

Comparative Effectiveness of an Automated Text Messaging Service for Monitoring COVID-19 at Home

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Background: Although most patients with SARS-CoV-2 infection can be safely managed at home, the need for hospitalization can arise suddenly.

Objective: To determine whether enrollment in an automated remote monitoring service for community-dwelling adults with COVID-19 at home ("COVID Watch") was associated with improved mortality.

Design: Retrospective cohort analysis.

Setting: Mid-Atlantic academic health system in the United States.

Participants: Outpatients who tested positive for SARS-CoV-2 between 23 March and 30 November 2020.

Intervention: The COVID Watch service consists of twice-daily, automated text message check-ins with an option to report worsening symptoms at any time. All escalations were managed 24 hours a day, 7 days a week by dedicated telemedicine clinicians.

Measurements: Thirty- and 60-day outcomes of patients enrolled in COVID Watch were compared with those of patients who were eligible to enroll but received usual care. The primary outcome was death at 30 days. Secondary outcomes included emergency department (ED) visits and hospitalizations. Treatment effects

were estimated with propensity score-weighted risk adjustment models.

Results: A total of 3488 patients enrolled in COVID Watch and 4377 usual care control participants were compared with propensity score weighted models. At 30 days, COVID Watch patients had an odds ratio for death of 0.32 (95% CI, 0.12 to 0.72), with 1.8 fewer deaths per 1000 patients (CI, 0.5 to 3.1) ($P = 0.005$); at 60 days, the difference was 2.5 fewer deaths per 1000 patients (CI, 0.9 to 4.0) ($P = 0.002$). Patients in COVID Watch had more telemedicine encounters, ED visits, and hospitalizations and presented to the ED sooner (mean, 1.9 days sooner [CI, 0.9 to 2.9 days]; all $P < 0.001$).

Limitation: Observational study with the potential for unobserved confounding.

Conclusion: Enrollment of outpatients with COVID-19 in an automated remote monitoring service was associated with reduced mortality, potentially explained by more frequent telemedicine encounters and more frequent and earlier presentation to the ED.

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As of 24 August 2021, the United States is experiencing its fourth surge of SARS-CoV-2 (COVID-19) cases, averaging more than 153 000 cases per day, with several regions experiencing severe hospital-capacity strain (1). Nearly 90% of patients with COVID-19 are asked to self-isolate and monitor their symptoms at home (2-5). Remote outpatient monitoring of patients with COVID-19 has been needed because patients with SARS-CoV-2 infection can decline rapidly and unpredictably, and because of their own limited capacity to manage acute symptoms and concerns about staff safety, office-based outpatient practices often redirect patients with confirmed or suspected COVID-19 to hospitals. As a result, emergency departments (EDs) and hospitals have been overwhelmed during surge periods of high community incidence rates and prevalence (6, 7). However, patients with COVID-19 whose symptoms are worsening at home may delay or face delays in seeking care (8-10). Remote monitoring has the potential to facilitate ED- and hospital-level care for patients who require it while supporting access to care for patients who can safely remain at home (11-13).

Toward those goals, the University of Pennsylvania Health System (Penn Medicine) developed COVID Watch, an automated text message-based, remote monitoring program with 24/7 clinical support (12). This study compares outcomes for patients enrolled in COVID Watch with those of patients who were eligible to enroll but received usual care, with the hypothesis that enrollment in COVID Watch was associated with reduced mortality.

See also:

Editorial comment

Web-Only

Supplement

METHODS

This is a retrospective cohort study that follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline for reporting observational studies. It was approved by the Institutional Review Board at the University of Pennsylvania.

Setting

Penn Medicine is an academic health system serving large portions of southeast Pennsylvania, New Jersey, and Delaware, with 6 hospitals and hundreds of outpatient practices.

Community-dwelling adults (aged >18 years) with presumed or confirmed COVID-19 could be enrolled in COVID Watch through an electronic health record order. The health care worker entering the electronic order did not have to be a physician and could include nurses, social workers, and care coordinators involved in the patient's care in the health system. Enrollment often occurred during or after a provider had a conversation with a patient. Patients were not required to have established care with a Penn Medicine provider, having only received COVID-19 testing at Penn Medicine, for example. The design of COVID Watch is detailed elsewhere (12) and in **Supplement Figures 1 and 2** (available at [Annals.org](https://annals.org)). The first patient was enrolled on 23 March 2020.

The enrollment order results in an instantaneous text message sent to the patient introducing them to the program. Once enrolled and the patient texts back confirming they want to engage with the program, they begin receiving twice-daily automated text message check-ins asking the following question: "How are you feeling compared to 12 hours ago: better, same, or worse?" Patients replying "worse" receive a follow-up question: "Is it harder than usual for you to breathe: yes or no?" For patients who respond "yes," an alert is generated for a telemedicine clinician to contact the patient by telephone within 1 hour. Outside of the twice-daily check-ins, patients were instructed to text "worse" to trigger a clinician call back. During the daytime, nurses were the primary responders, with support from nurse practitioners and physicians. At night, escalations were directly relayed to on-call nurse practitioners and physicians.

