Original Research

Cost Comparison Between Home Telemonitoring and Usual Care of Older Adults: A Randomized Trial (Tele-ERA)

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Abstract

Background: *From 1992 to 2008, older adults in the United States incurred more healthcare expense per capita than any other age group. Home telemonitoring has emerged as a potential solution to reduce these costs, but evidence is mixed. The primary aim of the study was to evaluate whether the mean difference in total direct medical cost consequence between older adults receiving additional home telemonitoring care (TELE) (n = 102) and those receiving usual medical care (UC) (n = 103) were significant. Inpatient, outpatient, emergency department, decedents, survivors, and 30-day readmission costs were evaluated as secondary aim.* ***Materials and Methods:*** *Multivariate generalized linear models (GLMs) and parametric bootstrapping method were used to model cost and to determine significance of the cost differences. We also compared the differences in arithmetic mean costs.* ***Results:*** *From the conditional GLMs, the estimated mean cost differences (TELE versus UC) for total, inpatient, outpatient, and ED were −$9,537 (p = 0.068), −$8,482 (p = 0.098), −$1,160 (p = 0.177), and $106 (p = 0.619), respectively. Mean postenrollment cost was 11% lower than the prior year for TELE versus 22% higher for UC. The ratio of mean cost for decedents to survivors was 2.1:1 (TELE) versus 12.7:1 (UC).* ***Conclusions:*** *There were no significant differences in the mean total cost between the two treatment groups. The TELE group had less variability in cost of care, lower decedents to survivors cost ratio, and lower total 30-day readmission cost than the UC group.*

Key words: *cost comparison, home telemonitoring, older adult, telemedicine, 30-day readmission*

Introduction

From 1992 to 2008, older adults in the United States, 65 years of age and older, incurred more healthcare expense per capita than any other age group. The average annual health expenditure for those with five or more chronic conditions was $24,658, compared with only $5,520 for those with no chronic condition.[1] Home telemonitoring has emerged as a potential solution to reduce the cost of care for older adults with chronic conditions.

There is mixed evidence as to whether home telemonitoring can reduce total cost of care, and the results depend on the cost elements included. Although a recent study of telehealth for patients with long-term conditions (e.g., congestive heart failure [CHF], chronic obstructive pulmonary disease, or diabetes) indicated an insignificant total cost difference, the mean total cost of care at the 12-month follow-up was $360 lower (standardized difference of 11.6%) for telemonitoring care ($n = 431$) compared with usual care ($n = 538$) when the intervention cost was excluded and $308 (9.9%) higher when it was included.[2] In a home telecare study of CHF patients, the mean total costs of care (all causes) in the telecare group (mean [standard deviation (SD)]: $5,850 [$21,094], $n = 13$) and telephone care group ($7,320 [$24,440], $n = 12$) interventions trended lower but were not significantly different than those for usual care ($44,479 [$121,214], $n = 12$). However, the mean costs of CHF-related emergency department (ED) visits for both interventions were significantly lower than those for usual care (mean [SD]: telecare, $399 [$1,438]; telephone care, $1,036 [$2,387]; usual care, $2,882 [$4,166]; $p = 0.0487$).[3] In patients with multimorbidity, we have even less evidence.

In this study, we are interested in evaluating the differences in the total standardized direct medical cost (or "total cost") during 12 months postenrollment between the telemonitoring care (TELE) group and the usual medical care (UC) group. The initial findings of the Tele-Elder Risk Assessment (ERA) trial indicated a lack of significant differences in the mean inpatient and ED visits and in hospital days between patients in the TELE and UC groups.[4]

