CARE DELIVERY ReCAP

Association of a Remote Patient Monitoring (RPM) Program With Reduced Hospitalizations in Cancer Patients With COVID-19

Joshua C. Pritchett, MD1,2; Bijan J. Borah, PhD3; Aakash P. Desai, MD, MPH1,2; Zuoer Xie, MD, MS1,2; Antoine N. Saliba, MD1,2; Konstantinos Leventakos, MD, PhD2,3; Jordan D. Coffey, MBA, MHA, MA4; Kristina K. Pearson, MS5; Leigh L. Speicher, MD, MPH5; Robert Orenstein, DO6; Abinash Virk, MD7; Ravindra Ganesh, MBBS, MD8; Jonas Paludo, MD1; Thorvardur R. Halfdanarson, MD2, and Tufi'a C. Haddad, MD2,4

QUESTION ASKED: Does an interdisciplinary remote patient monitoring (RPM) program reduce acute care resource utilization and improve clinical outcomes in cancer patients diagnosed with COVID-19?

SUMMARY ANSWER: Implementation of a COVID-19 RPM program, composed of in-home technology and a centralized virtual care team, was associated with a reduction in hospital admission rate and lower overall acute care resource utilization among cancer patients with COVID-19. Rates of hospitalization for patients managed with and without RPM were 2.8% and 13%, respectively, implying that the use of RPM was associated with a 78% relative risk reduction in hospital admission rate (95% CI, 54 to 102; \( P < .002 \)).

WHAT WE DID: The simultaneous deployment of the Mayo Clinic Cancer Center COVID-19 universal screening initiative and implementation of the Mayo Clinic COVID-19 RPM program across all sites presented a unique opportunity to conduct a comparative analysis and assess the association between RPM enrollment and risk of hospital admission through inverse propensity score weighting (IPW).

WHAT WE FOUND: Between March 18 and July 31, 2020, 224 patients with cancer were diagnosed with COVID-19, of which 187 patients (83%) were initially managed in the outpatient setting. Those managed with the RPM program were significantly less likely to experience hospitalization than those managed without RPM; furthermore, when hospitalized, RPM patients experienced a shorter length of stay and fewer prolonged hospitalizations, intensive care unit admissions, and deaths, although these trends did not reach statistical significance.

BIAS, CONFOUNDING FACTOR(S): Although this study is limited by its retrospective design, it was conducted with prospectively collected data as part of an observational study of the universal COVID-19 screening initiative for patients with cancer at our institution. The modest number of patients in the study cohort is a function of the predefined timeframe of the screening initiative. This study design aimed to minimize information and selection biases that typify retrospective analyses. Additionally, although the study was conducted at a single healthcare system, patients were enrolled and monitoring occurred at several diverse regional sites encompassing rural and urban locations throughout the United States.

REAL-LIFE IMPLICATIONS: Beyond the COVID-19 pandemic, a crisis is looming. With the continuous rise in cancer incidence and survival, as well as the soaring costs and complexities associated with cancer care, established hospital and ambulatory oncology practices will be unable to optimally support patients without a fundamental change in our models of cancer care delivery. Although initially a force of necessity, the unprecedented adoption and expansion of virtual care and telehealth services during the pandemic have offered a potential long-term solution to some of these challenges. Studies have demonstrated the effectiveness of RPM for longitudinal management of chronic conditions such as congestive heart failure; however, its value and impact in acute care and cancer populations had been unknown. This study is among the first reported evaluations of a novel RPM program to support the management of patients with cancer. We have demonstrated the feasibility, safety, and efficacy of an RPM program in cancer patients with COVID-19. Interdisciplinary RPM programs may offer oncology practices the opportunity to provide high-level, customizable care for patients with cancer at scale. Our findings support the urgent need for further implementation and evaluation of innovative RPM programs that can transform the model of cancer care delivery.

ASSOCIATED CONTENT
Data Supplement
Author affiliations and disclosures are available with the complete article at ascopubs.org/journal/op.

Accepted on May 6, 2021 and published at ascopubs.org/journal/op on June 4, 2021:
DOI https://doi.org/10.1200/OP.21.00307

CORRESPONDING AUTHOR
Tufi'a C. Haddad, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905; e-mail: haddad.tufia@mayo.edu.
Association of a Remote Patient Monitoring (RPM) Program With Reduced Hospitalizations in Cancer Patients With COVID-19

Joshua C. Pritchett, MD1,2; Bijan J. Borah, PhD3; Aakash P. Desai, MD, MPH1,2; Zhuoer Xie, MD, MS1,2; Antoine N. Saliba, MD1,2; Konstantinos Leventakos, MD, PhD2,3; Jordan D. Coffey, MBA, MHA, MA4; Kristina K. Pearson, MS5; Leigh L. Speicher, MD, MPH5; Robert Orenstein, DO6; Abinash Virk, MD7; Ravindra Ganesh, MBBS, MD8; Jonas Paludo, MD1; Thorvardur R. Halfdanarson, MD2; and Tuﬁa C. Haddad, MD2,4

PURPOSE The goal of this study was to assess the impact of an interdisciplinary remote patient monitoring (RPM) program on clinical outcomes and acute care utilization in cancer patients with COVID-19.

METHODS This is a cross-sectional analysis following a prospective observational study performed at Mayo Clinic Cancer Center. Adult patients receiving cancer-directed therapy or in recent remission on active surveillance with polymerase chain reaction–conﬁrmed SARS-CoV-2 infection between March 18 and July 31, 2020, were included. RPM was composed of in-home technology to assess symptoms and physiologic data with centralized nursing and physician oversight.