The clinical team for COVID Watch received regular training and guidelines for managing patients with COVID-19. After an escalation, clinicians could provide reassurance, advise how best to manage symptoms at home, prescribe medications, or redirect patients to the ED. The program continued for 14 days from enrollment, at which point patients were offered the option to remain enrolled for 7 more days. A Spanish-language version of COVID Watch was made available on 18 May 2020.

Data Sources and Study Sample

We included all community-dwelling adults who tested positive for SARS-CoV-2 at Penn Medicine as outpatients between 23 March (the start of COVID Watch) and 30 November 2020 and determined if they were enrolled in COVID Watch versus usual care. We excluded patients who did not meet eligibility criteria for COVID Watch: those who were younger than 18 years, were actively enrolled in home

health services or hospice, or were currently in long-term care (for example, skilled-nursing facility, long-term acute care, or acute rehabilitation). To further reduce the potential for bias, we excluded those who were tested in a location where COVID Watch enrollment had not yet begun, were previously in long-term care or hospice, or had a documented do not resuscitate or do not intubate code status before COVID-19 test collection. If patients had multiple positive test results for COVID-19, the first test with a positive result was chosen as the index test. We excluded patients enrolled in COVID Watch more than 7 days before or after the date of their index COVID-19 test collection to avoid attribution of outcomes to COVID Watch enrollment for other episodes of care (for example, repeated COVID-19 testing).

We derived patient-level sociodemographic and clinical characteristics from Penn Medicine's electronic health record. We derived patient death data, clinical encounter details (ED visits, hospitalizations, outpatient office visits, and telemedicine), and documented details (for example, encounter dates and in-hospital vs. out-of-hospital mortality) from Penn Medicine's electronic record and a regional health information exchange containing data from 53 surrounding hospitals in Pennsylvania, New Jersey, and Delaware (14).

Outcomes

Outcomes were ascertained within 30 days of the date of COVID-19 test collection. We used an intention-to-treat approach in which any patient enrolled in COVID Watch was included in the COVID Watch group even if they did not respond to any text messages. The primary outcome was any-site mortality. We separately analyzed deaths that occurred in hospital or out of hospital. Secondary outcomes included rates of total ED encounters (including discharges and hospitalizations), hospitalizations (inpatient admissions and observation), and outpatient encounters (in-person office visits and telemedicine, including video or telephone visits). We tabulated a composite outcome of days alive and out of the hospital, which factors in death and the ability to remain out of the hospital by accounting for ED visits and, if hospitalized, the length of stay (15-18). As a secondary analysis, we extended the follow-up window to 60 days for mortality and health care use measures.

Among patients who required acute care, we tabulated the time from the collection of the positive result to ED presentation, the ED vital signs, the length of stay if hospitalized, and whether the patient needed intubation and mechanical ventilation. Finally, we tabulated process outcomes among those enrolled in COVID Watch, including how many text message check-ins they responded to, the proportion who triggered an escalation to the on-call nurse, and the triage recommendations of the on-call nurse.

Covariates

We collected patients' COVID-19 test data, age, sex, race/ethnicity, primary insurance, county of residence, and household income derived from ZIP code median values. We included comorbidities known to be associated with severe COVID-19 illness or treatment adherence (19-24). We captured whether patients had a listed primary care provider and baseline health care use,

