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Enhanced registered nurse care coordination with sensor technology: Impact on length of stay and cost in aging in place housing

Marilyn Rantz, PhD, RN, FAAN[a,*], Kari Lane, PhD, RN[b], Lorraine J. Phillips, PhD, RN[b], Laurel A. Despins, PhD, RN, ACNS-BC[b], Colleen Galambos, PhD, MSW, ACSW, LCSW-C[c], Gregory L. Alexander, PhD, RN, FAAN[b], Richelle J. Koopman, MD, MS[d], Lanis Hicks, PhD[e], Marjorie Skubic, PhD[f], Steven J. Miller, MA[b]

[a] Sinclair School of Nursing and Family and Community Medicine, University of Missouri, Columbia, MO
[b] Sinclair School of Nursing, University of Missouri, Columbia, MO
[c] School of Social Work, University of Missouri, Columbia, MO
[d] Department of Family & Community Medicine, School of Medicine, University of Missouri, Columbia, MO
[e] Health Management and Informatics, School of Medicine, University of Missouri, Columbia, MO
[f] Electrical and Computer Engineering, University of Missouri, Columbia, MO

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ABSTRACT

Background: When planning the Aging in Place Initiative at TigerPlace, it was envisioned that advances in technology research had the potential to enable early intervention in health changes that could assist in proactive management of health for older adults and potentially reduce costs.

Purpose: The purpose of this study was to compare length of stay (LOS) of residents living with environmentally embedded sensor systems since the development and implementation of automated health alerts at TigerPlace to LOS of those who are not living with sensor systems. Estimate potential savings of living with sensor systems.

Methods: LOS for residents living with and without sensors was measured over a span of 4.8 years since the implementation of sensor-generated health alerts. The group living with sensors ($n = 52$) had an average LOS of 1,557 days (4.3 years); the comparison group without sensors ($n = 81$) was 936 days (2.6 years); $p = .0006$. Groups were comparable based on admission age, gender, number of chronic illnesses, SF12 physical health, SF12 mental health, Geriatric Depression Scale (GDS), activities of daily living, independent activities of daily living, and mini-mental status examination scores. Both groups, all residents living at TigerPlace since the implementation of health alerts, receive registered nurse (RN) care coordination as the standard of care.

Discussion: Results indicate that residents living with sensors were able to reside at TigerPlace 1.7 years longer than residents living without sensors, suggesting that proactive use of health alerts facilitates successful aging in place. Health alerts, generated by automated algorithms interpreting environmentally

* *Corresponding author:* Marilyn Rantz, Sinclair School of Nursing, University of Missouri, 2440 Shady Hills Lane, Rocheport, MO 65279.
E-mail address: rantzm@missouri.edu (M. Rantz).
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embedded sensor data, may enable care coordinators to assess and intervene on health status changes earlier than is possible in the absence of sensor-generated alerts. Comparison of LOS without sensors TigerPlace (2.6 years) with the national median in residential senior housing (1.8 years) may be attributable to the RN care coordination model at TigerPlace. Cost estimates comparing cost of living at TigerPlace with the sensor technology vs. nursing home reveal potential saving of about $30,000 per person. Potential cost savings to Medicaid funded nursing home (assuming the technology and care coordination were reimbursed) are estimated to be about $87,000 per person.

Conclusions: Early alerts for potential health problems appear to enhance the current RN care coordination care delivery model at TigerPlace, increasing LOS for those living with sensors to nearly twice that of those who did not. Sensor technology with care coordination has cost saving potential for consumers and Medicaid.

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Introduction

Aging in Place (AIP) is a term used to describe the ability of a person to live in one's own home and community independently regardless of age, income, or ability (Centers for Disease Control and Prevention [CDC], 2013). One of the goals of the University of Missouri's (MU) AIP initiative, TigerPlace, was to build an ideal housing community encompassing the AIP model. Collaboration with Americare Systems Inc., and state legislation in 1999 and 2001, allowed a facility of 54 apartments to be built to nursing home standards and licensed as an intermediate care facility with waivers to operate as an AIP facility. TigerPlace is operated as an independent housing with health care and support added or removed as the individual requires through the end of life, without the need to move to traditional nursing home for care (Rantz et al., 2011).