Materials and Methods

TRIAL DESIGN AND STUDY POPULATION

The full details of the study protocol and population can be found in our earlier publications and are summarized here.[4,5] We randomized a total of 205 participants ≥60 years (TELE group, $n = 102$; UC group, $n = 103$), all of whom lived in Southeastern Minnesota and

were enrolled in the Employee and Community Health primary care panel at the Mayo Clinic (Rochester, MN). Eligible patients were identified based on their ERA Index score, which stratifies all patients for risk of hospitalizations and ED visits based on administrative data such as age, sex, previous hospitalizations and ED visits, and comorbid conditions.[6] The study excluded patients who lived in a nursing home, had dementia, scored less than 29 on the Kokmen short test of mental status,[7] were unable to give informed consent, or were unable to use the telemonitoring equipment. The 12-month trial used a staggered entry approach from November 2009 through July 2011. The study was approved by the Mayo Clinic Institutional Review Board, and secondary analysis was also approved by Purdue University (West Lafayette, IN).

INTERVENTION

UC group participants had access to the same services as all primary care patients at Employee and Community Health (e.g., primary care and specialty office visits, phone services, and home healthcare). Participants in the TELE group had access to usual medical care plus additional telemonitoring case management, which involved the Intel® (Santa Clara, CA) Health Guide telemonitoring device along with other peripheral equipment (e.g., weight scale, blood pressure cuff, glucometer, and pulse oximeter). Vital sign measurement and real-time videoconference protocols were based on the participant's specific medical conditions. Vital sign measurements were automatically transmitted and downloaded to the Web-based Intel Health Suite for access by the provider.[5,8] RNs evaluated the transmitted information daily and called or held a videoconference with patients as needed. Participants were advised to call 911 for emergencies and/or visit the ED because the telemonitor was not a lifesaving device.[5]

PRIMARY AND SECONDARY AIMS

The primary aim was to compare the estimated total standardized cost per participant between the TELE and UC groups. The secondary aim was to compare subcategories of total cost: inpatient, outpatient, ED, the mean cost for decedents and survivors, and total 30-day readmission costs. We hypothesized that the mean total cost and the individual cost subcategory for the TELE group was different than those for the UC group.

DATA COLLECTION

The first set of data was collected for use as covariates for the analysis of differences in mean inpatient, outpatient, ED, and total costs. The participants' baseline characteristics, consisting of age, sex, race, and marital status, were collected through a questionnaire at an initial home visit. The baseline frailty status had been previously assessed in an earlier publication.[9] The prior 5-year history of chronic diseases (i.e., cancer, diabetes, dementia, stroke, chronic obstructive pulmonary disease, coronary artery disease, myocardial infarction, CHF, and renal insufficiency) was obtained from the electronic medical records. All of the included chronic diseases, except renal insufficiency, had been previously determined to be key predictors of future hospitalizations and ED visits in the elderly population.[6]

The 12-month pre- and postenrollment direct medical cost data were obtained from the Olmsted County Healthcare Expenditure and Utilization Database, which contained detailed patient-level administrative data on healthcare utilization and the associated cost of care at the Mayo Clinic and other local hospitals. This research database provided a standardized inflation-adjusted estimate of the costs up to 2011 constant dollar that represented the national cost norms, of each service or procedure provided by using a widely accepted valuation technique.[10]

Intervention cost was estimated using the May 2011 national average, annual wage for one full-time equivalent RN and medical assistant.[11] During the trial, GE Healthcare (Little Chalfont, UK) covered the cost of Internet services, and Intel Corporation provided the equipment at no charge. However, we included the 2011 cost for DSL service in the area and our estimate of the telemonitoring equipment rental fee. The intervention cost was prorated for each participant in the TELE group based on the number of days he or she was actively participating in the trial.

We also reported participants' mortality status. For participants who died during the study, the date of death was obtained from the electronic medical record, and the cause of death was obtained from the Anatomic Pathology Department. We (G.J.H, P.Y.T.) assessed whether the cause of death was acute or related to a chronic condition based on the death certificate.