Table 1. Unadjusted Baseline Characteristics

Characteristic	Overall (n = 7865)	COVID Watch Group (n = 3488)	Usual Care Group (n = 4377)	Standardized Mean Difference*
Mean age (SD), y	43.4 (15.7)	43.5 (14.8)	43.3 (16.4)	0.013
Age group, n (%)				
<40 y	3656 (46.5)	1585 (45.4)	2071 (47.3)	0.038
40-49 y	1472 (18.7)	687 (19.7)	785 (17.9)	0.045
50-59 y	1353 (17.2)	611 (17.5)	742 (17.0)	0.015
60-69 y	945 (12.0)	439 (12.6)	506 (11.6)	0.031
≥70 y	439 (5.6)	166 (4.8)	273 (6.2)	0.065
Male, n (%)	3157 (40.1)	1295 (37.1)	1862 (42.5)	0.111
Race/ethnicity, n (%)				0.362
Hispanic	697 (8.9)	298 (8.5)	399 (9.1)	
Non-Hispanic Black	3076 (39.1)	1671 (47.9)	1405 (32.1)	
Non-Hispanic White	2989 (38.0)	1026 (29.4)	1963 (44.8)	
Other/unknown	1103 (14.0)	493 (14.1)	610 (13.9)	
Insurance coverage, n (%)				0.082
Blue Cross Blue Shield, commercial, or managed care	5201 (66.1)	2279 (65.3)	2922(66.8)	
Medicaid or managed Medicaid	818 (10.4)	398 (11.4)	420 (9.6)	
Medicare or managed Medicare	1365 (17.4)	623 (17.9)	742 (17.0)	
Other	481 (6.1)	188 (5.4)	293 (6.7)	
Source of primary care, n (%)				0.118
Non-Penn Medicine primary care	2450 (31.2)	990 (28.4)	1460 (33.4)	
Penn Medicine primary care	3354 (42.6)	1510 (43.3)	1844 (42.1)	
No primary care provider	2061 (26.2)	988 (28.3)	1073 (24.5)	
Mean body mass index (SD), kg/m²	31.4 (67.38)	33.6 (10.87)	29.7 (7.21)	0.054
Preexisting conditions, n (%)				
Hypertension	1619 (20.6)	800 (22.9)	819 (18.7)	0.104
Diabetes	679 (8.6)	383 (11.0)	296 (6.8)	0.149
Hyperlipidemia	1308 (16.6)	599 (17.2)	709 (16.2)	0.026
Chronic heart failure	79 (1.0)	44 (1.3)	35 (0.8)	0.046
Atrial fibrillation	154 (2.0)	54 (1.5)	100 (2.3)	0.054
Chronic obstructive pulmonary disease	83 (1.1)	41 (1.2)	42 (1.0)	0.021
Asthma	680 (8.6)	363 (10.4)	317 (7.2)	0.112
Chronic kidney disease	171 (2.2)	86 (2.5)	85 (1.9)	0.036
Cancer	447 (5.7)	201 (5.8)	246 (5.6)	0.006
Venous thromboembolism	108 (1.4)	59 (1.7)	49 (1.1)	0.049
Received a transplant	36 (0.5)	21 (0.6)	15 (0.3)	0.038
Dementia	14 (0.2)	5 (0.1)	9 (0.2)	0.015
Substance use diagnosis	45 (0.6)	11 (0.3)	34 (0.8)	0.063
State of residence, n (%)				0.138
New Jersey	803 (10.2)	276 (7.9)	527 (12.0)	
Pennsylvania	6952 (88.4)	3160 (90.6)	3792 (86.6)	
Other	110 (1.4)	52 (1.5)	58 (1.3)	
Median household income of home ZIP code (SD), \$	56 583 (29 767)	51 491 (27 389)	60 638 (30 943)	0.313
Mean hospital and office visits per patient 1 y before COVID-19 testing (SD), n				
ED visit	0.14 (0.52)	0.17 (0.57)	0.12 (0.48)	0.098
Admission—observation	0.01 (0.13)	0.02 (0.16)	0.01 (0.11)	0.054
Admission—inpatient	0.05 (0.27)	0.05 (0.30)	0.04 (0.24)	0.034
Office visit	2.15 (3.51)	2.37 (3.74)	1.98 (3.30)	0.109
Prior discharge to home health and no longer receiving home health, n (%)	127 (1.6)	65 (1.9)	62 (1.4)	0.035
Mean time between COVID-19 test and result (SD), d	1.4 (2.0)	1.4 (1.6)	1.4 (2.2)	0.019
Month of index positive test, n (%)				0.421
March	625 (7.9)	294 (8.4)	331 (7.6)	
April	2282 (29.0)	1259 (36.1)	1023 (23.4)	

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Table 1—Continued

Characteristic	Overall (n = 7865)	COVID Watch Group (n = 3488)	Usual Care Group (n = 4377)	Standardized Mean Difference*
May	1205 (15.3)	655 (18.8)	550 (12.6)	
June	380 (4.8)	128 (3.7)	252 (5.8)	
July	557 (7.1)	182 (5.2)	375 (8.6)	
August	333 (4.2)	93 (2.7)	240 (5.5)	
September	209 (2.7)	67 (1.9)	142 (3.2)	
October	488 (6.2)	186 (5.3)	302 (6.9)	
November	1786 (22.7)	624 (17.9)	1162 (26.5)	

ED = emergency department.

* A standardized mean difference >0.10 is generally considered statistically significant.

including the frequency of encounters with Penn Medicine in the prior year—ED visits, hospitalizations, and outpatient encounters.

Statistical Analysis

All extracted variables were checked for outliers and missingness. Only 21 patients of 7865 who met inclusion criteria (0.27%) were missing any covariate data and excluded from the primary analysis. To account for imbalances on covariates between comparison groups in the outpatient cohort, we estimated propensity scores (the probability of enrollment in COVID Watch) using logistic regression. After using inverse probability of treatment weighting, we found that all covariates achieved balance between patients enrolled in COVID Watch and usual care with mean standardized differences of less than 0.1 (25). Outcome models weighted by inverse probability of treatment weights were either logistic for binary outcomes or linear for continuous outcomes. We did a priori subgroup analyses of outcomes by race/ethnicity.

To assess the robustness of our findings, we assessed the sensitivity of our mortality results to potential unmeasured confounding by using the Rosenbaum γ approach. We also tabulated any deaths that occurred in patients with missing covariates ($n = 21$). We also did a per protocol analysis, excluding any patients enrolled in COVID Watch who did not respond to any text messages, including the enrollment invitation text. Finally, we tabulated baseline characteristics and diagnoses of patients who died. All analyses were done using R, version 3.6.0 (R Project for Statistical Computing). All analyses used 2-sided statistical tests, and a P value less than 0.05 was considered statistically significant. Additional methodological details about the development of propensity scores can be found in the Supplement (available at Annals.org).

