abnormal lab work and reporting of low saturation, two patients visited for DVT/ leg swelling, and one patient each for fatigue and chest pain. Finally, among the patients in the RPM group, 10% (16/150) of patients exhibited 90% or less oxygen saturation for two consecutive monitoring days.

3.4. Patient satisfaction survey

In the RPM group, 65% (84/130) of patients, including six patients who visited the ED, responded to the satisfaction survey. 86% of the responders rated "very satisfied" with the explanation regarding the placement of sensors. However, 6% of patients rated "very challenging" regarding the setting up of the RPM devices. (Fig. 3). Additionally,13% of the patients reported contacting the monitoring center with an issue. The most common reason for contacting the monitoring center was because one of the devices was malfunctioning.

The majority of the patients reported remote monitoring during COVID-19 provided them with a feeling of security and provided

Table 1
RPM patient and control demographics.

	All patients	RPM	Control	P value
Age (Years)	65 (53–74)	64 (58–74)	65.50 (44–73)	0.373
Sex (F)%	56.5 (170)	58.7 (88)	54.3 (82)	0.445
Race				
Ethnicity Hispanic/ Latino	59.1% (179)	58.6 (89)	59.6 (90)	0. 479
BMI	28 (25–33)	29 (25–35)	27 (25–31)	0.020
Duration of symptoms before 1st ED visit (days)	4 (2–7)	4 (2–7)	3 (2–7)	0.200
Diabetes	27.9 (84)	29.3 (44)	26.5 (40)	0.582
HTN	43.2 (130)	50.7 (76)	35.8 (54)	0.009
Asthma	19.4 (56)	22.9 (33)	15.9 (23)	0.129
COPD	4.5 (13)	6.9 (10)	2.1 (3)	0.46
Allergic Disorders	3.5 (10)	2.1 (3)	4.8 (7)	0.202
Cardiac disease	9 (26)	10.4 (15)	7.6 (11)	0.400
WBC	5.65 (4.38–7.20)	5.9 (4.7–7.4)	5.5 (4.2–7)	0.104
Hemoglobin	13.30 (12.40–14.40)	13.40 (12.30–14.30)	13.25 (12.40–14.40)	0.872
D-Dimer (55)	0.62 (0.36–0.98)	0.49 (0.32–0.81)	0.74 (0.50–1.19)	0.017
Platelet	207 (163–258)	214 (160.50–288.50)	189 (163–250.25)	0.306
ED X-ray abnormality %	45.5 (91)	41.7% (40)	49% (51)	0.296

Abbreviations: BMI, Body Mass Index; HTN, hypertension; COPD, Chronic Obstructive Pulmonary Disease; WBC White Blood Cell; ED emergency department. Continuous variables are reported as median (25th–75th percentile) and categorical variables are reported as percentage (n). * For D-dimer only values for 55 patients were available. P values were analyzed using Mann Whitney U test and Chi-square analysis.

awareness of health status during the monitoring period (Fig. 4). Patient comments to one of the open end questions echo the survey results.

"*Was very comforting to know you had someone on the other end with any concern if an issue would arise. Thank you for your services*".

Additionally, 74% percent of patients responded that remote monitoring positively influenced their daily functioning activities. However, 18% reported no influence, and 4% reported negative influence.

In recommending remote monitoring for COVID-19 patients, 99% of the patients responded that they would recommend RPM, and 92% of patients reported no disadvantage in using RPM for COVID-19 monitoring. However, 14% of patients reported contacting the hospital or monitoring center during the monitoring days. (Fig. 5). Finally, 72% of the patients reported the highest satisfaction regarding the overall RPM experience (Fig. 6). The comments made by the patients validated the positive experience of the patients.

"*Great program, easy to identify if a medical concern presents itself. Provides you with a peace of mind. Great for preventing unnecessary ER trips. It is a good idea to provide vital signs that are concerning*".

4. Discussion

This prospective study explored the impact of continuous monitoring versus intermittent institutional monitoring (control) for reducing

Table 2
ED presentation symptoms.

ED presentation	RPM	Control	P value
Cough	56% (84)	57% (87)	0.337
Shortness of breath	29.3% (44)	21.2% (32)	0.266
Sore throat	15.3% (23)	13.2% (20)	0.538
Nasal congestion	21.3% (32)	13.3% (20)	0.114
Chest pain/ tightness	22% (33)	13.9% (21)	0.187
Abdominal pain	14.7% (22)	14.6% (22)	0.608
Nausea	24% (36)	16.6% (25)	0.175
Vomiting	12% (18)	9.3% (14)	0.454
Diarrhea	19.3% (29)	13.3% (20)	0.160
Headache	32% (47)	29.9% (44)	0.705
Heart rate	92 (81–100)	86 (77–97)	0.027
Respiratory rate	18 (16–19)	18 (16–19)	0.731
SpO2	97 (96–99)	98 (97–100)	0.023

Abbreviations: bpm, beats per minute. Categorical data are presented as percentage (number) * Oxygen saturation is presented as median (25th–75th percentile) P values were analyzed using Mann Whitney *U* test and Chi-square analysis.