STATISTICAL ANALYSIS

All analyses were performed according to original group assignment at the time of randomization using an intent-to-treat approach. The baseline characteristics of the two treatment groups were compared by using a two-sample *t* test, Pearson chi-squared test, and Fisher's exact test. We computed the arithmetic mean, interquartile range, and percentage of total cost for all participants and by treatment group for the pre- and postenrollment periods. Total cost was also grouped by survival status. We conducted multivariate analyses using generalized linear models (GLMs) to statistically compare the cost between the two treatment groups.[12–14]

We compared the postenrollment difference between them by modeling inpatient, outpatient, and ED costs separately and summed up those differences to obtain the total cost difference. These models included age, sex, race, mortality status at the end of trial, telemonitoring status, frail and prefrail status indicator at baseline, prior year standardized direct medical cost, and various chronic disease indicators as described in the Data collection section.

Outpatient cost was modeled using a GLM with gamma distribution and a power 0.2 link, which is between a square root transformation (power 0.5 link) and log transformation (power 0 link or log link).[15,16]

Inpatient and ED costs were determined using a two-part model because many participants incurred no costs.[13,17,18] The first part estimated the probability of having a positive cost using a logistic regression model, and the second part estimated cost in participants whose cost was positive using GLM with gamma distribution and log link. The unconditional predicted cost was obtained by multiplying

the probability and the expected cost.[16] The modified Park test was used to determine the appropriate family of distribution.[17,19,20] The suitable link functions were identified using two goodness of link tests (Pregibon link test[21] and modified Hosmer-Lemeshow test[22]).

The estimated mean inpatient, outpatient, and ED costs were predicted based on the full sample model by using the recycled prediction method,[15,17,23] and these predictions were used to compute differences in the estimated mean costs between the two groups. The confidence intervals and *p* values of the cost difference were generated by using the parametric bootstrapping method with 2,000 replicates.[24–27]

The analyses were conducted using STATA version 12.1 software (StataCorp, College Station, TX). We had no censored cost data. All active participants remained in the same city throughout the trial period, even for those who withdrew from active participation. No data were missing. Death was not a censoring event; those who passed away during the trial had a known cost of nothing after their passing.

Results

STUDY POPULATION

The telemonitoring and the usual care groups had similar baseline characteristics (*Table 1*).

Table 1. Baseline Characteristics

	TOTAL (*N* = 205)	TELE (*N* = 102)	UC (*N* = 103)	*P* VALUE
Age (years) [mean (SD)]	80.2 (8.2)	80.3 (8.8)	80.2 (7.7)	0.958
Male	94 (45.8)	50 (49.0)	44 (42.7)	0.365
Nonwhite race	4 (2.0)	4 (3.9)	0	0.059
Married	96 (46.8)	47 (46.1)	49 (47.6)	0.830
Nonfrail	79 (38.5)	33 (21.4)	46 (44.7)	0.070
Prefrail	94 (45.9)	52 (51.0)	42 (40.8)	0.143
Frail	32 (15.6)	17 (16.7)	15 (14.6)	0.678
History of chronic diseases				
Cancer	120 (58.5)	64 (62.7)	56 (54.4)	0.224
CAD/MI/CHF	174 (84.9)	86 (84.3)	88 (85.4)	0.822
COPD	99 (48.3)	52 (51.0)	47 (45.6)	0.443
Dementia	27 (13.2)	16 (15.7)	11 (10.7)	0.289
Diabetes	119 (58.0)	57 (55.9)	62 (60.2)	0.532
Renal insufficiency	73 (35.6)	35 (34.3)	38 (36.9)	0.700
Stroke	83 (40.5)	39 (38.2)	44 (42.7)	0.513

Data are number (%) except as indicated.

CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; SD, standard deviation; TELE, telemonitoring care group; UC, usual medical care group.

TREATMENT GROUP COMPARISON (POSTENROLLMENT)

From the conditional GLM and two-part models that included all the covariates as described in Materials and Methods section, the estimated difference in mean total, inpatient, outpatient, and ED cost per participant between the TELE and UC groups indicated no significant difference at alpha of 0.05 (*Table 2*). We found that estimated mean total cost in the TELE group was $19,239 compared with $28,776 in the UC group ($p = 0.068$). Although the differences in mean total, inpatient, and outpatient costs were lower for the TELE group, the variability in the data was high as reflected by the large SD ($5,218, total; $5,128, inpatient; $861, outpatient), as per *Table 2*. The numbers of participants who incurred no inpatient, ED, and outpatient costs were 107 (58 TELE, 49 UC), 129 (59 TELE, 79 UC), and 1 (TELE), respectively.