At TigerPlace, Sinclair Home Care, a home care agency operated by the MU Sinclair School of Nursing for the AIP initiative, provides routine assessment, wellness activities, social work services, exercise classes, health promotion activities, and veterinary services. Registered nurse (RN) staff are on-call 24 hr per day 7 days a week to assist with triaging any emergency situations and operate a wellness clinic that is open Monday to Friday 9 a.m. to 4 p.m. Residents can receive health care information and assistance in the clinic. In addition, an RN care coordinator works with all health care staff to manage care for the residents and communicate changes in condition to primary care providers (PCP). The AIP initiative has undergone extensive evaluation of the RN Coordination model of care offered first in the community (Marek et al., 2010; Marek, Popejoy, Petroski, & Rantz, 2006, Marek et al., 2005; Marek, Stetzer, Adams, Popejoy, & Rantz, 2012), then within TigerPlace (Rantz et al., 2011; Rantz et al., 2014a). Results have been reported in prior publications and revealed the Initiative is effective in restoring health and maintaining independence while being cost effective. All residents at TigerPlace receive the RN Care Coordination model of care that has been previously evaluated and reported.

The Center for Eldercare and Rehabilitation Technology (CERT) in the College of Engineering at the MU developed an embedded sensor system to assist with health status trend monitoring. All sensors are non-wearable and do not require the resident actively "do anything" with the sensors; this feature has proven essential to continuously living with the sensors for years that has enabled the research and development. The health sensors include 1) bed sensor (fits under the mattress with no active engagement by the resident) to monitor heart rate, respiratory rate, and nighttime bed restlessness; 2) motion sensors to monitor activity in rooms; and 3) Kinect depth images to automatically monitor walking and gait parameters and report falls in real time with alerts emailed to direct care staff (Rantz et al., 2015).

Computer algorithms are designed to determine differences in health patterns compared to the previous 14 day period (Skubic, Guevara, & Rantz, 2015). This occurs without any human intervention. Pattern changes in sensor data that generate alerts were developed through research and are associated with certain illnesses (Rantz et al., 2012). For example, elevated heart rate coupled with increased nighttime bed restlessness often indicates worsening congestive heart failure; or increased nighttime bed restlessness and increased time in the bathroom has often lead to early detection of a urinary tract infection. Increased activity in the apartment during the evening or nighttime hours or leaving the apartment in the middle of the night may indicate changes in dementia behaviors such as wandering. Reduced activity in the apartment and increased time in bed or recliner chair may indicate an onset of depression.

Health alerts are automatically triggered by the computer algorithms to detect changes in trends in each resident's sensor data that may indicate a change in health status. These alerts are intended to notify health care providers of potential illness or functional decline so interventions could be introduced earlier to improve health outcomes. An RN Care Coordinator and Social Worker at TigerPlace review the health alerts to determine if additional assessment is needed. After completion of additional assessment, an RN Care Coordinator contacts the resident's primary care provider (PCP) to review the health status change or initiate a PCP visit. Staff are able to use embedded sensor technology with *some of residents* to assist in their care coordination (Rantz et al., 2010) because about 40% to 50% of the residents voluntarily participate in the sensor technology development research.

When planning the AIP initiative at TigerPlace, it was envisioned that technology research had the potential to enable early intervention in health changes that could assist in proactive management of health for older adults. Thus far, research results at TigerPlace have been positive with better 3-, 6-, and 12-month functional outcome measures for those living with sensors; and multiple illnesses such as pneumonia, upper respiratory infections, congestive heart failure, posthospitalization pain, delirium, hypoglycemia, and urinary tract infections are often detected by the sensor alerts (Rantz et al., 2012). However, longitudinal evaluation has not been undertaken. One common measure in long-term care, length of stay (LOS) has potential to evaluate a longitudinal outcome that could be affected by the use of health alerts. Nationally, the median of LOS in residential senior living is just below 2 years, 22 months (Caffrey et al., 2012). Most (about 60%) are discharged to nursing homes, about one-third die, and the remainder move home or to another residential senior living site (AAHSA, AHSA, ALFA, NCAL, & NIC, 2009).