RESULTS During the study timeframe, 224 patients with cancer were diagnosed with COVID-19. Of the 187 patients (83%) initially managed in the outpatient setting, those who did not receive RPM were signiﬁcantly more likely to experience hospitalization than those receiving RPM. Following balancing of patient characteristics by inverse propensity score weighting, rates of hospitalization for RPM and non-RPM patients were 2.8% and 13%, respectively, implying that the use of RPM was associated with a 78% relative risk reduction in hospital admission rate (95% CI, 54 to 102; P = .002). Furthermore, when hospitalized, these patients experienced a shorter length of stay and fewer prolonged hospitalizations, intensive care unit admissions, and deaths, although these trends did not reach statistical signiﬁcance.

CONCLUSION The use of RPM and a centralized virtual care team was associated with a reduction in hospital admission rate and lower overall acute care resource utilization among cancer patients with COVID-19.

JCO Oncol Pract 17:e1293-e1302. © 2021 by American Society of Clinical Oncology

INTRODUCTION

The COVID-19 pandemic has presented unprecedented challenges to patients and healthcare systems worldwide.1 Studies have indicated that patients with cancer might have an increased risk of acquiring SARS-CoV-2 infection and poorer clinical outcomes following diagnosis.2-9 For this vulnerable population, cancer centers have been charged with the diﬃcult task of balancing access and continuity of care in the setting of widespread disease transmission.

Early in the pandemic, many cancer centers implemented rigorous screening initiatives in an eﬀort to reduce the risk of exacerbating COVID-19 severity by cancer-directed therapy (CDT) and to minimize exposure and spread of asymptomatic illness.10 These intensive screening programs appear to have been minimally impactful despite signiﬁcant resource utilization and logistical burden,10 and there remains a lack of evidence for additional clinical management strategies that may favorably aﬀect outcomes in cancer patients diagnosed with COVID-19.

Mayo Clinic is a multisite institution with three geographically diverse main campuses in Minnesota, Florida, and Arizona, as well as several rural, community-based practice sites throughout the aﬃliated Mayo Clinic Health System (MCHS) in Western Wisconsin, Southern Minnesota, and Northern Iowa. In March 2020, the Mayo Clinic Cancer Center (MCCC) practice committee implemented a COVID-19 universal screening initiative for patients with cancer across all Mayo Clinic sites (Xie et al).11
The declaration of the Public Health Emergency and executive shelter-in-place orders also urged US healthcare systems to develop new ways to provide medical care to ambulatory patients.1 In response, Mayo Clinic began rapidly scaling established telemedicine and virtual care services while concurrently developing new services with existing products to meet the unique needs of those with COVID-19.12-15 One such example is the Mayo Clinic interdisciplinary COVID-19 Remote Patient Monitoring (RPM) program that used the existing RPM technology products and supply chain, as well as the operational infrastructure of the Mayo Clinic Center for Connected Care. The original RPM program was designed and implemented in the MCHS practice in 2016, and subsequently expanded to all sites, to provide patients with complex chronic conditions with technology-enabled, centralized monitoring and nursing support. Leveraging this framework, an innovative COVID-19 RPM program was developed with an interdisciplinary team of Infectious Disease, Pulmonary or Critical Care, and General Internal Medicine specialists in COVID-19 diagnosis and management. The COVID-19 RPM program aimed to support ambulatory patients with COVID-19 at risk for severe illness.13 As of November 2020, this program served more than 8,000 patients across 41 US states in rural and urban locations, many of whom suffer from complex comorbidities and illnesses including active cancer (Coffey et al, under review).

Studies have previously demonstrated the effectiveness of RPM programs for the longitudinal management of chronic conditions such as congestive heart failure16,17 and diabetes.18,19 The use of RPM in patients with peritoneal dialysis has also been shown to reduce the risk of hospitalization during the COVID-19 pandemic.20 However, only a limited number of health systems nationwide have established RPM services as part of routine clinical care that meet the Centers for Medicare & Medicaid Services RPM billing code requirements.21

Evaluation of RPM technology platforms and corresponding clinical care models for patients at risk of, suspicion of, or confirmed diagnosis of COVID-19—a novel, acute illness with unpredictable disease course, variable clinical presentation, and risk for decompensation—has begun, and early results are encouraging. Ambulatory monitoring of patients with COVID-19 symptoms has been shown to be feasible, safe, and associated with high patient satisfaction.22 In a separate study, the use of RPM in patients discharging from the hospital following acute COVID-19 illness has been associated with fewer subsequent emergency department (ED) visits and readmissions.23 However, we are among the first to evaluate the use of an RPM program in the management of patients with cancer.

The simultaneous deployment of the MCCC COVID-19 universal screening initiative and implementation of the Mayo Clinic COVID-19 RPM program across all sites presented a unique opportunity to assess the impact of the RPM program on patient outcomes. Our primary objective was to compare outcomes of cancer patients with COVID-19 when managed with or without the COVID-19 RPM program. Herein, we report the impact of the COVID-19 RPM program on clinical outcomes and acute care resource utilization in cancer patients diagnosed with COVID-19.

**METHODS**

**MCCC COVID-19 Universal Screening Initiative**

From March 18 to July 31, 2020, all patients scheduled to receive CDT at a Mayo Clinic site were universally screened for COVID-19 using a nasopharyngeal SARS-CoV-2 polymerase chain reaction test at least 24-96 hours before the scheduled treatment. Modes of CDT included parenteral chemotherapy, biologic therapy including immune checkpoint inhibitors, chimeric antigen receptor T-cell therapy, hematopoietic stem-cell transplant, surgery, and radiation therapy. In addition, adults (> 18 years old) with cancer diagnosed and/or treated within the past 5 years (excluding uncomplicated nonmelanoma skin cancers) were offered SARS-CoV-2 polymerase chain reaction testing at MCCC if they self-reported symptoms or exposure. These criteria defined our cohort of cancer patients with COVID-19.

