

Long-term effect of home telehealth services on preventable hospitalization use

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Abstract—In this study, we assessed the longitudinal effect of a Department of Veterans Affairs (VA) patient-centered Care Coordination Home Telehealth (CCHT) program on preventable hospitalization use by veterans with diabetes mellitus (DM) at four VA medical centers. We used a matched treatment-control design ($n = 387$ for both groups). All patients were followed for 4 years. We operationalized ambulatory care-sensitive conditions (ACSCs) by applying Agency for Healthcare Research and Quality criteria to VA inpatient databases to determine preventable hospitalization use. We used a generalized linear mixed model to estimate the adjusted effect of the CCHT program on preventable hospitalization use over time. During the initial 18 months of follow-up, CCHT enrollees were less likely to be admitted for a preventable hospitalization than their nonenrollee counterparts, and this difference diminished during the rest of the 4-year follow-up period. The VA CCHT program for DM patients reduced preventable hospitalizations. These findings are some of the first that have systematically examined the extent to which home telehealth programs have a long-term effect on preventable hospitalization use.

Key words: ambulatory care-sensitive conditions, cohort study, diabetes mellitus, follow-up study, health services utilization, preventable hospitalization, rehabilitation, telehealth, VA, veterans.

BACKGROUND

A large body of literature has found that hospitalizations for ambulatory care-sensitive conditions (ACSCs) could be prevented if timely and appropriate ambulatory care were accessible to patients. Prevention of avoidable hospitalizations may be achieved by delaying the disease onset or proactively managing a chronic condition in such a way as to prevent its deterioration to the stage that requires hospitalization [1]. Further, improving patient accessibility to care providers at home is associated with lower rates of hospitalization for ACSCs [2–4].

Abbreviations: ACSC = ambulatory care-sensitive condition, AHRQ = Agency for Healthcare Research and Quality, CCHT = Care Coordination Home Telehealth, DM = diabetes mellitus, ICD-9 = International Classification of Diseases-9th Revision, PQI = Prevention Quality Indicator, SD = standard deviation, VA = Department of Veterans Affairs, VAMC = VA medical center, VISN = Veterans Integrated Service Network.

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Home telehealth can be one mechanism to improve patient accessibility. Home telehealth is the use, by a home care provider, of modern telecommunication and information technology to link patients to single or multiple out-of-home sources of care information, education, or service over short or long distances [5–6]. Therefore, home telehealth enables patients to remain at home while having their health information monitored over geographical, social, and cultural distances. Studies suggest that home telehealth may benefit patients by detecting health issues at an early stage, improving access to care, and improving compliance with treatment plans [6–8]. However, insufficient evidence is available to support that home telehealth may improve access by coordinating care in a way that would not have occurred through conventional care.

Within the Department of Veterans Affairs (VA), a transition from a hospital-based system to one that emphasizes ambulatory and patient-centered care has occurred [9]. The national VA Care Coordination Home Telehealth (CCHT) program was developed as one transforming strategy to improve accessibility and provide timely and appropriate care for community-dwelling veterans with chronic diseases, such as diabetes mellitus (DM), and complex needs for multiple adverse conditions. This approach is achieved through care coordination by nurse practitioners or registered nurses and disease monitoring with the use of supportive home telemonitoring technology. Patients enrolled in the VA CCHT program receive a home telehealth device (e.g., a messaging device installed at home that requires basic landline telephone service and an electrical outlet). On a daily basis, CCHT enrollees answer scripted questions from the messaging device about their symptoms and health status. The care coordinators monitor patients' daily updates from the devices and take follow-up actions such as (1) placing a telephone call to the patient, (2) arranging a referral to the patient's physician or scheduling new appointments with VA clinicians as needed, (3) placing new orders for patient medications, (4) helping patients manage their medications, (5) reminding patients of their clinic appointments, and (6) aiding with technology difficulties. A detailed description of the CCHT program can be found elsewhere [10].