This research brief will present a retrospective secondary analysis of the LOS differences between residents living with environmentally embedded sensor systems since the development and implementation of automated health alerts at TigerPlace and those who did not. A cost analysis of the potential savings with the use of in-home sensors and early illness detection will be described.

Methods

All research at TigerPlace, including the sensor research, is approved by the University's Institutional Review Board. Residents provide informed consent to participate in the sensor research. All residents also provide informed consent on admission to TigerPlace for the use of deidentified health and demographic data to inform current and future research and evaluations; this facilitates the analysis of comparison groups (Rantz et al., 2014a; Rantz, Popejoy, Musterman & Miller, 2014b). Analysis of this LOS comparison has institutional review board approval.

The sample was selected from the population of all residents who have lived at TigerPlace since it opened in 2004, those who voluntarily chose to participate in the sensor research and live with the sensor systems embedded in their apartments and those who did not. Research and installations began in October 2005 when all residents who were living in TigerPlace at the time had the opportunity to consent and participate. The cost of the sensors was covered by research grants, so there were no sensor expenses for participants. The sensor research has progressed continuously since 2005; as participating residents died or are discharged, those living there were offered the opportunity to participate on a first come, first served basis. All residents have the opportunity to request to participate, as they are informed of the sensor and other research in progress on admission. Requests for enrollment in the sensor research have been accommodated within a matter of weeks of individual requests. This approach results in continuous enrollment of 21 to 25 residents in the research; this level of enrollment continues today. Sensors are easily relocated from apartment to apartment, so location of enrollees varies throughout the entire building.

Sensor research progressed from initial developmental work (Skubic, Alexander, Popescu, Rantz, & Keller, 2009) to automated health alerts derived by the sensor data (Rantz et al., 2012). The automated health alerts were implemented for clinical use in March 2010. Therefore, *all residents discharged before* March 1, 2010, *before health alerts*, were *excluded* ($n = 48$) from the potential sample for the sensor alert group (intervention) or the comparison group for this retrospective analysis. There have been three dropouts from sensor research: one resident lived with sensors for several years and withdrew near the end of his life and one couple withdrew from a specific sensor study, shortly after enrollment because of the "appearance and location of the fall detection sensor." Both of these situations occurred before the availability of health alerts and were therefore excluded.

Exclusion resulted in a sensor alert group who lived at TigerPlace sometime from March 1, 2010, to December 31, 2014, ($n = 52$; range of admission date, 2004–2014) and *who lived with sensors in addition to usual care*. The comparison group was all remaining residents after the exclusion, not living with sensors, and therefore no health alerts ($n = 81$; range of admission date, 2004–2014), who also had complete access to usual care at TigerPlace (the RN care coordination model) sometime from March 1, 2010, to December 31, 2014.

For the sensor alert group, care coordinators received health alerts and followed up as they determined appropriate with early assessments and interventions to resolve the potential health changes. Examples of early assessments frequently used include general observation of signs of respiratory illness, shortness of breath with walking or at rest, ankle swelling, or more specific observations based on the nurse's knowledge of the health conditions and medication use of a particular person. Frequently used interventions are targeted to the health condition detected from the assessment with reporting of the early symptoms of the condition to the primary care provider as needed for early treatment.

Characteristics of residents who live at TigerPlace are typical of older persons who live in residential senior living in the Midwestern United States. Typically, about 71% are female, and about 4% are ethnically diverse (Asian is most common). About 80% of residents have at least one chronic disease, and many have more than one. The most common chronic diseases include diabetes, heart disease, arthritis, depression, and dementia. Some residents use assistive devices such as canes or wheelchairs to assist with mobility.