An Institutional Review Board–approved prospective observational study was developed to assess the clinical effectiveness and impact of the universal screening initiative in this cohort (Xie et al).11 Predefined clinical and lab data were collected from review of the electronic health record (EHR) of all patients who provided authorization to use EHR data for research purposes. Data were abstracted for 60 days after first positive test to allow sufficient assessment of COVID-19–associated outcomes.

**Mayo Clinic Interdisciplinary COVID-19 RPM Program**

**Program design.** The Mayo Clinic COVID-19 RPM program was designed and implemented by an interdisciplinary team composed of RPM clinical nurse specialists, physicians, patient education specialists, and COVID-19 physician experts from the Divisions of General Internal Medicine, Infectious Disease, and Pulmonary or Critical Care Medicine. Details related to this RPM program, including clinical workflow design and escalation parameters, have been described elsewhere (Coffey et al, under review).13 Briefly, once enrolled, the patient receives a technology package composed of a cellular-enabled tablet preloaded with vended clinical RPM software (Resideo Life Care Solutions, WI) and preconnected, Bluetooth-enabled devices (blood pressure cuff and monitor, pulse oximeter, thermometer, and scale) to passively collect physiologic data. For patients with cancer specifically, the tablet notifies patients to perform vital sign measurements and complete COVID-19 symptom assessments twice daily. For those who are immunosuppressed, the assessments are
conducted four times daily. Patient-generated data trigger alerts on the basis of predetermined parameters, and all data are integrated with the EHR (Epic). Key to the RPM program is the clinical care model that includes a centralized team of RPM nurse care coordinators who provide daily monitoring, education, and health coaching; complete clinical evaluations in response to alerts; use decision trees and protocols for interventions; and escalate care as necessary to the appropriate regional physician and advanced practice provider COVID-19 care teams supporting Mayo Clinic Arizona, FL, and the Midwest (Minnesota and all MCHS sites). The standard program duration is approximately 21 days with extension as needed to support recovery for patients who remain symptomatic.

**Patient enrollment.** Upon confirmation of a positive SARS-CoV-2 test at any Mayo Clinic site, patients are screened for RPM enrollment by a member of the regional COVID-19 care team. Patients were eligible for enrollment if they had one or more of the following risk factors for severe COVID-19 illness, as defined by the Centers for Disease Control and expert consensus:

- age > 65 years, diabetes, current smoker, body mass index > 40, chronic liver disease, chronic lung disease, congestive heart failure, active cancer therapy, bone marrow or solid organ transplant, other immunocompromised state, and end-stage renal disease.

Under a separate Institutional Review Board–approved protocol, we retrospectively reviewed all patients from the above MCCC COVID-19 universal screening cohort for enrollment and utilization of RPM. For this study, those included in the RPM cohort were confirmed for enrollment by documentation of the EHR order for the service and received at least one day of monitoring as confirmed by the presence of at least one digital exchange with the technology platform.

**Study End Points, Data Procurement, and Analysis**

**End points.** For the MCCC COVID-19 universal screening initiative, the clinical end points recorded included 60-day all-cause hospital admission, intensive care unit (ICU) admission, and mortality. These were determined by manual EHR review for each patient in the study. In addition to this, system-level billing and encounter data were retrospectively queried for all study patients who were initially managed in the outpatient setting to independently identify and confirm instances of acute care utilization during a 30-day period following COVID-19 diagnosis. Acute care utilization end points included ED visit, ED conversion to inpatient hospital admission, ICU admission, hospital length of stay, prolonged hospitalization (defined as ≥ 7 inpatient days), and mortality. A 30-day follow-up period was chosen for this study because the average COVID-19 RPM program duration for patients is approximately 14 days and an acute exacerbation of COVID-19 illness rarely occurs beyond 30 days from initial diagnosis (Coffey et al, under review).

**EHR review.** Manual EHR review was performed to obtain predefined clinical and demographic data for all patients enrolled in the MCCC prospective universal screening study, as outlined above and detailed elsewhere (Xie et al). EHR review also included review of any records from institutions outside the Mayo Clinic available through the Epic Care Everywhere function. Notably, this information is only available for review if a patient has authorized access to this function. Additionally, information is only made available through Care Everywhere by partnering institutions that participate in this electronic record sharing tool.

When instances of acute care utilization were identified, all instances were rigorously reviewed to confirm that care utilization was properly assigned and documented before performing detailed comparative analysis. Additionally, all instances were also reviewed and assigned on the basis of whether the instance was associated directly with COVID-19 illness.

**Comparative analysis.** The association between RPM enrollment and risk of hospital admission among 187 patients who did not initially require urgent hospitalization was assessed through inverse propensity score weighting (IPW).

The IPW method helps estimate the treatment effect between the intervention (RPM) and control (no RPM) cohorts after balancing the observed patient characteristics.

IPW balancing was based on 15 key baseline covariates that multiple studies have identified as associated with poorer COVID-19 outcomes. These include age, sex, race, ethnicity, body mass index, diabetes, hypertension, underlying cardiopulmonary disease (which we have characterized further by specific entities including coronary artery disease, chronic obstructive pulmonary disease, and/or asthma), chronic kidney disease, cancer type, active cancer status, symptomatic COVID-19 at diagnosis, and diagnosis before June 1, 2020.