PRE- AND POSTENROLLMENT COMPARISON

The arithmetic mean, interquartile range, and a percentage breakdown of the direct medical cost consequence for the 12-month pre- and postenrollment periods are shown in *Table 3*. Within group comparisons between the pre- and postenrollment periods revealed that the mean total post-enrollment cost for the TELE group dropped by $2,467 but rose by $4,836 for the UC group. The reduction in cost for the TELE group was across all categories, with the biggest drop in the mean outpatient cost ($1,896). The increase in average cost for the UC group was due to higher average inpatient cost ($5,151) and less substantial cost reductions in outpatient and ED categories. The one area where the UC group had a higher mean cost reduction was in the outpatient primary care category.

If all the telemonitored participants completed the trial, then the average estimated intervention cost would be $983 per person. Because 15 deaths occurred in this group, the prorated intervention cost reduced to $837 per person. The national average wage for an RN and medical assistant was $69,110 and $30,170, respectively.[11] The 2011 local cost for DSL service was $29.99 per month, and the expected telemonitoring equipment rental cost was $50 per person.

Table 2. Estimated Mean Direct Medical Cost Consequence per Participant from Conditional Model

	TELE	UC	DIFFERENCE (TELE–UC)	STANDARD ERROR[a]	95% CI OF DIFFERENCE	*P* VALUE
Inpatient	12,943	21,425	− 8,482	5,128	(− 18,532, 1,568)	0.098
Outpatient	5,589	6,750	− 1,160	861	(− 2,848, 527)	0.177
ED	707	601	106	213	(− 312, 524)	0.619
Total	19,239	28,776	− 9,537	5,218	(− 19,673, 689)	0.068

Generalized linear models included covariates as described in the Data collection section. Cost values are in U.S. dollars.

[a]Standard error and standard deviation were equivalent because each bootstrap replicate represents a mean cost difference, and we are summing the differences.

CI, confidence interval; ED, emergency department; TELE, telemonitoring care group; UC, usual medical care group.

Table 3. Pre- and Postenrollment Mean Cost per Participant by Category

	TOTAL			TELE			UC		
	MEAN COST	INTERQUARTILE RANGE (Q1, Q3)	%	MEAN COST	INTERQUARTILE RANGE (Q1, Q3)	%	MEAN COST	INTERQUARTILE RANGE (Q1, Q3)	%
Pre-enrollment									
Inpatient	14,335	(0, 20,397)	64.5	13,858	(0, 20,165)	63.1	14,807	(0, 20,624)	66.0
Outpatient	7,134	(1,936, 8,576)	32.1	7,186	(1,839, 8,426)	32.7	7,082	(1,946, 9,305)	31.6
Primary care	439	(190, 558)	2.0	470	(222, 671)	2.1	408	(162, 530)	1.8
Specialty care	651	(235, 932)	2.9	701	(260, 1,085)	3.2	601	(230, 799)	2.7
Other	6,044	(1,164, 7,044)	27.2	6,015	(1,077, 6,757)	27.4	6,073	(1,165, 8,576)	27.1
ED	743	(0, 939)	3.3	932	(0, 1,233)	4.2	556	(0, 537)	2.5
Total	22,212	(3,586, 30,344)	100.0	21,977	(2,900, 30,344)	100.0	22,445	(4,723, 30,444)	100.0
Post-enrollment									
Inpatient	16,733	(0, 14,754)	71.5	13,476	(0, 14,280)	69.1	19,958	(0, 16,768)	73.2
Outpatient	6,041	(1,780, 7,644)	25.8	5,290	(1,818, 6,839)	27.1	6,786	(1,605, 8,899)	24.9
Primary care	407	(167, 580)	1.7	451	(200, 586)	2.3	364	(136, 571)	1.3
Specialty care	471	(106, 607)	2.0	411	(110, 583)	2.1	530	(103, 674)	1.9
Other	5,163	(1,112, 6,529)	22.1	4,427	(1,102, 5,640)	22.7	5,891	(1,112, 7,551)	21.6
ED	640	(0, 801)	2.7	744	(0, 1,032)	3.8	537	(0, 659)	2.0
Total	23,414	(2,949, 24,315)	100.0	19,510	(2,996, 24,553)	100.0	27,281	(2,718, 24,315)	100.0
Difference									
Post – pre	1,202		5.4	− 2,467		− 11.2	4,836		21.5
Intervention									
Equipment rental, Internet service, and support staff	837	(983, 983)	3.5	837	(983, 983)	4.3	0	(0, 0)	0.0
Total postenrollment with intervention	23,831	(3,529, 24,315)	100.0	20,346	(3,979, 25,535)	100.0	27,281	(2,718, 24,315)	100.00