Several observational studies have evaluated the effectiveness of the CCHT program. In a 12-month preenrollment to 12-month postenrollment comparison study, Chumbler et al. reported that the patients with DM

in the program had a significant reduction in inpatient use (50% reduction), emergency room use (11% reduction), and average number of bed days of care (3.0 day average decrease), as well as improvement in health-related quality of life [11]. In a separate treatment-control matched study on healthcare utilization, Barnett et al. found that compared with the patients in the matched group, the CCHT enrollees were significantly less likely to be admitted for inpatient care during the 24 months post-enrollment [10]. While these findings were informative, no studies have been done regarding the long-term effect of home telehealth programs in general, and the VA CCHT program in particular, on preventable hospitalization use.

The present study assessed the longitudinal effect of the VA CCHT program by determining the extent to which it was associated with a lower probability of preventable hospitalization use by veterans with DM over a 4-year period.

METHODS

Study Design and Patients

This was a retrospective matched treatment-control study. The treatment group consisted of 387 veterans who were diagnosed with DM and enrolled in the CCHT program at four VA medical centers (VAMCs) located in a single Veterans Integrated Service Network (VISN) in the southern region. The inclusion criteria for the CCHT program included (1) $> 1\times$ use of VA inpatient or emergency services within the 12 months prior to enrollment date, (2) noninstitutionalized at enrollment time, and (3) a telephone landline at home. The control group consisted of 387 VA DM patients from the same VAMCs as the CCHT program enrollees who had not received or been approached by the telehealth service; control subjects were chosen from a pool of patients by a propensity score.

Patients in the treatment group were randomly matched on the basis of the CCHT programs' enrollment dates and patient care settings so that both groups (treatment and control) had the same allocations of enrollment and service period [10]. Further, to improve the quality of the match between the treatment and control groups, we applied the propensity score method to enhance the balance between the different groups of patients [12]. The propensity score is a single summary score of a patient's background characteristics and it represents the probability that a patient belongs to a naturally occurring treatment

group. As such, it has a distinct advantage over standard matching techniques. For instance, it has been used extensively in medical and health services research that uses survey or observational data, and it has the potential to reduce selection bias [13]. Three controls were randomly selected for each study participant of the treatment group to guarantee an adequately sized control group [14]. The propensity score-based matching was performed by (1) estimating the probability that a patient is “chosen” into the treatment group as opposed to the control group, (2) separating the sample into quintiles of the predicted propensity scores distribution (<20%, 20%–40%, 40%–60%, 60%–80%, and 80%–100%), and (3) randomly sampling the controls with a size equal to the number of cases within each quintile. The veterans were selected to fit our outcome models, and more detailed information about this method is published elsewhere [10,14].

All patients were community-dwelling veterans with a primary diagnosis of DM and were followed for 4 years postbaseline or enrollment date. VA automated inpatient, outpatient, and extended care databases were used to obtain patient information. The Agency for Healthcare Research and Quality (AHRQ) definitions of ACSCs for adults were adopted to determine study participants’ preventable hospitalization use during the 4 years of follow-up (please see the following “Outcome Variable” section).

This study was approved by the institutional review board at the University of Florida and the local Research and Development Subcommittee for Clinical Investigations at the North Florida/South Georgia Veterans Health System in Gainesville, Florida.

Outcome Variable

The outcome variable was the semiannual count of preventable hospitalization use by each patient, regardless of his or her group designation (i.e., treatment vs control group), within the 4 years postenrollment. We used the AHRQ’s Prevention Quality Indicators (PQIs) version 3.1 to calculate the outcome measure [15]. The PQIs are a set of measures that can be used with hospital inpatient data to identify ACSCs. The PQIs consist of 14 categories of ACSCs, and for the purposes of the present study, we adopted 12 of them that are commonly used for adult patients: angina, asthma, bacterial pneumonia, chronic obstructive pulmonary disease, congestive heart failure, dehydration, diabetes long-term complications, diabetes short-term complications, diabetes uncontrolled, hypertension, lower-limb amputation among

diabetes patients, and urinary infection. The specific International Classification of Diseases-9th Revision (ICD-9) codes for each category of diagnosis are published elsewhere [16]. The two categories of PQIs that were excluded in this study were low birth weight and perforated appendix admissions. The former was excluded because it was not applicable to our study cohort, 98 percent of whom were male. The latter was excluded because the indicator was not listed as an ACSC by the Institute of Medicine and no admission for perforated appendix was identified for the cohort during the 4-year follow-up.