The pre- and post-IPW balance in patient characteristics was assessed through standardized difference, with an absolute standardized difference < 10% in the value of variable between the intervention and control being considered as balanced. Both absolute and relative risks of hospitalization for patients receiving RPM versus non-RPM were then calculated.

**RESULTS**

Between March 18 and July 31, 2020, 224 patients with cancer were diagnosed with COVID-19 at a Mayo Clinic site. As highlighted in Figure 1, initial management included urgent hospitalization (within 48 hours of diagnosis) in 37 patients (17%), whereas the remaining 187 patients (83%) were managed in the outpatient setting with or without the
### TABLE 1. Baseline Data, All Patients

| Demographics | RPM | Non-RPM |
|--------------|-----|---------|
| Sex          |     |         |
| Male         | 67  | 61      |
| Female       | 42  | 39      |
| Age, years   |     |         |
| Median (range) | 63 (35-90) | 62 (22-89) |
| < 65         | 64  | 59      |
| ≥ 65         | 45  | 41      |
| Ethnicity    |     |         |
| Non-Hispanic or Latino | 92  | 84      |
| Hispanic or Latino | 14  | 13      |
| Unknown, not reported | 3  | 3       |
| Race and ethnicity |   |         |
| White        | 60  | 55      |
| Others with Hispanic or Latino ethnicity | 10 | 9 |
| African American | 6  | 6       |
| American Indian or Alaska Native | 1 | 1 |
| Asian        | 1  | 1       |
| Unknown, not reported | 31 | 28 |
| Region       |     |         |
| Midwest      | 51  | 47      |
| Arizona      | 42  | 39      |
| Florida      | 16  | 15      |
| Clinical characteristics |   |         |
| Underlying pulmonary disease |   |         |
| Asthma       | 10  | 9       |
| COPD         | 9   | 8       |
| Obstructive sleep apnea | 21 | 19 |
| Other pulmonary diseases | 4 | 4 |
| Use of oxygen at home | 1 | 1 |
| Underlying nonpulmonary disease |   |         |
| Hypertension | 55  | 50      |
| BMI > 30 kg/m² | 40 | 37 |
| Diabetes mellitus | 22 | 20 |
| CKD          | 18  | 17      |
| Coronary artery disease | 14 | 13 |
| Atrial fibrillation | 10 | 9 |
| Alcohol use disorder | 8 | 7 |
| Peripheral vascular disease | 3 | 3 |
| Smoking status |   |         |
| Never smoker | 63  | 58      |

(continued in next column)

| Cancer characteristics | RPM | Non-RPM |
|------------------------|-----|---------|
| Solid malignancy       | 83  | 76      |
| Genitourinary          | 29  | 27      |
| Breast                 | 16  | 15      |
| GI                     | 13  | 12      |
| Lung                   | 6   | 6       |
| Head and neck          | 5   | 5       |
| CNS                    | 3   | 3       |
| Skin                   | 3   | 3       |
| Thyroid                | 3   | 3       |
| Gynecologic            | 3   | 3       |
| Neuroendocrine         | 2   | 2       |
| Other solid malignancies | 0 | 0     |
| Hematologic malignancy | 26  | 24      |
| Dysproteinemia         | 11  | 10      |
| Lymphoma               | 10  | 9       |
| Myeloid                | 4   | 4       |
| CLL                    | 1   | 1       |
| Cancer disease or treatment status |   |         |
| Remission, no evidence of disease | 51 | 47 |
| Active disease, responding to treatment | 23 | 21 |
| Active disease, stable | 15 | 14 |
| Active disease, progressing | 12 | 11 |
| Unknown                | 5   | 5       |
| COVID-19 characteristics |   |         |
| Reason for COVID-19 testing |   |         |
| Symptomatic            | 71  | 65      |
| Routine screening      | 33  | 30      |
| Exposure to COVID-19   | 5   | 5       |
| Initial severity of COVID-19 disease |   |         |
| Mild or asymptomatic (no hospitalization required) | 74 | 68 |
| Moderate (hospitalization indicated) | 33 | 30 |
| Severe (ICU admission indicated) | 2 | 2 |
| Symptoms at onset (most common) |   |         |
| No symptoms            | 21  | 19      |
| Cough                  | 55  | 50      |

(continued on following page)
COVID-19 RPM program (71 and 116, respectively). In total, 109 patients (49%) were enrolled in the RPM program at any point during the study timeframe.

Baseline patient characteristics are provided in Table 1. There were no significant differences in age, race, or ethnicity observed with regard to RPM enrollment at MCCC during the study timeframe. More male patients were diagnosed with COVID-19, consistent with known features of the disease, although the rate of RPM enrollment did not differ significantly according to sex. Regionally, although the Arizona region accounted for the majority of COVID-19 cases (47% vs 30% and 23% in Midwest and Florida, respectively), the Midwest region demonstrated a higher rate of RPM enrollment (76% of patients enrolled in RPM vs 40% and 31% in Arizona and Florida, respectively), because of earlier deployment and availability of the RPM program at Midwest sites during the study timeframe (Data Supplement, online only). Consistent with eligibility guidelines for enrollment in the RPM program, patients receiving RPM were found to have increased rates of underlying pulmonary disease and higher rates of underlying nonpulmonary comorbidities including hypertension, obesity, diabetes, chronic kidney disease, and coronary artery disease. Although underlying cancer disease groups were similarly represented, patients enrolled in RPM predictably demonstrated a trend toward more active cancer, whereas non-RPM patients were more likely to be in remission. Finally, although the reason for initial COVID-19 testing was relatively consistent between groups, patients enrolled in RPM demonstrated higher severity of COVID-19 disease at onset as characterized by higher rates of dyspnea and hypoxia with new oxygen requirement.