ED revisits following initial COVID-19 diagnosis and discharge from the ED in a largely underrepresented population of the Bronx and greater NYC area.

Our study demonstrated that continuous remote patient monitoring showed no significant difference in preventing ED revisits within fourteen days of the index hospital visit compared to non-standardized intermittent monitoring. There were also no differences in mortality, but the data points were too few to draw significant conclusions. Our results are contrary to other published studies evaluating the utilization of RPM in COVID-19 patients [2,13,14,16,17], which reported success in various capacities. However, variations in the implementation of the different remote monitoring programs and the non-standardized outcome evaluations prevent direct comparison of results from our study. Additionally, the utilization of RPM for chronic diseases has been a part of healthcare for many decades; randomized studies have reported mixed results regarding the use of RPM in several diseases [18,19].

Despite showing no significant benefits of continuous monitoring, a few baseline comorbidities need to be considered when evaluating our study results. First, patients enrolled in the RPM group had significantly higher BMI and diagnosis of hypertension compared to patients in the control group. Second, although not statistically significant, a higher rate of patients in the RPM group were diagnosed with diabetes, asthma, COPD, and cardiac disease. Finally, the initial ED symptom presentations differed in the two groups. This is potentially a significant difference since several published studies have demonstrated the negative impact of high BMI and hypertension on patient outcomes with COVID-19 [20,21]. Thus, the differences in baseline patient characteristics and ED presentations potentially point to RPM patients being relatively high-risk compared to the control group.

It is worth noting that our referral data to the ED suggest that, to an extent, continuous patient monitoring successfully identified patients who required inpatient care due to worsening COVID-19 symptoms. The higher rate of hospital readmission justifies this observation. However, as there is no direct comparison of day-to-day COVID-19 symptoms between the groups, it is challenging to evaluate the impact thoroughly. Finally, of the three patients in the RPM group who were not readmitted, all visited the ED without a referral from the monitoring team, supporting the notion that RPM could potentially be useful in the early identification of patients with deteriorating symptoms. However, additional studies evaluating RPM as a competent and effective approach toward analyzing patient health needs to be further explored.

One of the important aspects of evaluating any interventional study is to gather patient feedback. In our study, 59.1% of the patients identified as Hispanic compared to lower rates in other studies [2,14]. Health
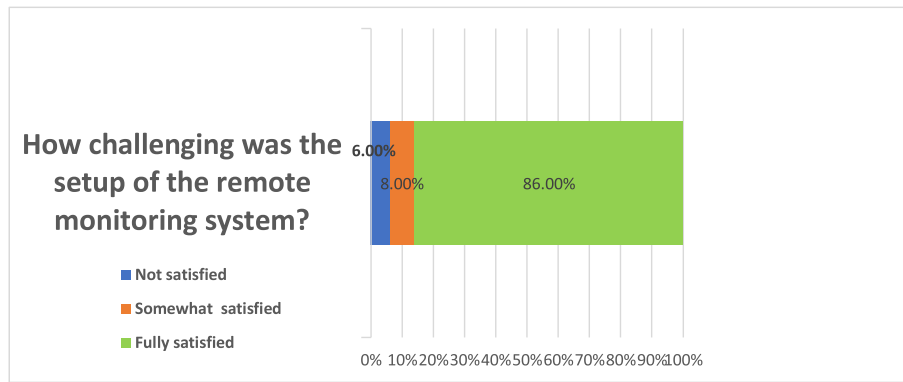
Fig. 3. Patient-reported satisfaction regarding the setting up of RPM devices.

equity has been identified as a risk of increased COVID-19 infection [22,23]. The study was successful in increasing access to health care using RPM among the traditionally underserved populations of the Bronx. Among survey responders, 90% of patients reported continuous monitoring to provide a feeling of security, and approximately 84% of patients rated the program with the highest satisfaction. These survey results should be evaluated in the context that several published studies have reported higher anxiety and stress among patients infected with COVID-19 [24,25]. Additionally, survey responses and comments written by patients reflected feelings of security, comfort, and protection from continuous monitoring during uncertain times.

