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Impact of a Large-Scale Remote Patient Monitoring Program on Hospitalization Reduction

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Abstract

Introduction/Methods: *Patient Monitoring at Home is a Remote Patient Monitoring (RPM) program through Michigan Medicine, which provides symptoms and vital sign monitoring via a provided cellular tablet and Bluetooth-connected devices. A team of registered nurses monitors patients 7 days per week.*

Results: *The team examined 6-month outcomes for 1,139 encounters from November 2020 to August 2022, which showed a 59% reduction in the average number of hospital admissions 6 months after the start of enrollment (1.38 vs. 0.57, $p < 0.0001$) across multiple enrollment diagnoses including COVID-19, congestive heart failure, and hypertension. The duration of enrollment varied, ranging from 7 to 386 days, with a median of 38 days. A shorter duration of monitoring was associated with a more favorable outcome (hospitalization reduction).*

Discussion: *Our findings show that RPM is effective in reducing hospital admissions for a wide variety of conditions. More research is needed to optimize patient selection, ideal method, and duration of monitoring.*

Keywords: *remote patient monitoring, hospital readmission, congestive heart failure, hypertension, COVID-19, telemedicine, telehealth*

Introduction

Hospital readmissions and recurrent hospitalizations increase medical costs and capacity strain on health care systems.[1] A subset of high-cost, high-need patients, often older adults with multiple chronic conditions and complex psychosocial needs, utilizes a disproportionate fraction of hospital resources.[2] Interest is high in interventions to improve chronic disease management in this patient population and prevent hospitalization.[3,4] Especially in older, frail, or multimorbid adults, hospitalization-associated complications pose significant risk.[5] Hospital capacity strain, which is associated with increased mortality and worsened health outcomes, peaked during the COVID-19 pandemic, and continues to remain high, especially in academic medical centers.[6,7]

Remote Patient Monitoring (RPM), a form of telehealth that collects symptom and biometric data outside of the clinical setting, gained popularity during the COVID-19 pandemic as a means to offload hospital capacity strain. RPM is proposed as an intervention to help reduce hospitalization through close supervision of biometric data and early recognition of warning signs for potential decompensation. RPM has been studied in a variety of acute and chronic disease states, including COVID-19, congestive heart failure (CHF), postoperative conditions, chronic obstructive pulmonary disease (COPD), and type 2 diabetes, with mixed results in readmission-related outcomes.[8–13] The longitudinal effects on readmission, costs, and other patient outcomes are still being investigated, along with the long-term feasibility for health care systems to sustain these programs. Michigan Medicine (MM) began an RPM program in April 2020 during the COVID-19 pandemic with a goal to improve hospital capacity and bridge postdischarge care transitions.

Methods

In April 2020, MM began enrolling medically complex patients (two or more chronic health conditions) into a comprehensive RPM program known as the Patient Monitoring at Home program (PM@H). We target patients at high risk of readmission (LACE index >10) with multiple chronic conditions and at least one diagnosis amenable to vitals and symptom monitoring. The LACE index is a validated tool that predicts 30-day hospital readmission using length of stay ("L"), acuity of admission ("A"), comorbidities ("C"), and emergency department use ("E").[14] Exclusion criteria include diagnoses not amenable to monitoring, such as frequent falls, mental health conditions, and substance use disorders, and patients not residing in the community (e.g., assisted living or skilled nursing facility). As COVID-19 rates have declined, target conditions have expanded to include CHF and other cardiac conditions, liver disease, cancers, sepsis, uncontrolled hypertension, diabetes, and chronic lung disease. Referrals come from inpatient, outpatient, and postacute rehabilitation services.