Patients initially managed in the outpatient setting without RPM were more likely to have experienced inpatient hospitalization within 30 days after COVID-19 diagnosis than those enrolled in RPM, as demonstrated in Table 2. The difference in the risk of hospital admission on the basis of RPM utilization was assessed through inverse propensity score weighting (IPW). As shown in Figure 2, all patient characteristics were balanced following IPW. The estimated risk of hospital admission without RPM was 13% (95% CI, 6.9 to 18.3), whereas the estimated risk of hospital admission with RPM was 2.8% (95% CI, −0.06 to 5.7). Thus, independent of measured baseline covariates, the estimated treatment effect was −0.098 (P = .002; 95% CI, −0.160 to −0.036), implying that the RPM program was associated with an approximately 10% absolute risk reduction and 78%

### Table 1. Baseline Data, All Patients (continued)

| Condition                        | RPM | Non-RPM | RPM | Non-RPM |
|----------------------------------|-----|---------|-----|---------|
| Dyspnea                          | 39  | 36      | 18  | 16      |
| Fever                            | 35  | 32      | 35  | 30      |
| Hypoxemia with new oxygen        | 29  | 27      | 11  | 10      |
| Fatigue                          | 28  | 26      | 26  | 23      |
| Myalgia                          | 23  | 21      | 32  | 28      |
| Chills                           | 17  | 16      | 17  | 15      |
| Nausea                           | 15  | 14      | 10  | 9       |
| Diarrhea                         | 13  | 12      | 28  | 24      |
| Headache                         | 13  | 12      | 14  | 12      |
| Sore throat                       | 12  | 11      | 17  | 15      |

Abbreviations: BMI, body mass index; CKD, chronic kidney disease (defined as an estimated glomerular filtration rate < 60 mL/min); CLL, chronic lymphocytic leukemia; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; RPM, remote patient monitoring.

**FIG 1.** Initial management and disposition of cancer patients diagnosed with COVID-19 at Mayo Clinic. RPM = enrollment in the Mayo Clinic COVID-19 RPM program with centralized virtual care team support, as detailed in Methods. RPM, remote patient monitoring.

**TABLE 1.** Baseline Data, All Patients (continued)
TABLE 2. Comparative Analysis of Patients Initially Managed in the Outpatient Setting With RPM Versus No Monitoring

| Acute Care Utilization for 30 Days | RPM | Non-RPM |
|-----------------------------------|-----|---------|
| COVID-19 Diagnosis                | n = 71 | n = 116 |
| ED visit                          | 64  | 90    | 98  | 84  |
| COVID-19–related                  | 7   | 10    | 18  | 16  |
| Not related to COVID-19           | 5   | 17    |     |     |
| ED visit converted to inpatient hospitalization | 2 | 1 | | |
| Hospitalization details           |     |       |     |     |
| Median days, diagnosis to admission (range) | 7 (3-8) | 6 (3-18) |
| Median days in hospital (range)   | 3 (2-4) | 6 (1-35) |
| Prolonged hospitalization (7 or more days) | 0 | 6 | | |
| Patients requiring ICU            | 0   | 6     |     |     |
| Death at discharge                | 0   | 4     |     |     |
| Discharged to home                | 3   | 11    |     |     |
| Discharged with RPM               | 3   | 7     |     |     |
| Discharged with no monitoring     | 0   | 4     |     |     |

Abbreviations: BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease (defined as an estimated glomerular filtration rate < 60 mL/min); COPD, chronic obstructive pulmonary disease; ED, emergency department; ICU, intensive care unit; RPM, remote patient monitoring.

*No ED visits or hospitalizations for 30 days following COVID-19 diagnosis.

Symptoms of acute pulmonary disease or other symptoms directly attributed to COVID-19.

All hospitalizations during the follow-up period were found to be COVID-19–related, characterized by symptoms of acute pulmonary disease directly attributable to COVID-19 disease.

relative risk reduction in hospital admission (95% CI, 54 to 102; P = .002).

Furthermore, although ED visit rates were similar between groups (10% RPM and 16% non-RPM), conversion to hospital admission occurred less frequently for patients who were enrolled in RPM (42.9% v 83.3%). Additionally, when hospitalized, the RPM patients experienced shorter length of stay (median 3 days vs 6 days) and were also less likely to experience prolonged hospitalization (0% v 5%), ICU admission (0% v 5%), and death (0% v 3%), although these trends did not reach statistical significance.

DISCUSSION

In the setting of a global pandemic associated with inpatient bed, ventilator, and personal protective equipment shortages, the RPM program provided an effective strategy for clinical management of cancer patients with COVID-19 in the ambulatory setting while simultaneously offering an opportunity to mitigate the increased risks of exposure, transmission, and resource utilization associated with conventional care. This study represents one of the first known evaluations of an RPM program for the management of patients with cancer.

During the design of the Mayo Clinic COVID-19 RPM program, co-primary objectives were established to optimize the clinical outcomes of patients and to reduce hospital utilization attributed to COVID-19. The RPM program leaders hypothesized that early detection of adverse trends in patient generated health data and early supportive care interventions could favorably alter the disease trajectory for vulnerable patient populations. However, it was unknown how the program would affect acute care utilization.

Within our study population of cancer patients with COVID-19, those managed through the RPM program during the study timeframe, despite being more symptomatic of COVID-19 and having more risk factors for severe illness, experienced better clinical outcomes and lower overall acute care resource utilization than patients not enrolled in the program.