An important question that needs further discussion is the utilization of continuous versus intermittent monitoring for COVID-19 similar diseases. Continuous monitoring implemented in this study required patients to wear monitoring devices throughout the day compared to intermittent monitoring, where patients are only required to wear devices when prompted. In our study cohort, one-third of patients requested a no-call policy during the nighttime. Additionally, 13% of the patients refused to wear the proprietary patch. This demonstrates the importance of patient selection when implementing RPM technologies as patient compliance and availability play a significant role in any monitoring program's outcome. If effectively implemented, the ability of continuous monitoring in the early detection of warning signs is unquestionable. However, continuous monitoring contains multiple requirements for proper implementation, such as an around-the-clock dedicated monitoring team, built-in alarm systems, specialized wearable devices, uninterrupted data streaming infrastructure, and an IT service for potential technical issues. Other requirements must also be

considered, such as prompt equipment deliveries, the willingness of patients to communicate with their care team as needed, and the high financial cost needed to fulfill these requirements. These inherent conditions make continuous monitoring more complex and potentially less practical than traditional intermittent monitoring, usually conducted with a phone call and a cross-sectional evaluation with or without specific wearable devices. In our study cohort, most of the patients in the control group were monitored intermittently by the hospital, NYC Test, and Trace Crops program; however, the monitoring protocol or the number of days monitored were not standardized [26]. Our study results indicate that, in symptomatic COVID-19 patients, continuous remote monitoring is not superior to intermittent remote monitoring.

According to published reports, 80% of patients infected with COVID-19 infections experienced mild symptoms, 20% required hospital admission, and 5% needed intensive care treatments [27,28]. Therefore, the utilization of constant monitoring is questionable in the general population, especially in relatively healthy patients with mild symptoms. Assessment of individual patient symptoms and stratification of patient acuity may be necessary to determine which type of monitoring – continuous or intermittent – would be most beneficial. Finally, as silent hypoxia is one of the critical precursors of COVID-19 related complications [29], additional studies comparing a combination of patient education and patient self-monitoring of oxygen levels with continuous and intermittent monitoring via an external care team needs to be performed.

While our study did not find continuous RPM to be more beneficial over intermittent monitoring among the COVID-19 patient population,
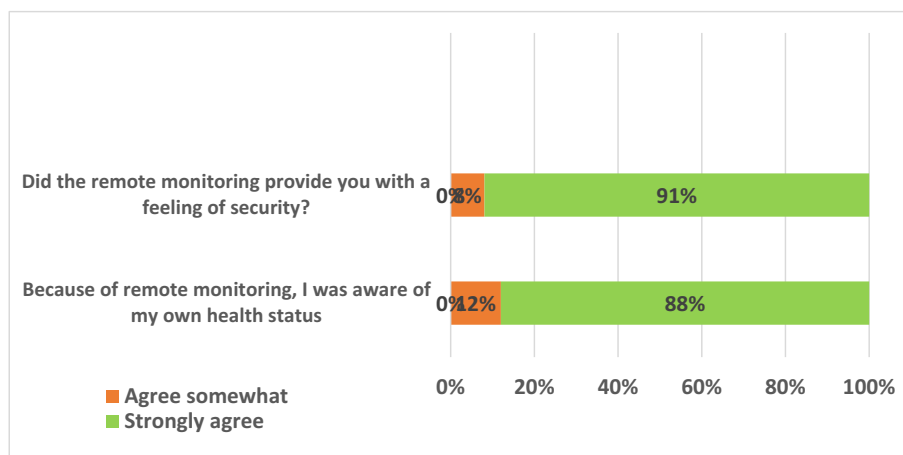