Each enrolled patient is given a kit that includes a cellular tablet and a Bluetooth-enabled blood pressure cuff, heart rate monitor, pulse oximeter, weight scale, and thermometer based on their clinical needs. All vitals, measured using the kit, are transmitted instantly into a third-party website, Health Recovery Solutions (HRS), through Bluetooth technology. A team of registered nurses (Post-Acute Care Service [PACS] RNs) with home care experience are trained in program administration and monitor patients' data. The PACS RNs receive specialized training, including use of the HRS electronic medical record (EMR), patient onboarding and kit set-up, and kit deactivation. The PACS RNs coach patients on how to properly check their vitals and use the tablet to answer survey questions and review education materials. The patients can also contact the RNs directly using the tablet from 8 am to 6 pm, 7 days per week. The tablets have a cellular connection so that patients do not need to have Wi-Fi. Using Bluetooth technology ensures the vitals are recorded on the EMR instantly, without having the patients manually enter them. Patients' technology proficiency level was not recorded before enrollment. The percentage of participants who struggled with using this technology was not measured but thought to be very small due to the ease of use. The tablets are designed at the 4th grade level, and our RNs coached the patient on their use.

The PACS RNs triage dashboard alerts and intervene quickly to prevent decompensation by escalating cases to the PACS providers and coordinating care with a patient's primary care provider and specialists. The patients check vitals at least once per day and answer a daily symptoms survey relevant to the monitored condition(s). Each patient was scheduled for an initial video visit with one of our providers within 3 days of enrollment in the program and a final video visit before discharge from the program. There were also visits throughout enrollment depending on each patient's needs. Adherence to daily vital signs and survey completion between July 2021 and June 2022 was 59% and 56%, respectively. Given our ongoing effort to improve adherence through our RNs contacting patients directly, those metrics have improved to 75% and 71%, respectively, between July 2022 and June 2023. Discharge was at the discretion of the provider. Once symptoms and vitals were controlled for 4–5 days and the conditions deemed to be stable, the patient was discharged from the program. The kit was returned through parcel pick-up service at the patient's home.

The team collected data for 1,809 encounters from November 2020 through April 2023 (1,724 unique patients). Patients who were enrolled for less than a week or died within 6 months of enrollment were excluded from the study. For the outcome analysis, we only included encounters between November 2020 through August 2022 to allow for monitoring of hospitalizations in the following 6 months (1,139 encounters). The data from the initial 6 months of the program, from April 2020 through October 2020, were excluded as the program was in a pilot phase. The team compared the average number of hospital admissions for this group of patients 6 months before and after the start of enrollment. These 1,139 encounters were then categorized in subgroups based on duration of enrollment and patient diagnoses.

Results

Study population demographics are displayed in *Table 1*. The median age was 66 years, with balanced female-to-male

Table 1. Study Population Demographics, 1,724 Unique Patients from November 2020 through April 2023

	NUMBER OF PATIENTS (PERCENT)
Age	
18–45	251 (14.6)
46–64	548 (31.8)
65–84	740 (42.9)
85+	185 (10.7)
Gender	
Female	871 (50.6)
Male	851 (49.4)
Missing	2
Race	
White	1,274 (73.9)
Black	305 (17.7)
Asian	45 (2.6)
Other	100 (5.8)
Ethnicity	
Hispanic	49 (2.8)
Non-Hispanic	1,675 (97.2)
Payor	
Medicare	1,019 (59.2)
Medicaid	244 (14.2)
BCBSM	177 (10.3)
BCN	157 (9.1)
Other Commercial	102 (5.9)
Unknown/other	23 (1.3)
Missing	2

BCBSM, Blue Cross Blue Shield of Michigan; BCN, Blue Care Network.

patients (50.6% vs. 49.4%). Most enrollees were White (73%), followed by Black (17.3%) and other race (8.7%); 2.8% were Hispanic. A modest majority (56%) followed with MM primary care providers. The most common enrollment diagnoses were COVID-19 (n = 611 encounters), CHF (n = 352), and hypertension (n = 319).