It is worth noting that patients in this study could be enrolled in the RPM program either in the outpatient setting immediately following COVID-19 diagnosis or upon hospital discharge following acute COVID-19 illness. Given that patients with COVID-19 are on different trajectories with the disease at initial diagnosis (acute phase) and following hospital discharge (recovery phase), the value proposition for RPM and patient care goals were distinct for each setting. As such, we elected to focus our RPM program analysis on the majority of patients who were initially managed with RPM in the ambulatory setting upon diagnosis, with the aim of determining whether early detection of patient decompensation was associated with improved outcomes.

Even within the constraints of this focused analysis, a significant reduction in hospital admission rate directly attributable to RPM enrollment was observed in patients who were initially monitored in the outpatient setting. Although ED visits occurred at a relatively comparable rate among patients, fewer of those enrolled in RPM were subsequently admitted. Importantly, when hospitalized, the RPM patients experienced a shorter duration of stay and fewer prolonged hospitalizations, ICU admissions, and deaths, although further research is needed to confirm these trends.

Limitations of this study include retrospective design, modest number of patients, and single healthcare system; however, patients and monitoring occurred at several diverse regional sites encompassing rural and urban locations. Additionally, although every effort was made to capture and confirm instances of acute care utilization experienced by the patients in this study throughout the
follow-up period, we acknowledge the inherent limitations of such data elements, which include the possibility of study patients being evaluated at outside institutions that may not be visible or accessible through the Mayo Clinic EHR.

In conclusion, the use of a novel RPM program and centralized virtual care team was associated with a significant reduction in hospital admission rate and lower overall acute care resource utilization among cancer patients with COVID-19. Throughout the COVID-19 pandemic, innovative methods of care delivery have proved to be essential to ensure ongoing care for many of our most vulnerable populations. The success of this RPM program was made possible only through commitment to a team-based, interprofessional, and multidisciplinary collaboration across our health system.

Our findings affirm the emerging evidence regarding the feasibility, safety, and effectiveness of an RPM program to support the management of acute conditions, such as COVID-19. Additionally, this is among the first reported evaluations of an RPM program for the management of patients with cancer. Future directions include the need for pragmatic trials to further evaluate the impact and value of RPM for the management of other acute and chronic conditions and in postacute or postoperative settings. Additional studies are needed to validate the safety of escalating care in the home with low-risk diagnostic and treatment interventions that can complement the monitoring and further drive down acute care utilization.

**AFFILIATIONS**
1Division of Hematology, Mayo Clinic, Rochester, MN
2Division of Medical Oncology, Mayo Clinic, Rochester, MN
3Kern Center for the Science of Healthcare Delivery, Mayo Clinic, Rochester, MN
4Center for Connected Care, Mayo Clinic, Rochester, MN
5Division of General Internal Medicine, Mayo Clinic, Jacksonville, FL
6Division of Infectious Diseases, Mayo Clinic, Phoenix, AZ
7Division of Infectious Diseases, Mayo Clinic, Rochester, MN
8Division of General Internal Medicine, Mayo Clinic, Rochester, MN

**CORRESPONDING AUTHOR**
Tufia C. Haddad, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905; e-mail: haddad.tufia@mayo.edu.

**PRIOR PRESENTATION**
Presented in part at the ASCO21 Virtual Scientific Program, Chicago, IL, June 4-8, 2021.

**SUPPORT**
There are no direct funding sources associated with this research study. The Mayo Clinic Remote Patient Monitoring program is an enterprise shared service supported by the Mayo Clinic practice.

**AUTHORS’ DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST**
Disclosures provided by the authors are available with this article at DOI https://doi.org/10.1200/OP.21.00307.
AUTHOR CONTRIBUTIONS
Conception and design: Joshua C. Pritchett, Bijan J. Borah, Aakash P. Desai, Antoine N. Saliba, Jordan D. Coffey, Abinash Virk, Tufia C. Haddad
Administrative support: Tufia C. Haddad
Collection and assembly of data: Joshua C. Pritchett, Zhuoer Xie, Antoine N. Saliba, Jordan D. Coffey, Robert Orenstein, Thorvardur R. Halfdanarson
Data analysis and interpretation: Joshua C. Pritchett, Bijan J. Borah, Aakash P. Desai, Zhuoer Xie, Antoine N. Saliba, Konstantinos Leventakos, Kristina K. Pearson, Abinash Virk, Ravindra Ganesh, Jonas Paludo, Thorvardur R. Halfdanarson, Tufia C. Haddad
Manuscript writing: All authors
Final approval of manuscript: All authors