Mean computation is based on arithmetic mean. Estimated intervention cost was prorated. Cost values are in U.S. dollars.

ED, emergency department; Q, quartile; TELE, telemonitoring care group; UC, usual medical care group.

DECEDENT AND SURVIVOR COMPARISONS (POSTENROLLMENT)

The inpatient, outpatient, ED and intervention costs during the trial were aggregated by mortality status (*Table 4*). The ratio of mean cost for decedents to survivors was 2.1 to 1 for the TELE group and 12.7 to 1 for the UC group. Mortality incidences (15 TELE, 4 UC)[4] occurred at least once a month except for 1 month. The average number of days that decedents were alive during the trial was 203 days for the TELE group and 198.5 days for the UC group.

Of the 15 decedents in the home telemonitoring group, the cause of death for 8 participants was related to a chronic condition that could have been impacted by the telemonitoring intervention. The cause for

Table 4. Mean Inpatient, Outpatient, and Emergency Department Costs per Participant by Mortality Status

	TELE		UC	
	MEAN COST	INTERQUARTILE VALUES (Q1, Q3)	MEAN COST	INTERQUARTILE VALUES (Q1, Q3)
Decedents	35,180	(4,200, 63,792)	237,929	(15,746, 460,112)
Survivors	16,808	(2,949, 21,274)	18,770	(2,178, 23,711)
Ratio	2.1		12.7	

Cost values are in U.S. dollars.

Q, quartile; TELE, telemonitoring care group; UC, usual medical care group.

the rest was due to cancer or other acute symptoms unrelated to home telemonitoring.

30-DAY READMISSION COST

Because of the current focus by Centers for Medicare and Medicaid Services in reducing 30-day hospital readmissions, we estimated the inpatient cost associated with all readmissions within 30 days of discharge to be $253,150 for the TELE group (22 events from 72 discharges) and $482,612 for the UC group (13 events from 60 discharges).

Discussion

We found no significant difference in mean estimated total costs and the three main cost components between the two treatment groups. Given that inpatient costs made up more than two-thirds of the total cost and that outpatient costs made up about one-fourth, we anticipated significant cost savings for the TELE group. Approximately 50% of both cohorts incurred no inpatient costs, and the UC group's SD was more than twice as high as the TELE group's. Similarly, the CHF telecare study,[3] which had a nonsignificant total cost difference, reported that at least 50% of the cohort had no hospitalizations and ED costs, and the SD for their usual care group was almost four times higher than for their telecare group. This large variability likely reflects variations in hospital stays within both groups. We did not find an overall difference in costs because the telemonitoring intervention did not reduce combined hospitalization and ED stays, with 64% suffering an event in telemonitoring and 57% in usual care.[4] We had a small sample size, which could have contributed to a lack of power to detect an effect and contributed to the wide variability. It is possible that telemonitoring intervention in this high-risk population is ineffective because the clinical management models could not effectively integrate this information.