Of 1,724 total patients, most patients were enrolled once during the period (n = 1,649), with a small number with two (n = 65) or three (n = 10) enrollments. The length of time in the program ranged from 7 days to 386 days, with a median of 38 days. Among the 1,139 encounters analyzed, there was a 59% relative risk reduction in the average number of hospital admissions in the 6 months following the start of enrollment (1.38 vs. 0.57, $p < 0.0001$). This effect persisted when encounters with only COVID-19 diagnosis were eliminated; for the remaining 575 encounters, there was a relative risk reduction of 49% in average hospital admission 6 months pre- and postenrollment (1.56 vs. 0.79, $p < 0.0001$). There was a reduction in the average number of hospital admissions for a wide variety of enrollment diagnoses including 75% reduction for COVID-19 (1.22 vs. 0.31, $p < 0.0001$), a 57% reduction for CHF (1.47 vs. 0.64, $p < 0.0001$), a 54% reduction for hypertension (1.55 vs. 0.71, $p < 0.0001$), and, though not statistically significant, a 12% reduction for liver cirrhosis (2.13 vs. 1.88, $p = 0.2875$). The duration of monitoring varied based on clinical needs. The monitoring duration for most encounters (n = 930) was less than 90 days, with few encounters (n = 44) lasting over 150 days. All groups experienced benefits (i.e., less hospitalizations over a 6-month period); however, the shorter durations of monitoring were associated with more favorable outcomes (see *Fig. 1*). When looking at the length of stay (LOS) for all encounters (n = 1,809) per diagnosis monitored, COVID-19 had the shortest LOS (mean 40, median 30), followed by hypertension (mean 60, median 49), and then CHF (mean 67, median 53). Cirrhosis had the longest LOS (mean 73, median 66). Among all encounters (n = 1809), the vast majority (74.2%) of referrals came from inpatient services. There were 4.3% encounters with missing referral sources.

Discussion

This longitudinal cohort study demonstrated our PM@H program to be an effective tool in reducing hospital admissions for a wide variety of conditions, with a sustained benefit after monitoring is completed. When comparing the 6 months prior to the 6 months after enrollment, PM@H reduced the average count of hospitalizations by over half. Even after eliminating encounters with only COVID-19 diagnosis, PM@H reduced hospitalization by half. This highlights the potential role of RPM programs to address frequent hospitalizations, a barrier to cost-efficient and high-quality care in medically complex patient populations. RPM allows providers to closely monitor patients in real-time in their home and detect early signs of potential decompensation with the hope of intervening to prevent hospitalization. In addition, it helps to address the "voltage drop"—the sharp decline in frequency of vitals and symptom monitoring with transition from the hospital to home. Strengths of our program include the dedicated group of PACS RNs trained to quickly recognize and triage concerns and the integration within a large academic medical center, allowing direct escalation to PACS providers and coordination with primary care providers and specialists.

Previous studies, including randomized trials, have demonstrated the efficacy of RPM in reducing readmission in a variety of conditions, including CHF, COPD, diabetes, and postoperative care.[8–13] However, a large, international systematic review of RPM for all disease conditions demonstrated mixed results, with approximately half of studies demonstrating reduced acute care (inpatient hospital and emergency department) use and half demonstrating no change.[12] Authors identified six "theories of intervention success": targeting populations at high risk, accurately detecting a decline in health, providing responsive and timely care, personalizing care, enhancing self-management, and ensuring collaborative and coordinated care.[15] While responsiveness and coordination within the larger health care system appear to be key strengths of our program, further efforts in identifying and reaching our target high-risk patient population are underway. Similar to other programs, we instituted workflows to accommodate multilingual patients, patients requiring surrogate support, and patients without home internet or technological proficiency, but these could be expanded to improve the inclusiveness of our program.[8]

A comprehensive RPM program is costly, and direct compensation from payers does not offset the cost of the program. The program cost from July 2021 through June 2022 was $1,101,476, which has increased gradually over the years. The exact net income (total revenues) was not calculated but is thought to be 10–25% of the cost. However, cost savings from the program primarily come from reducing hospitalizations. Per the Agency for Healthcare Research and Quality, a readmission within 30 days in 2020 costs 12.4% more on average than the index admission.[16] If we consider the cost of an admission to be $14,500, our return on investment is over $12,000,000 over 6 months. This estimate is based on subtracting the total cost of the admissions before enrollment in our RPM ($21,576,000 for 1,488 admissions) from the cost of the admissions after enrollment ($8,917,500 for 615 admissions), which is $12,658,500.