Role of the Funding Source

The funding source had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication.

RESULTS

Baseline Characteristics

After ineligible patients (Appendix Figure, available at Annals.org) were excluded, 7865 outpatients were available

for analysis: 3488 patients enrolled in COVID Watch and 4377 in usual care. Patients in COVID Watch were enrolled a mean of 1.8 days (SD, 2.3) after the date of COVID-19 test collection. Before propensity score weighting, patients enrolled in COVID Watch were similar to those who received usual care in age but were less likely to be male (37.1% vs. 42.5%) and were more likely to identify as non-Hispanic Black (47.9% vs. 32.1%), have public insurance (29.3% vs. 26.6%), not have a primary care provider (28.3% vs. 24.5%), have a higher mean body mass index (33.6 vs. 29.7 kg/m²), have certain comorbidities (hypertension, diabetes, and asthma), have a lower median household income (\$51 491 vs. \$60 638), have higher rates of ED and office visits in the past year, and be enrolled in the earlier months of the pandemic (Table 1; Supplement Figure 3, available at Annals.org). Covariates were well balanced after propensity score weighting (Table 2; Supplement Figure 4, available at Annals.org).

Outcomes

Of the 3488 patients enrolled in COVID Watch, 3028 (86.8%) engaged by responding to at least 1 text (mean, 23 check-in responses). Of patients who engaged, 434 (14.3%) triggered an escalation to a registered nurse, with mean response time of 24 minutes (Supplement Table 1, available at Annals.org).

At 30 days, 3 of 3488 (0.09%) patients enrolled in COVID Watch died versus 12 of 4377 (0.27%) who received usual care (Table 3). Of the deaths, 0 in COVID Watch occurred outside the hospital versus 6 of those who received usual care. Among in-hospital deaths, 2 of the 3 in COVID Watch occurred in hospitals outside of Penn Medicine compared with 5 of 6 in the usual care group. At 60 days, there were 2 additional in-hospital deaths among those enrolled in COVID Watch and 4 among those who received usual care. In total, 37.5% of the deaths at 60 days in the usual care group occurred outside the hospital. After propensity score weighting and modeling, at 30 days, those enrolled in COVID Watch had an odds ratio for overall mortality of 0.32 (95% CI, 0.12 to 0.72), with a difference of -1.8 deaths per 1000 patients (CI, -3.1 to -0.5) ($P = 0.005$). At 60 days, COVID Watch outcomes remained consistently better, with a difference of -2.5 deaths per 1000 patients (CI, -4.0 to -0.9) ($P = 0.002$). Furthermore, we found that COVID Watch was associated with equitable treatment benefits, with White, Black, and Hispanic subgroups all having reduced mortality by 60 days (Table 3).

Within 30 days, COVID Watch patients had a total of 489 ED encounters (121 per 1000), with 384 (78.5%)

Table 2. Propensity Score–Weighted Baseline Characteristics

Characteristic	COVID Watch Group (n = 7841.3)	Usual Care Group (n = 7865.6)	Standardized Mean Difference*
Mean age (SD), y	43.3 (15.2)	43.4 (16.1)	0.005
Age group, n (%)			
<40 y	3658.9 (46.7)	3663.2 (46.6)	0.002
40–49 y	1461.0 (18.6)	1460.8 (18.6)	0.002
50–59 y	1348.7 (17.2)	1342.1 (17.1)	0.004
60–69 y	945.8 (12.1)	959.3 (12.2)	0.004
≥70 y	426.8 (5.4)	440.1 (5.6)	0.007
Male, n (%)	3156.6 (40.3)	3162.5 (40.2)	0.001
Race/ethnicity, n (%)			0.01
Hispanic	699.6 (8.9)	701.7 (8.9)	
Non-Hispanic Black	3063.9 (39.1)	3052.8 (38.8)	
Non-Hispanic White	2950.4 (37.6)	2996.0 (38.1)	
Other/unknown	1127.4 (14.4)	1115.1 (14.2)	
Insurance coverage, n (%)			0.05
Blue Cross Blue Shield, commercial, or managed care	5177.9 (66.0)	5188.1 (66.0)	
Medicaid or managed Medicaid	812.2 (10.4)	810.4 (10.3)	
Medicare or managed Medicare	1384.3 (17.7)	1390.9 (17.7)	
Other	466.9 (6.0)	476.2 (6.1)	
Source of primary care, n (%)			0.012
Non-Penn Medicine primary care	2412.1 (30.8)	2451.6 (31.2)	
Penn Medicine primary care	3279.9 (41.8)	3296.5 (41.9)	
No primary care provider	2149.3 (27.4)	2117.5 (26.9)	
Mean body mass index (SD), kg/m²	32.1 (77.7)	30.1 (7.4)	0.035
Preexisting conditions, n (%)			
Hypertension	1622.7 (20.7)	1608.3 (20.4)	0.006
Diabetes	666.4 (8.5)	664.6 (8.4)	0.002
Hyperlipidemia	1288.6 (16.4)	1300.7 (16.5)	0.003
Chronic heart failure	75.3 (1.0)	76.8 (1.0)	0.002
Atrial fibrillation	142.7 (1.8)	152.8 (1.9)	0.009
Chronic obstructive pulmonary disease	80.8 (1.0)	87.3 (1.1)	0.008
Asthma	672.4 (8.6)	671.0 (8.5)	0.002
Chronic kidney disease	172.3 (2.2)	171.9 (2.2)	0.001
Cancer	450.0 (5.7)	453.6 (5.8)	0.001
Venous thromboembolism	112.7 (1.4)	116.4 (1.5)	0.004
Received a transplant	37.4 (0.5)	39.2 (0.5)	0.003
Dementia	12.7 (0.2)	14.2 (0.2)	0.004
Substance use diagnosis	36.8 (0.5)	44.7 (0.6)	0.014
State of residence, n (%)†			0.003
New Jersey	793.6 (10.1)	801.2 (10.2)	
Pennsylvania	6932.9 (88.4)	6951.1 (88.4)	
Other	114.7 (1.5)	113.3 (1.4)	
Median household income of home ZIP code (SD), \$	56 537 (30 137)	56 586 (29 731)	0.002
Mean hospital and office visits per patient 1 y before COVID-19 testing (SD), n			
ED visit	0.15 (0.51)	0.15 (0.62)	0.007
Admission–observation	0.01 (0.13)	0.01 (0.12)	0.004
Admission–inpatient	0.04 (0.27)	0.04 (0.25)	0.001
Office visit	2.15 (3.48)	2.15 (3.57)	0.002
Prior discharge to home health and no longer receiving home health, n (%)	127.9 (1.6)	131.2 (1.7)	0.003
Mean time between COVID-19 test and result (SD), d	1.4 (1.6)	1.4 (2.0)	0.012
Month of index positive test, n (%)			0.016
March	648.6 (8.3)	646.0 (8.2)	
April	2249.2 (28.7)	2243.6 (28.5)	