ACCOUNTABLE FOR ALL ASPECTS OF THE WORK: All authors

REFERENCES
1. Helmy YA, Fawzy M, Elasawad A, et al: The COVID-19 pandemic: A comprehensive review of taxonomy, genetics, epidemiology, diagnosis, treatment, and control. J Clin Med 9:1225, 2020
2. Liang W, Guan W, Chen R, et al: Cancer patients in SARS-CoV-2 infection: A nationwide analysis in China. Lancet Oncol 21:335-337, 2020
3. Miyashita H, Mikami T, Chopra N, et al: Do patients with cancer have a poorer prognosis of COVID-19? An experience in New York City. Ann Oncol 31: 1088-1089, 2020
4. Kuderer NM, Choueiri TK, Shah DP, et al: Clinical impact of COVID-19 on patients with cancer (CCC19): A cohort study. Lancet 395:1907-1918, 2020
5. Jee J, Foote MB, Lumish M, et al: Chemotherapy and COVID-19 outcomes in patients with cancer. J Clin Oncol 38:3538-3546, 2020
6. Brar G, Pinheiro LC, Shusterman M, et al: COVID-19 severity and outcomes in patients with cancer: A matched cohort study. J Clin Oncol 38:3914-3924, 2020
7. Desai A, Gupta R, Advari S, et al: Mortality in hospitalized patients with cancer and coronavirus disease 2019: A systematic review and meta-analysis of cohort studies. Cancer 127:1459-1468, 2021
8. Grivas P, Khaki AR, Wise-Draper TM, et al: Association of clinical factors and recent anti-cancer therapy with COVID-19 severity among patients with cancer: A report from the COVID-19 and cancer consortium. Ann Oncol 10.1016/j.annonc.2021.02.024 [epub ahead of print on March 19, 2021]
9. Williamson EJ, Walker AJ, Bhaskaran K, et al: Factors associated with COVID-19-related death using OpenSAFEELY. Nature 584:430-436, 2020
10. Shah MA, Mayer S, Emlen F, et al: Clinical screening for COVID-19 in asymptomatic patients with cancer. JAMA Netw Open 3:e2023121, 2020
11. Xie Z, Saliba AN, Abeykoon J, et al: Outcomes of COVID-19 in patients with cancer: Results of a prospective observational comparison of routine screening strategy versus testing based on clinical suspicion. JCO Oncol Pract 17:e1382-e1393, 2021
12. Temesgen ZM, DeSimone DC, Mahmood M, et al: Health care after the COVID-19 pandemic and the influence of telemedicine. Mayo Clin Proc 95:S66-S68, 2020
13. Haddad TC, Blegen RN, Prigge JE, et al: A scalable framework for telehealth: The Mayo Clinic Center for connected care response to the COVID-19 pandemic. Telemed Rep 2:78-87, 2021
14. Ganesh R, Salonen BR, Bhuiyan MN, et al: Managing patients in the COVID-19 pandemic: A virtual multidisciplinary approach. Mayo Clin Proc Innov Qual Outcomes 5:118-126, 2020
15. Russi CS, Heaton HA, Demaerschalk BM: Emergency medicine telehealth for COVID-19: Minimize front-line provider exposure and conserve personal protective equipment. Mayo Clin Proc 95:2065-2068, 2020
16. Bashi N, Karunanthi M, Fateh F, et al: Remote monitoring of patients with heart failure: An overview of systematic reviews. J Med Internet Res 19:e18, 2017
17. Iqbal FM, Lam K, Joshi M, et al: Clinical outcomes of digital sensor alerting systems in remote monitoring: A systematic review and meta-analysis. NPJ Digit Med 4:7, 2021
18. Su D, Michaud TL, Estabrooks P, et al: Diabetes management through remote patient monitoring: The importance of patient activation and engagement with the technology. Telemed J E Health 25:652-659, 2019
19. Michaud TL, Shahpush M, Estabrooks P, et al: Association between weight loss and glycemic outcomes: A post hoc analysis of a remote patient monitoring program for diabetes management. Telemed J E Health 26:621-628, 2020
20. Scarpioni R, Manini A, Chiappini P: Remote patient monitoring in peritoneal dialysis helps reduce risk of hospitalization during Covid-19 pandemic. J Nephrol 33:1123-1124, 2020
21. Medicare Services: Summary of Policies in the Calendar Year (CY) 2020 Medicare Physician Fee Schedule (MPFS) Public Health Emergency (PHE) Interim Final Rules, MLN Matters: MM11805 Related CR 11805. https://www.cms.gov/files/document/mm11805.pdf
22. Annis T, Pleasants S, Hultman G, et al: Rapid implementation of a COVID-19 remote patient monitoring program. J Am Med Inform Assoc 27:1326-1330, 2020
23. Gordon WJ, Henderson D, DeSharone A, et al: Remote patient monitoring program for hospital discharged COVID-19 patients. Appl Clin Inform 11:792-801, 2020
24. Centers for Disease Control and Prevention: People With Certain Medical Conditions, in Prevention: COVID-19. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html
25. Lauer SA, Grantz KH, Bi Q, et al: The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: Estimation and application. Ann Intern Med 172:577-582, 2020
26. Wiersinga WJ, Rhodes A, Cheng AC, et al: Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): A review. JAMA 324:782-793, 2020
27. Austin PC, Stuart EA: Moving towards best practice when using inverse probability of treatment weighting (IPTW) using the propensity score to estimate causal treatment effects in observational studies. Stat Med 34:3661-3679, 2015
28. Goodman KE, Magder LS, Baghdadi JD, et al: Impact of sex and metabolic comorbidities on COVID-19 mortality risk across age groups: 66,646 inpatients across 613 U.S. hospitals. Clin Infect Dis 10.1093/cid/ciaa1787 [epub ahead of print on December 18, 2020]
29. Yanez ND, Weiss NS, Romand JA, et al: COVID-19 mortality risk for older men and women. BMC Public Health 20:1742, 2020
30. Garg S, Kim L, Whitaker M, et al: Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019—COVID-19, 14 states, March 1-30, 2020. MMWR Morb Mortal Wkly Rep 69:458-464, 2020
31. Centers for Disease Control and Prevention: Risk for COVID-19 Infection, Hospitalization, and Death by Race/Ethnicity. https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html
32. Escobar GJ, Adams AS, Liu V, et al: Racial disparities in COVID-19 testing and outcomes: Retrospective cohort study in an integrated health system. Ann Intern Med 174:786-793, 2021
33. Sze S, Pan D, Nevill CR, et al: Ethnicity and clinical outcomes in COVID-19: A systematic review and meta-analysis. E Clinical Medicine 29:100630, 2020
34. Yates T, Razieh C, Zaccardi F, et al: Obesity, walking pace and risk of severe COVID-19 and mortality: Analysis of UK Biobank. Int J Obes (Lond) 45:1155-1159, 2021
35. Barron E, Bakhai C, Kar P, et al: Associations of type 1 and type 2 diabetes with COVID-19-related mortality in England: A whole-population study. Lancet Diabetes Endocrinol 8:813-822, 2020
36. de Almeida-Pititto B, Dualib PM, Zajdenverg L, et al: Severity and mortality of COVID 19 in patients with diabetes, hypertension and cardiovascular disease: A meta-analysis. Diabetol Metab Syndr 12:75, 2020
37. Mehra MR, Desai SS, Kuy S, et al: Cardiovascular disease, drug therapy, and mortality in Covid-19. N Engl J Med 382:e102, 2020
38. Schultz A, Walker AJ, MacKenna B, et al: Risk of COVID-19-related death among patients with chronic obstructive pulmonary disease or asthma prescribed inhaled corticosteroids: An observational cohort study using the OpenSAFELY platform. Lancet Respir Med 8:1106-1120, 2020
39. Alqahtani JS, Oyelade T, Aldhahir AM, et al: Prevalence, severity and mortality associated with COPD and smoking in patients with COVID-19: A rapid systematic review and meta-analysis. PLoS One 15:e0233147, 2020
40. Lee SC, Son KJ, Han CH, et al: Impact of comorbid asthma on severity of coronavirus disease (COVID-19). Sci Rep 10:21805, 2020
41. Cai R, Zhang J, Zhu Y, et al: Mortality in chronic kidney disease patients with COVID-19: A systematic review and meta-analysis. Int Urol Nephrol 50:e13362, 2021
42. Pakhchanian H, Raiker R, Mukherjee A, et al: Outcomes of COVID-19 in CKD patients: A multicenter electronic medical record cohort study. Clin J Am Soc Nephrol 16:785-786, 2021
43. Zhou F, Yu T, Du R, et al: Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. Lancet 395:1054-1062, 2020
44. Wynants L, Van Calster B, Collins GS, et al: Prediction models for diagnosis and prognosis of covid-19 infection: Systematic review and critical appraisal. BMJ 369:m1328, 2020
45. Huang H, Cai S, Li Y, et al: Prognostic factors for COVID-19 pneumonia progression to severe symptoms based on earlier clinical features: A retrospective analysis. Front Med (Lausanne) 7:557453, 2020
46. Horwitz LJ, Jones SA, Cerfolio RJ, et al: Trends in COVID-19 risk-adjusted mortality rates. J Hosp Med 16:90-92, 2021
47. Asch DA, Shelsis NE, Islam MN, et al: Variation in US hospital mortality rates for patients admitted with COVID-19 during the first 6 months of the pandemic. JAMA Intern Med 181:471-478, 2020
48. Austin PC: The performance of different propensity-score methods for estimating differences in proportions (risk differences or absolute risk reductions) in observational studies. Stat Med 29:2137-2148, 2010
49. Austin PC: The performance of different propensity-score methods for estimating relative risks. J Clin Epidemiol 61:537-545, 2008
50. Smith MJ, Maringe C, Rachet B, et al: Tutorial: Introduction to Computational Causal Inference Using Reproducible Stata, R and Python Code. arXiv: 2012.09920, 17 Dec 2020. https://arxiv.org/abs/2012.09920
AUTHORS’ DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Association of a Remote Patient Monitoring (RPM) Program With Reduced Hospitalizations in Cancer Patients With COVID-19