Overall, the outcomes are very promising for hospitals and support investing in RPM to reduce rehospitalization and health care costs. The large sample size and prolonged follow-up of this study suggest sustainable RPM benefits. The efficacy of the program in reducing hospitalizations diminished when patients were enrolled for a longer duration (*Fig. 1*). One explanation is that prolonged monitoring selects for socially and medically complex patients for whom frequency of hospitalization is less modifiable. The ideal duration of monitoring is probably 30–60 days based on our data. RPM programs are heterogeneous groups of services that vary in what they can offer. Further research is needed to elucidate when, how, and for whom RPM should be implemented to better serve patients, cut hospital costs, and reduce readmissions. Since our program had mainly enrolled posthospital discharges, further research is needed to study the efficacy of RPM in medically complex outpatient cases and patients discharged from postacute rehabilitation. For future research, we recommend collecting further data regarding patient characteristics such as frailty index, physical activity at program entry, and comorbid conditions to use in a regression model to identify patients who would benefit most from this robust RPM service.

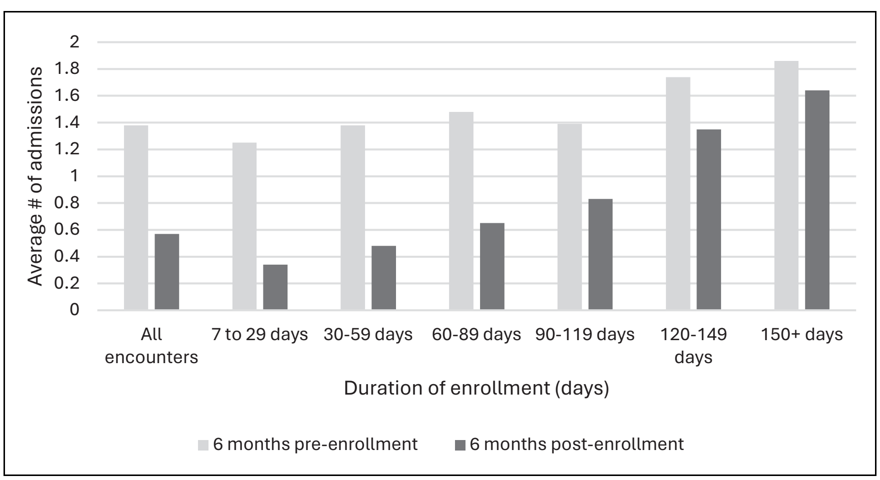

Fig. 1. Average Number of Hospital Admissions 6-months Pre- and Post-Enrollment by Duration, 1,139 encounters from November 2020 through August 2022.

Limitations

This study was performed within a single, large academic medical center, which may limit generalizability. Historically, RPM designs have varied widely in terms of target population and interventions used. Our study population underwent close monitoring 7 days per week with direct escalation to postacute care providers who assume primary responsibility for the patients while on the service. This infrastructure limits our findings to similar comprehensive RPM programs. This was a case series study without a matched control group. In addition, the large proportion of patients enrolled with COVID-19 diagnosis may limit generalizability, though the target effect persisted when these patients were excluded from the analysis. Lastly, we only looked at admissions (before and after enrollment) within our MM health system.

Authors' Contributions

S.M.: Writing—original draft, writing—review and editing, visualization, conceptualization; H.C.: Formal analysis, methodology, data curation; M.R.: Formal analysis, methodology, data curation; T.H.: Conceptualization, methodology; M.F: Formal analysis, data curation; A.P.: Writing—original draft; C.E.: Conceptualization, supervision, writing—review and editing; G.J.: Conceptualization, supervision, writing—review and editing; and G.T.: Conceptualization, supervision, writing—review and editing, project administration.

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No competing financial interests exist.

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