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Table 2—Continued

Characteristic	COVID Watch Group (n = 7841.3)	Usual Care Group (n = 7865.6)	Standardized Mean Difference*
May	1198.9 (15.3)	1212.9 (15.4)	
June	410.1 (5.2)	392.1 (5.0)	
July	556.2 (7.1)	558.3 (7.1)	
August	339.3 (4.3)	33.4 (4.2)	
September	197.7 (2.5)	207.1 (2.6)	
October	481.3 (6.1)	487.1 (6.2)	
November	1760.0 (22.4)	1785.2 (22.7)	

ED = emergency department.

* A standardized mean difference >0.10 is generally considered statistically significant.

† County of residence used in propensity score weighting.

occurring within Penn Medicine and 105 (21.5%) outside the health system. Of the 489 ED encounters by COVID Watch patients, only 62 (12.7%) were by those who never engaged with COVID Watch. Patients receiving usual care had a total of 252 ED encounters (50 per 1000), with 161 (63.9%) occurring within Penn Medicine and 91 (36.1%) outside the health system. After propensity score weighting, we found that COVID Watch patients had a higher mean number of ED encounters per patient (adjusted difference, 0.06 [CI, 0.04 to 0.07]; $P < 0.001$) and mean number of hospitalizations per patient (adjusted difference, 0.03 [CI, 0.01 to 0.04]; $P < 0.001$). Patients in COVID Watch had a similar number of office visits but a greater mean number of telemedicine encounters per patient (adjusted difference, 0.31 [CI, 0.27 to 0.34]; $P < 0.001$) than usual care patients within 30 days after their date of COVID-19 test collection.

When ED and hospital use was factored in with mortality, the mean number of days alive and out of the hospital within 30 days was marginally lower among COVID Watch patients (adjusted absolute difference, -0.2 [CI, -0.3 to -0.1]; $P < 0.001$) but was similar at 60 days (adjusted absolute difference, -0.1 [CI, -0.3 to 0.03]; $P = 0.103$) (Table 4) as deaths accrued and health care use diminished.

Among patients who presented to any hospital (within Penn Medicine or outside) for the first time in the 30 days after their date of COVID-19 test collection (Table 4), COVID Watch patients presented to the ED sooner (6.6 vs. 8.9 days) (propensity score-weighted difference, -1.9 days [CI, -2.9 to -0.9 days]; $P < 0.001$).

Among the subset of patients who presented to the ED within Penn Medicine (Table 5), COVID Watch enrollees compared with usual care patients presented to the ED even sooner (6.1 vs. 9.0 days) (propensity score-weighted difference, -2.9 days [CI, -4.1 to -1.7 days]; $P < 0.001$). During the ED evaluation, there were no statistically significant differences in vital signs or need for intubation and ventilation. However, compared with the 10.8% of usual care patients who received dexamethasone in Penn Medicine hospitals, the 11.3% of COVID Watch patients who were treated with dexamethasone received it sooner (propensity score-weighted difference, -3.0 days [CI, -5.6 to -0.4 days]; $P = 0.026$).