To determine patients’ status for preventable hospitalization use during the 4-year follow-up period, we applied the ICD-9 codes for each category of ACSCs to three VA automated inpatient data sets: the Patient Treatment File—Main, the Surgery File, and the Procedure File. These files are automated national data sets containing VA enrollees’ sociodemographic and clinical information, and they are commonly used by VA researchers. The outcome was counted semiannually at the patient level.

Independent Variable

Patients who were enrolled in the CCHT program were referred to as treatment group participants. Thus, the independent variable was categorized as treatment versus control group.

Other Covariates

The covariates of interest (sociodemographic and clinical characteristics as well as prior health services utilization) were collected at three different time points. At baseline, we collected the patients’ sociodemographics (age, race/ethnicity, sex, marital status, and priority for VA medical care) from the VA inpatients files. Patient age was a continuous variable showing a patient’s actual age at the time of enrollment. Patient’s self-reported race/ethnicity was obtained at the time of the baseline interview (treatment group only) or obtained from VA inpatient or outpatient databases (control group). Patient sex was obtained from VA inpatient databases. Patient priority for VA medical care was created based upon the Means Test indicator from VA inpatient databases. A patient’s priority for VA medical care was coded as high if his or her Means Test category was either “AS” for all compensable service-connected (0%–100%) veterans and special category of veterans or “AN” for non-service-connected low-income veterans. A patient’s priority was coded as low if his or her Means Test category was “C” for those veterans who,

based upon income and/or net worth, were subject to a copayment for care rendered [17–18].

We used a modified Charlson comorbidity index to assess the patients' medical comorbid conditions, with the higher the weighted summary score the more severe the burden of comorbidity [19–20]. The information was collected in the 6 months prior to the patients' enrollment date.

In addition, we obtained patients' volume of health services use (inpatient use and outpatient visits) during the 12 months prior to their enrollment date. VA inpatient and outpatient databases were used for the data matching and extraction.

STATISTICAL ANALYSIS

All data were analyzed with SAS version 9.13 (SAS Institute, Inc; Cary, North Carolina). First, descriptive statistics were obtained for the sociodemographic and utilization characteristics. Statistical inference tests (chi-square tests on discrete variables, *t*-tests on continuous variables, and the log-rank test on survival time in days) were performed to compare the demographic and utilization characteristics between the treatment and control groups. Second, Poisson regression analyses were conducted to compare the occurrence rate of these ACSCs between the treatment and control groups. Third, multicollinearity diagnostics (conditional indices and variance proportion) were calculated to measure degrading or harmful multicollinearity among all independent and controlling variables. Fourth, a generalized linear mixed model was fitted to estimate the longitudinal impact of the CCHT program on preventable hospitalization use over a period of 4 years, with adjustment for patient age, sex, marital status, race/ethnicity, priority for medical care within the VA health-care system, comorbid conditions, preenrollment inpatient and outpatient utilization, patients' medical care sites, and time. The model also included an interaction effect between treatment and time on the semiannual count of preventable hospitalization use.

RESULTS

Table 1 presents the characteristics of the study cohort ($n = 774$). At baseline, the study patients averaged 67.6 years of age, with 98.3 percent being male, 61.9 percent married, 39.4 percent white, 49.2 percent Hispanic, and 97.9 percent with high VA medical care priority. The pro-

portion of patients from the four VAMCs ranged from 14.6 percent for site A to 14.5 percent for site B, 46.3 percent for site C, and 24.7 percent for site D. The mean \pm standard deviation (SD) 6-month preenrollment comorbidity summary score was 0.2 ± 0.5 and the mean \pm SD numbers of 12-month preenrollment inpatient use and outpatient visits were 0.8 ± 1.3 and 26.5 ± 21.6 times, respectively. The mean \pm SD 4-year postenrollment preventable hospitalization use was 0.8 ± 1.6 times for the entire cohort, and 22.9 percent of the patients died during the 4-year follow-up, with an average survival time of 1,313.8 days.