The following represents disclosure information provided by the authors of this manuscript. All relationships are considered compensated unless otherwise noted. Relationships are self-held unless noted. I = Immediate Family Member, Inst = My Institution. Relationships may not relate to the subject matter of this manuscript. For more information about ASCO’s conflict of interest policy, please refer to www.asco.org/rwc or ascopubs.org/op/authors/author-center.

Open Payments is a public database containing information reported by companies about payments made to US-licensed physicians (Open Payments).

Joshua C. Pritchett
Patents, Royalties, Other Intellectual Property: Novel discovery with intellectual property interests in ongoing development with Mayo Clinic Ventures, patent pending, US Patent Application No. 63/109625
Uncompensated Relationships: Biofourmis

Konstantinos Leventakos
Consulting or Advisory Role: AstraZeneca, Boehringer Ingelheim, Targeted Oncology, OncLive, Takeda
Research Funding: AstraZeneca, Mirati Therapeutics

Robert Orenstein
Speakers’ Bureau: Ferring
Research Funding: ReBiotox, Astellas Scientific and Medical Affairs Inc, Finch Therapeutics, Humanigen, Vedanta

Ravindra Ganesh
Stock and Other Ownership Interests: Pfizer
Research Funding: InteraXon, Pear Therapeutics

Jonas Paludo
Research Funding: Verily
Other Relationship: Jazz Pharmaceuticals

Thorvardur R. Halfdanarson
Consulting or Advisory Role: Lexicon, Ipsen, Advanced Accelerator Applications, Curium Pharma, ScioScientific, Terumo
Research Funding: Ipsen, Agios, Thermo Fisher Scientific, Basilea, Turnstone Bio, Advanced Accelerator Applications, Novartis

Tufia C. Haddad
Research Funding: Takeda

No other potential conflicts of interest were reported.

© 2021 by American Society of Clinical Oncology