Sensitivity Analyses

The Rosenbaum bounds analysis showed there would need to be 1.8 times greater odds of differential assignment to COVID Watch attributable to unobserved

factors, a substantial amount of unmeasured confounding needed to reverse the statistically significant findings (Supplement Table 2, available at Annals.org). There were also no deaths among the 21 patients excluded from the outpatient cohort because of missing covariate data (Supplement Table 3, available at Annals.org). We also found that 2 of the 5 deaths in COVID Watch occurred among the 13.2% of the patients who never engaged with the system. The per protocol analysis of patients who engaged with COVID Watch indicated even stronger treatment effects: odds ratio for death of 0.25 (CI, 0.10 to 0.55), with a difference of -2.8 deaths per 1000 patients (CI, -4.3 to -1.3 deaths) ($P = 0.001$) (Supplement Table 4, available at Annals.org). Finally, baseline characteristics of patients who died varied but were not statistically significant from each other across treatment groups (Supplement Table 5, available at Annals.org), and coded diagnoses of in-hospital deaths were consistent with COVID-19 being the primary cause of death (Supplement Table 6, available at Annals.org).

DISCUSSION

This study has 4 main findings. First, the mortality rate for community-dwelling adults with COVID-19 was significantly lower among those in COVID Watch compared with usual care, even after adjustment for differences in patients' clinical and sociodemographic characteristics. Second, more than one third of the deaths in the usual care group occurred outside the hospital versus none among those in COVID Watch. Third, patients in COVID Watch were more likely to present to the hospital, and they presented earlier. Fourth, all major racial and ethnic subgroups had reduced mortality rates when enrolled in COVID Watch.

These findings imply that COVID Watch is associated with a 64% relative reduction in the risk for death and that 1 life was saved for every 400 patients enrolled—or about 1 every 4 days during peak enrollment weeks. Although remote patient monitoring programs used to manage patients with COVID-19 outside of hospital settings have been described (26, 27), including 1 study from Kaiser Permanente that reported unadjusted mortality rates of 2.3% in usual care versus 1.3% with remote monitoring (28), we believe ours to be the first risk-adjusted study to show improved survival.

Public health messaging strongly promoted staying home to promote social distancing and decrease hospital strain during the pandemic (29, 30). However, those

Table 3. Mortality Outcomes

Outcome	Deaths at 30 d			Deaths at 60 d		
	COVID Watch Group	Usual Care Group	P Value	COVID Watch Group	Usual Care Group	P Value
Overall cohort, n	3488	4377		3488	4377	
All deaths, unadjusted, n (%)	3 (0.09)	12 (0.27)		5 (0.14)	16 (0.37)	
Out-of-hospital deaths, n (%)	0 (0)	6 (50.0)		0 (0.0)	6 (37.5)	
In-hospital deaths, n (%)	3 (100.0)	6 (50.0)		5 (100.0)	10 (62.5)	
Within the health system, n (%)	1 (33.3)	1 (16.8)		2 (40.0)	4 (40.0)	
Outside the health system, n (%)	2 (66.7)	5 (83.3)		3 (60.0)	6 (60.0)	
All deaths, adjusted odds ratio for death for COVID Watch vs. usual care (95% CI)	0.32 (0.12 to 0.72)		0.005	0.34 (0.16 to 0.67)		0.002
All deaths, adjusted difference in death rate for COVID Watch vs. usual care (95% CI)	−1.8 per 1000 (−3.1 to −0.5)		0.005	−2.5 per 1000 (−4.0 to −0.9)		0.002
Non-Hispanic White patients, n	1026	1963		1026	1963	
All deaths, unadjusted, n (%)	1 (0.10)	7 (0.36)		1 (0.10)	8 (0.41)	
Adjusted difference in mortality rate for COVID Watch vs. usual care (95% CI)	−2.4 per 1000 (−4.3 to −0.5)		0.014	−2.5 per 1000 (−4.3 to 0.7)		0.007
Non-Hispanic Black patients, n	1671	1405		1671	1405	
All deaths, unadjusted, n (%)	1 (0.06)	2 (0.14)		3 (0.18)	3 (0.21)	
Adjusted difference in mortality rate for COVID Watch vs. usual care (95% CI)	−1.3 per 1000 (−2.5 to 0)		0.045	−2.4 per 1000 (−4.2 to −0.5)		0.011
Hispanic patients, n	298	399		298	399	
All deaths, unadjusted, n (%)	1 (0.34)	1 (0.25)		1 (0.34)	3 (0.75)	
Adjusted difference in mortality rate for COVID Watch vs. usual care (95% CI)	−2.3 per 1000 (−5.2 to 0.6)		0.118	−4.1 per 1000 (−8.0 to −0.1)		0.043
Patients of other race/ethnicity, n	493	610		493	610	
All deaths, unadjusted, n (%)	0 (0.00)	2 (0.33)		0 (0.00)	2 (0.33)	
Adjusted difference in mortality rate for COVID Watch vs. usual care (95% CI)	−1.4 per 1000 (−3.2 to 0.4)		0.129	−1.3 per 1000 (−3.0 to 0.3)		0.119

messages were accompanied by decreases in emergent conditions presenting to the ED and increased out-of-hospital deaths (8, 9, 31–39). In this study, 37.5% of deaths among patients who received usual care occurred outside the hospital versus none among patients in COVID Watch, which is consistent with the interpretation that COVID Watch exerts its effect by increasing vigilance over those at home and efficiently sorting them into those who will benefit from the ED and those who will not (8, 32).