Chi-square tests and *t*-tests were used to determine the differences in characteristics between the two groups (treatment vs control). No significant differences were found at baseline in terms of patient age, sex, marital status, race/ethnicity, VA medical care priority status, implementation site, preenrollment comorbidity sum score, or preenrollment inpatient care use. However, compared with the control group, the treatment group had significantly more preenrollment outpatient visits (30.3 vs 22.6). Regarding 4-year postenrollment information, the treatment group had significantly fewer preventable hospitalizations (0.7 vs 1.0), lower crude death rate (19.4% vs 26.4%), and longer survival time (1,349.4 days vs 1,278.2 days) than the control group.

Table 2 lists the frequency of 4-year preventable hospitalization occurrences by study group. Compared with the treatment group, the control group had much higher frequency of all diabetes-related ACSCs: diabetes long-term (121 vs 42) and short-term (28 vs 7) complications, lower-limb amputation (55 vs 29), uncontrolled diabetes (15 vs 4), as well as bacterial pneumonia (34 vs 22) and angina (19 vs 8). Meanwhile, the treatment group had much higher frequency of congestive heart failure (84 vs 67), chronic obstructive pulmonary disease (31 vs 14), and dehydration (11 vs 9) than the control group. Poisson regression analyses showed that statistically significant differences existed ($p < 0.05$) between both groups in diabetes long-term complications, lower-limb amputation, and uncontrolled diabetes.

Table 3 shows the results of our generalized linear mixed model. As shown, patients in the treatment group were less likely to have preventable hospitalization use than patients in the control group after adjusting for sociodemographic and utilization risk factors. The relative risk of preventable hospitalization use in the treatment group was 0.19, 0.42, and 0.42 times that of the control group during the first, second, and third 6-month follow-up

Table 1.
Characteristics of study cohort.

| Characteristic | Study Cohort (N = 774) | Treatment (n = 387) | Control (n = 387) |
|-----------------------------------|---------------------------|------------------------|----------------------|
| | Mean ± SD or % | Mean ± SD or % | Mean ± SD or % |
| Baseline | | | |
| Age | 67.6 ± 10.1 | 68.0 ± 9.2 | 67.2 ± 10.9 |
| Male | 98.3 | 98.7 | 97.9 |
| Married | 61.9 | 64.3 | 59.4 |
| Race/Ethnicity | | | |
| White | 39.4 | 40.1 | 38.8 |
| Hispanic | 49.2 | 48.8 | 49.6 |
| All Other | 11.4 | 11.1 | 11.6 |
| VA Medical Care Priority | | | |
| High | 97.9 | 98.2 | 97.7 |
| Low | 2.1 | 1.8 | 2.3 |
| Study Site | | | |
| A | 14.6 | 15.3 | 14.0 |
| B | 14.5 | 15.0 | 14.0 |
| C | 46.3 | 46.0 | 46.5 |
| D | 24.7 | 23.8 | 25.6 |
| Preenrollment | | | |
| Comorbidity Sum Score | 0.2 ± 0.5 | 0.3 ± 0.6 | 0.2 ± 0.5 |
| Inpatient Care Use | 0.8 ± 1.3 | 0.7 ± 1.2 | 0.8 ± 1.5 |
| Outpatient Visit* | 26.5 ± 21.6 | 30.3 ± 21.7 | 22.6 ± 20.8 |
| 4-Year Postenrollment | | | |
| Preventable H Counts [†] | 0.8 ± 1.6 | 0.7 ± 1.3 | 1.0 ± 1.9 |
| Crude Death Rate [†] | 22.9 | 19.4 | 26.4 |
| Survival Time in Days* | 1,313.8 ± 329.6 | 1,349.4 ± 266.4 | 1,278.2 ± 379.6 |

* $p < 0.01$; all p -values were from chi-square tests for categorical variables and t -tests for continuous variables between the treatment and control groups (with exception that log-rank test was used for survival time in days).

[†] $p < 0.05$.

H = hospitalization, SD = standard deviation, VA = Department of Veterans Affairs.

periods, respectively (all $p < 0.001$). Furthermore, the difference between the two groups became nonsignificant after 18 months. The treatment by time interaction effect is further illustrated in the **Figure**.