The individual cost components were not statistically different between the TELE and UC groups. The 40% lower estimated mean inpatient cost for the TELE group over the UC group was believed to be due to the higher variability in the number of hospital days per person for the UC group (mean [SD]: TELE = 4.1 [8.1], UC = 6.1 [20.1]; $p = 0.61$).[4] Several participants in the UC group had long hospital stays, which drove up the cost. Early detection of health issues by primary care providers through home telemonitoring may lead to a more predictable average of annual hospital days and possibly the length of stay; however, this would require a larger study with greater numbers of patients. Quite possibly, a larger cohort of patients with less severe illnesses could lead to greater cost savings. The 17% lower estimated mean outpatient costs for the TELE group was in line with our assumption that this intervention could replace the need for some outpatient visits. The 18% higher estimated mean ED cost for the TELE group was a reflection of a shift from inpatient or outpatient visits to ED visits and of the trial protocol, which asked participants to call 911 and/or visit the ED in case of an emergency. Alternate care models may reduce this cost in the future.

We found a higher mean cost for decedents compared with survivors. Past literature has consistently demonstrated that Medicare beneficiaries have much higher medical costs during their last year of life.[28–30] In 2006, the mean Medicare payment per decedents was 6.5 higher than survivors ($38,975 versus $5,993). The cost ratio of decedents to survivors declined very little over each decade (7.2 in 1978, 6.7 in 1988, and 6.5 in 1997).[30] The relatively lower cost ratio for the TELE group compared with the UC group is encouraging. The TELE group had a trend toward enrollment into hospice, which impacted total costs of care.[4] As discussed, there was wide variability in hospital stay, and this higher ratio in the UC group may reflect exceptional patients. The impact of advanced care planning may also have varied but was not collected during the study.

This study has several key strengths and weaknesses. The first strength is that it is a randomized controlled trial (RCT), and the groups are similar. Other strengths included the use of standardized inflation-adjusted estimate of the costs and reported costs from two healthcare perspectives: (a) modeling, which estimated costs and standard errors for between-group comparisons; and (b) actual cost, which used arithmetic mean and interquartile range to describe costs by categories and mortality state. One of the main weaknesses of our study is the inability to fully assess the cost of the home telemonitoring program because the telemonitoring devices were provided free of charge.[5] We anticipate that as home telemonitoring technology advances and becomes more prevalent, the equipment costs will continue to decline.[31] Our rationale is that we can justify having a program if the cost is lower or equal to the cost savings found. Another weakness is the omission of a measure of potential effect of the intervention on clinical outcomes, such as quality of life, due to the previously reported lack of difference in the mean SF-12 physical quality of life score between the study groups.[4,32] Lastly, the small scale of this study yielded wide variability in hospital length of stay and cost estimates. Larger studies may help to reduce this wide variability.

Conclusions

Among high-risk and seriously ill elderly patients, the estimated inpatient, outpatient, ED, and total costs between our TELE and UC groups were not statistically different. When compared with the prior year, there is a trend toward a positive difference in total cost for the TELE group. The TELE group had less variability in cost of care and a smaller ratio of decedents to survivors than the UC group. These findings apply to a frail group of individuals with multiple medical problems. Potentially, a different cohort with higher readmission risk or subsets of high risk like heart failure may provide better outcomes at lower cost. Future research should shift to determining whether home telemonitoring can reduce cost associated with 30-day readmissions in the right subset of patients with the right care model. Potentially coupling telemonitoring with a home-based program would be an example. We can gain a more rapid understanding of the overall impact if we simultaneously study different segments of the patient population at various readmission risk level.

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Disclosure Statement

No competing financial interests exist.

B.U., W.K.K., and S.L.C. are responsible for analysis concept and design. B.U. is responsible for statistical analysis. B.U., W.K.K., D.L.W., and P.Y.T. are responsible for analysis and interpretation of data. All authors drafted the article, critically revised the manuscript, and approved the final version for submission.

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