Further evidence supports this mechanistic hypothesis. Patients in COVID Watch were more likely to present to the hospital and presented earlier, likely improving their ability to benefit from the care they receive. For example, dexamethasone reduces mortality and length of stay for patients with COVID-19 (40), and the benefit may be larger if the drug is administered earlier in the disease course (41–45). We found that among those who received dexamethasone in Penn Medicine hospitals, COVID Watch patients received the medication 3 days earlier on average. We also found that the treatment effects associated with COVID Watch were stronger among those who engaged with the remote monitoring service; 2 of the 5 deaths in the COVID Watch group were among the 13% of enrolled patients who never

engaged the system. The constellation of these findings is consistent with the view that COVID Watch operates as an early warning and referral system for community-dwelling patients (13).

The combination of technology-based, automated remote monitoring (46) backed by clinician support may be necessary ingredients for the observed clinical effect. Because COVID Watch was automated, only 2 to 4 staff members were required to oversee more than 1000 patients at a time, far fewer than personnel-intensive calling systems (26, 27). Because it relied on symptom self-report, COVID Watch did not require dedicated temperature sensors or pulse oximetry (12, 27, 47–49). The use of additional equipment in the home varies substantially across remote patient monitoring programs, and its incremental value is unknown (50). Future research is needed to determine whether this type of monitoring service could be adapted to other acute conditions (for example, pneumonia or cellulitis) and chronic conditions (for example, asthma or diabetes) in which automated text check-ins and low barrier access to rapid clinical assessment and ED triage could improve outcomes.

In our study, non-Hispanic Black patients were more likely to be enrolled in COVID Watch than usual care,

Table 4. Health Care Use Outcomes

Outcome	30 d			60 d		
	COVID Watch Group	Usual Care Group	P Value	COVID Watch Group	Usual Care Group	P Value
Overall cohort, n	3488	4377		3488	4377	
ED visits, n*	489	252		602	350	
Unadjusted mean per patient (SD)	0.10 (0.34)	0.04 (0.22)		0.13 (0.40)	0.06 (0.27)	
Unadjusted mean within the health system (SD)	0.07 (0.28)	0.02 (0.15)		0.08 (0.31)	0.03 (0.18)	
Unadjusted mean outside the health system (SD)	0.03 (0.19)	0.02 (0.16)		0.04 (0.25)	0.03 (0.20)	
Weighted difference in mean total ED visits per patient between COVID Watch and usual care† (95% CI)	0.06 (0.04 to 0.07)		<0.001	0.06 (0.04 to 0.07)		<0.001
Hospitalizations, n*	211	141		243	185	
Total unadjusted mean per patient (SD)	0.06 (0.25)	0.03 (0.20)		0.07 (0.29)	0.04 (0.25)	
Unadjusted mean within the health system (SD)	0.04 (0.22)	0.02 (0.18)		0.05 (0.25)	0.03 (0.22)	
Unadjusted mean outside the health system (SD)	0.02 (0.13)	0.01 (0.10)		0.02 (0.15)	0.01 (0.11)	
Adjusted difference in mean total hospitalizations per patient between COVID Watch and usual care† (95% CI)	0.03 (0.01 to 0.04)		<0.001	0.02 (0.01 to 0.03)		<0.001
DAOH‡						
Unadjusted mean per patient (SD)	29.5 (2.3)	29.7 (3.0)		59.4 (3.4)	59.5 (3.7)	
Adjusted difference in mean DAOH per patient between COVID Watch and usual care† (95% CI)	−0.2 (−0.3 to −0.1)		<0.001	−0.1 (−0.3 to 0.03)		0.103
Outpatient office visits within the health system, n	473	601		927	1270	
Unadjusted mean per patient (SD)	0.14 (0.40)	0.14 (0.41)		0.27 (0.62)	0.29 (0.67)	
Adjusted difference in mean office visits per patient between COVID Watch and usual care† (95% CI)	0.01 (−0.01 to 0.02)		0.58	−0.01 (−0.04 to 0.02)		0.67
Telemedicine visits within the health system, n§	2170	1265		2724	1677	
Unadjusted mean per patient (SD)	0.62 (1.03)	0.29 (0.61)		0.78 (1.26)	0.38 (0.78)	
Adjusted difference in mean telemedicine visits per patient between COVID Watch and usual care† (95% CI)	0.31 (0.27 to 0.34)		<0.001	0.34 (0.30 to 0.39)		<0.001

DAOH = days alive and out of the hospital; ED = emergency department.

* ED visits include discharges and hospitalizations. Hospitalizations included inpatient admissions and observation stays admitted from the ED.

† Propensity score-weighted model incorporating all variables listed in Table 2.