Fig. 4. Patient agreement regarding the feeling of security and awareness of health status while on RPM.
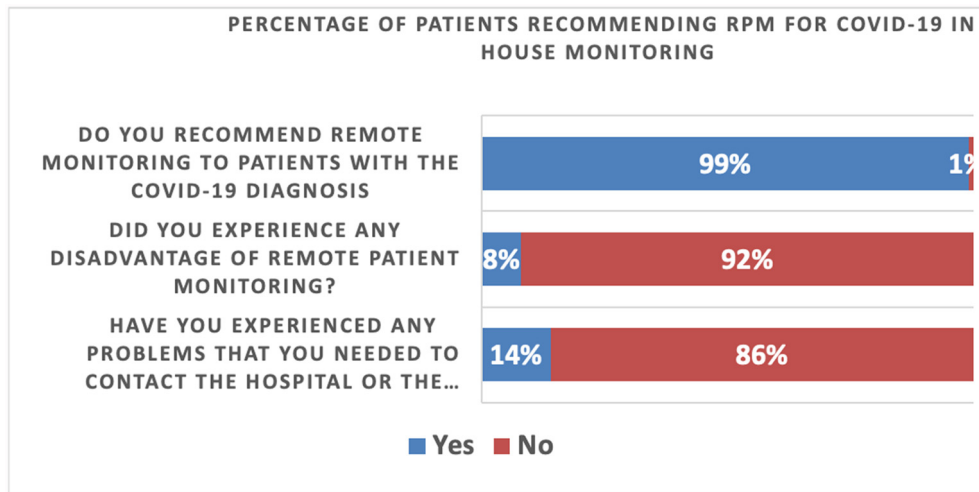
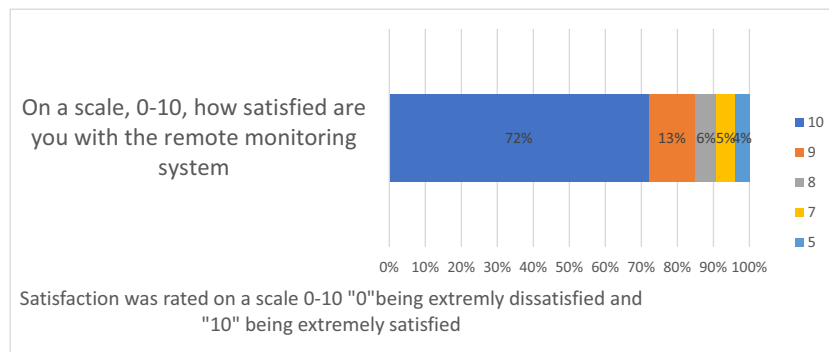**Fig. 5.** Patient experience with RPM for COVID-19.

Fig. 6. Overall patient satisfaction with RPM program.

there are potentially other acute care settings where RPM may be useful for identifying high-risk patients for early interventions. For example, high-risk surgical patients discharged home without surveillance and limited professional support is at high risk for complications. Additionally, for healthy patients who undergo complex surgical procedures, RPM may be beneficial in reducing the length of hospital stay. The concept of RPM in the surgical patient population and its utilization in the perioperative area needs to be further explored.

4.1. Limitations

There are several limitations to our study. Patient selection is one of the critical limitations of the study. Our patient enrollment was limited based on the availability of the monitoring devices. In addition, the selection of patients was determined based on the usefulness of monitoring for a specific patient rather than any random sampling from a cohort of patients. This may have contributed to potential selection bias in the intervention group. Also, the majority of the patients in the intervention cohort were in the age group >65 and above and had symptoms that required an ED visit; hence our results are not generalizable to the entire population of COVID-19 patients. Additionally, even though there is no significant difference in ED presentations between the groups, the severity of symptoms could range between different patients.

Even though the devices were delivered within two days of ED discharge, approximately 25% of patients delayed 1–2 days of communication with the monitoring center. The impact this delay may

have on the study results is unknown. None of the delayed patients required ED revisits. However, the one patient who died from the intervention group had delayed communication with the monitoring center by one day.

The multiwave pattern and the mutational abilities of coronavirus may have played a role in the study outcomes. As more seriously ill patients visited the ED during the height of the pandemic, our study results may have been different if the study were to be conducted during the surge. Additionally, the changing landscape of management and treatments administrated to patients may impact study outcomes. For example, halfway through the study, our hospital began administering antibody cocktails to selective patients. While the administration of cocktails required an additional ED visit, this extra visit during the initial days of disease onset may have reduced anxiety and built confidence in the patient toward their condition. Finally, we could not capture those patients who may have visited the EDs not affiliated with our hospital. However, as RPM patients are monitored continuously, missing ED visits could be more likely to happen in the control group.

5. Conclusion

In this single-center observational study, conducted among COVID-19 patients, continuous remote patient monitoring was no better than non-standardized intermittent monitoring in reducing ED revisits. However, patients reported that RPM monitoring created a feeling of security and awareness of health status during the quarantine period. The

cost-effectiveness of RPM and its utilization in high-risk patients warrant further studies.

Credit authorship contribution statement

Seung Mi Oh: Data curation, Investigation, Writing – original draft. **Singh Nair:** Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Alexander Casler:** Writing – original draft, Investigation. **Diana Nguyen:** Investigation, Writing – original draft. **Juan Pablo Forero:** Investigation. **Celina Joco:** Investigation, Project administration. **Jason Kubert:** Investigation. **David Esses:** Resources, Writing – review & editing, Project administration. **David Adams:** Writing – review & editing. **Sunit Jariwala:** Writing – review & editing. **Jonathan Leff:** Writing – review & editing, Supervision, Data curation, Conceptualization.

Declaration of Competing Interest

None.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2022.02.035.

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