Several covariates were also associated with preventable hospitalization use over time. Not being married and using more inpatient and outpatient services prior to enrollment date were also found to be significant predictors for preventable hospitalization use over time (**Table 3**).

DISCUSSION

The primary objective of the present study was to assess the longitudinal effect of the VA CCHT program by examining whether veterans with DM enrolled in the program had a lower probability of preventable hospitaliza-

tion use over a 4-year period. Results from the generalized linear mixed model indicated a statistically significant reduction of preventable hospitalization use during the initial 18-month postenrollment period, even after adjustment for potential sociodemographic and clinical risk factors. However, the program did not demonstrate a significant effect on preventable hospitalization use during the rest of the follow-up period. This result may largely be due to the fact that the control group had more deaths than the treatment group during the initial 18 months (40 vs 12 deaths). Generally, disease severity is positively associated with increased volume of health services use. The higher number of deaths in the control group at an early stage of the follow-up period likely resulted in the groups' decreased average number of preventable hospitalizations during the rest of the follow-up period. Additional Poisson regression analyses found that CCHT enrollees had significantly

Table 2.
Frequency of 4-year preventable hospitalization occurrences by study group.

| Preventable Hospitalization Condition | Treatment Group | Control Group |
|--|-----------------|---------------|
| Congestive Heart Failure | 84 | 67 |
| Diabetes Long-Term Complications* | 42 | 121 |
| Urinary Infection | 33 | 31 |
| Chronic Obstructive Pulmonary Disease | 31 | 14 |
| Lower-Limb Amputation Among Diabetes Patients* | 29 | 55 |
| Bacterial Pneumonia | 22 | 34 |
| Dehydration | 11 | 9 |
| Angina | 8 | 19 |
| Diabetes Short-Term Complications | 7 | 28 |
| Diabetes Uncontrolled* | 4 | 15 |
| Hypertension | 3 | 5 |
| Adult Asthma | 1 | 2 |

Note: Each condition listed in table consists of a number of International Classification of Diseases-9th Revision (ICD-9) codes. For example, long-term diabetes-related complications include renal, eye, neurological, circulatory, or complications not otherwise specified and short-term complications include ketoacidosis, hyperosmolarity, and coma. Detailed ICD-9 codes for each category can be found in the Agency for Healthcare Research and Quality Prevention Quality Indicators manual. (Agency for Healthcare Research and Quality (AHRQ). Guide to Prevention Quality Indicators: Hospital admission for ambulatory care sensitive conditions. Ver. 3.1. Rockville (MD): U.S. Department of Health and Human Services; 2007.)

* $p < 0.05$ based on Poisson regression analyses comparing occurrence rate of conditions between treatment and control groups.

Table 3.
Results from generalized linear mixed model.

| Variable | Relative Risk (95% CI) | <i>p</i> -Value |
|--|---------------------------|-----------------|
| Treatment vs Control by Time Period | | |
| 6 mo | 0.19 (0.10–0.37) | <0.001 |
| 12 mo | 0.42 (0.25–0.71) | <0.001 |
| 18 mo | 0.42 (0.27–0.65) | <0.001 |
| 24 mo | 1.09 (0.73–1.62) | 0.68 |
| 30 mo | 1.32 (0.85–2.05) | 0.21 |
| 36 mo | 0.80 (0.48–1.32) | 0.38 |
| 42 mo | 0.75 (0.40–1.39) | 0.36 |
| 48 mo | 0.60 (0.27–1.32) | 0.20 |
| All Other Covariates | | |
| Age | 1.02 (1.00–1.04) | 0.06 |
| Sex: Male vs Female | 1.38 (0.36–5.33) | 0.64 |
| Marital Status: Married vs All Other | 0.56 (0.39–0.82) | 0.002 |
| Race/Ethnicity: White vs All Other | 0.60 (0.35–1.04) | 0.07 |
| VA Medical Care Priority: High vs Low | 0.78 (0.22–2.75) | 0.70 |
| 6 mo Preenrollment Comorbid Sum Score | 1.38 (0.99–1.92) | 0.06 |
| 12 mo Preenrollment Inpatient Use | 1.57 (1.39–1.77) | <0.001 |
| 12 mo Preenrollment Outpatient Visit | 1.01 (1.01–1.02) | <0.001 |
| Study Site | | |
| A vs C | 1.12 (0.54–2.34) | 0.75 |
| B vs C | 1.65 (0.93–2.93) | 0.09 |
| D vs C | 1.67 (0.89–3.15) | 0.11 |

Note: Dependent measurement was “semiannual count of preventable hospitalization use.”