‡ This is a composite metric that accounts for ED visits and, if hospitalized, the length of stay as well as days after death.

§ Telemedicine visits included video and telephone visits.

and Hispanic patients were about as likely to be in either group. White, Black, and Hispanic populations also had significantly reduced mortality when enrolled in COVID Watch, and the overall mortality rates were lower relative to reports nationally (28, 39, 51, 52). These findings suggest no substantial racial or ethnic barriers to program enrollment or its effectiveness and that implementing this type of remote monitoring service has the potential to reduce racial disparities in regions in which Black and Hispanic patients have decreased access to care and higher mortality rates.

This study has limitations. First, we could observe deaths in our hospitals and hospitals outside our health system via a health information exchange linkage, but we may have incomplete ascertainment of out-of-hospital deaths. Death certificate linkage via the National Death Index was not available at the time of manuscript submission because of lag times in these databases. However, COVID Watch patients were highly engaged with Penn Medicine, replying to a mean of 23 text message check-ins through the program, which suggests that their deaths would more likely be ascertained.

Table 5. Timing and Severity of Initial Presentations to Health System EDs Within 30 Days*

Outcome	COVID Watch Group (n = 330)	Usual Care Group (n = 139)	Adjusted Difference Between COVID Watch and Usual Care† (95% CI)	P Value
Mean time to presentation to the ED after index COVID-19 test collection (SD), d	6.1 (5.5)	9.0 (8.4)	-2.9 (-4.1 to -1.7)	< 0.001
Mean time to receipt of dexamethasone after index COVID-19 test collection (SD), d	5.1 (2.7)	7.7 (6.6)	-3.0 (-5.6 to -0.4)	0.026
Mean lowest recorded oxygen saturation percentage in the ED (SD), %	93.4 (7.2)	92.5 (10.1)	0.8 (-0.8 to 2.3)	0.35
Supplemental oxygen provided in the ED, n (%)	88 (26.7)	38 (27.5)	0.2 (-5.6 to 5.9)	0.95
Mean maximum temperature in the ED (SD), ° C	37.7 (2.7)	37.4 (1.6)	0.4 (-0.1 to 0.9)	0.110
Mean lowest recorded SBP in the ED (SD), mm Hg	119.2 (16.1)	117.0 (14.9)	1.3 (-1.5 to 4.1)	0.36
Intubated and required ventilator support, n (%)	6 (1.8)	6 (4.3)	-1.5 (-3.5 to 0.6)	0.154

ED = emergency department; SBP = systolic blood pressure.

* This table does not include patients who presented to any of 53 hospitals outside the health system captured in the regional health information exchange. There were a total of 196 ED encounters to hospitals outside the health system (COVID Watch [n = 105], usual care [n = 91]).

† Propensity score-weighted model incorporating all variables listed in Table 2.

Second, we cannot capture hospital use outside of the geography of health information exchange. Fortunately, 99.4% of our study sample had residential ZIP codes within the geographic region covered by the health information exchange, decreasing the potential for incomplete capture of hospital use.

Third, we cannot capture the reasons patients were enrolled in COVID Watch or whether patients were verbally offered COVID Watch and declined it. We also cannot capture social needs, the nature and timing of symptoms before the testing date, and other unobserved confounders that may affect outcomes. However, higher rates of characteristics associated with worse outcomes from COVID-19 were seen in the COVID Watch group, including the lack of a primary care physician, Black race, residing in a lower-income ZIP code, greater body mass index, higher rates of high-risk comorbidities, and higher proportion treated early in the pandemic (6, 24, 53-55), all suggesting higher expected mortality among the COVID Watch group. Furthermore, our sensitivity analyses indicated there would need to be a 1.8 times greater odds of differential assignment to COVID Watch versus the control group that was attributable to unobserved factors. Given the large number of important covariates we have accounted for in our analysis, it is unlikely that such an impactful covariate was not included.

Fourth, outcomes measured reflect care received at a single health system, a select set of hospitals in a specific region of the United States, which may limit generalizability of our findings. However, this study included populations with a diverse set of comorbidities and sociodemographic characteristics. Relatedly, we were unable to measure clinical status and treatments provided during hospital encounters outside our health system. Given the differential use of hospitals outside our health system, clinical treatment rates seen within our health system should not be extrapolated to the subset treated in hospitals outside our health system.

This study also has strengths. It reflects what is, to our knowledge, the largest and most comprehensive sample and evaluation of a remote monitoring service for COVID-19 in the United States. There is careful adjustment for

differences in patient characteristics that have a conservative bias. The effect size is large, and the results are accompanied by plausible mechanisms whose specific elements are suggested by secondary analyses.

In conclusion, enrollment in an automated text messaging service among community-dwelling adults newly diagnosed with COVID-19 in outpatient settings was associated with reduced mortality, potentially explained by increased and earlier presentation to the ED by those benefiting from early interventions. These results reveal a model for outpatient health system management of patients with COVID-19 and possibly other conditions where the early detection of clinical declines is critical.

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Appendix Figure. Study sample flowchart and patients excluded.