CI = confidence interval, VA = Department of Veterans Affairs.

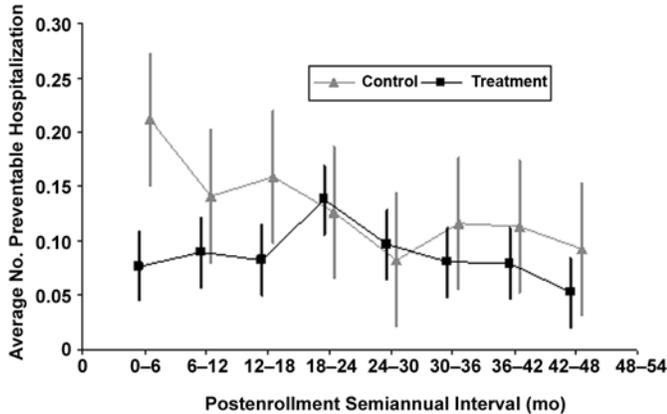


Figure.

Comparison of number of preventable hospitalization occurrences between treatment and control groups by time (mean \pm 1.96 standard error).

fewer preventable hospitalizations due to diabetes long-term complications, lower-limb amputations, and uncontrolled diabetes (**Table 2**). Overall, the findings from this study contribute to the current literature in several ways.

By applying the inclusive categories of ACSCs defined by the AHRQ [16] to the VA national automated medical databases, we were able to obtain and examine a broader category of preventable hospitalization use by the study patients and maximize the impact of the home telehealth program on potentially preventable hospitalization. Several studies in the field have also assessed the effect of the VA CCHT program on health services utilization [10,21]. These studies have provided important information about the positive impact of the CCHT program on the reduction of inpatient and outpatient use for all causes as well as the primary diagnoses-related preventable hospitalizations. However, these articles did not examine the overall and specific types of inpatient utilization that were potentially preventable, which further impedes our complete understanding of the impact of the program. The present study was the first to assess comprehensive preventable hospitalization use by home telehealth users longitudinally. Such information helps illustrate the accessibility benefits of telehealth service since we know that telehealth has the potential to offer timely and essential monitoring of patients' medical conditions at home and it can be a cost-effective means of providing effective self-care and disease management [22].

Another strength of the present study was that in the absence of a randomized controlled trial, we were able to compare the utilization outcomes in not only a large sam-

ple but also a matched treatment-control sample, employ propensity scores to improve the balance between the treatment and control groups, and further capitalize on both inpatient and outpatient VA automated medical databases. The results indicated that being married was inversely associated with preventable hospitalization. This finding is consistent with previous studies, which reported that marriage has a beneficial effect on health because it can provide individuals with social support and married individuals tend to experience less stress than their nonmarried counterparts [23–24].

Several limitations of the current study exist. First, the generalizability of our findings is limited by our focus on a single geographic region across the VA healthcare system. Second, our study patients were veterans who were enrolled in the VA healthcare system only. As a result of the unique characteristics of the VA patients (e.g., more male, older, more comorbid conditions) [18,25], our findings may not be applicable to the general population. In addition, all our patients were diagnosed with DM, a diagnosis that is associated with high rates of morbidity and mortality [26]. Patients with DM are two to five times more likely to be admitted for inpatient care than patients without DM [26], and patients with DM and concomitant comorbidities are at an increased risk of using greater resources [27–28]. As a result, the preventable hospitalization by DM patients may be higher than patients with other diagnoses.

CONCLUSIONS

Despite these limitations, our study results suggest that using information and communication technology to deliver health services, expertise, and information over a vast geographical distance and implementing home telehealth modalities may enhance users' timely accessibility to needed care, reduce preventable hospitalization use, and decrease direct and indirect medical costs over time. Additional research is necessary to examine and compare the long-term effect of home telehealth programs in patients with different medical diagnoses.

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