LOS was analyzed based on each person's date of admission (2004–2014) until their discharge and analyzed in two groups, those living with and without sensors since March 2010 to December 2014. (Recall health alerts for clinical use were implemented March 2010.) Descriptive statistics were summarized for both groups. LOS in days between groups was tested using the Satterthwaite method for *t* test in SAS due to slightly different variances between groups. Both groups were tested for homogeneity using regression analysis, and the groups were found to be homogeneous. Demographics, descriptive characteristics, and results are summarized in Table 1. Costs were analyzed comparing the cost of living the additional years at TigerPlace or in one's own home with skilled nursing home.

Findings

The group living with sensors ($n = 52$) was comprised of 35 females and 17 males with an average age of 83 years and an average of five chronic illnesses. The average LOS for the sensor group was 1,557 days (4.3 years). The comparison group ($n = 81$) was comprised of 51 females and 30 males, with an average age of 84 years and an average of four chronic diseases. The average LOS for the comparison group was 936 days (2.6 years). Results of *t* test were completed comparing the intervention group to the comparison group. The *t* test score was 3.55 with a $p = .0006$.

As indicated in Table 1, none of the descriptive characteristics were significantly different between groups on admission. These included admission age, gender, chronic illnesses, SF12 physical health, SF12 mental health, Geriatric Depression Scale, activities of daily living, independent activities of daily living, and mini-mental status examination, routinely collected for all TigerPlace residents on admission and every 6 months for ongoing evaluation of the AIP initiative (Rantz et al., 2014a).

Table 1 – Descriptive Characteristics of Residents Living with and without Environmentally Embedded Sensor Systems

Characteristic	Residents with Sensors ($n = 52$)	Residents without Sensors ($n = 81$)
Gender, *n* (%)		
Male	17 (33)	30 (37)
Female	35 (67)	51 (63)
Age	83	84
Number of chronic diseases	5	4
SF-12 PH	40.96	41.02
SF-12 MH	52.55	52.45
MMSE	26.31	25.31
GDS	2.98	2.90
ADL	4.19	4.33
IADL	6.54	6.94
LOS days	1,557* (4.3 years)	936 (2.6 years)

ADL, activities of daily living; GDS, Geriatric Depression Scale; IADL, independent ADL; LOS, length of stay; MMSE, mini-mental status examination scores.
Higher scores for SF-12 PH, SF-12 MH, and MMSE indicate better status. Score ranges for these assessments are 0–100, 0–100, and 0–30, respectively. SF-12 PH and SF-12 MH scores have been standardized to a mean of 50 and a standard deviation of 10. Lower scores for GDS, ADL, and IADL indicate better status. Score ranges for these assessments are 0–15, 0–36, and 0–32, respectively.
* $p = .0006$. All other comparisons of baseline characteristics between sensor and nonsensor groups were not significant at the $p < .05$ level.

The average cost to the consumer was computed for the additional 1.7 years of stay at TigerPlace with the added cost of the in-home sensor system. In Table 2, this cost is them compared to 1.7 years in a nursing home, using the average cost across the US (Genworth, 2014). Next, the potential cost savings to Medicaid-funded nursing home were estimated if seniors are able to stay in their own homes for an additional 1.7 years. Cost savings were projected assuming that the AIP technology (in-home sensor system) and the care coordination are reimbursed. As seen in Table 3, these

Table 2 – Cost Comparison of TigerPlace (independent living) vs. Skilled Nursing for 1.7 years

Projections	Components	Total
Average yearly cost at TigerPlace	$60,000	
Yearly sensor cost	$2,400	
Total yearly cost	$62,400	
1.7 years independent living		$106,080
Average yearly cost in skilled nursing*	$80,000	
1.7 years skilled nursing		$136,000
Cost savings per person		**$29,920**

* Genworth 2014 Cost of Care Survey

Table 3 – Reimbursement Cost Comparison of Aging in Place in Your Own Home with Technology and Care Coordination vs. Medicaid-Funded Nursing Home

Projections	Components	Total
Yearly sensor cost	$2400	
Yearly care coordination	$1800	
Yearly cost AIP in your home	$4200	
1.7 years AIP in your home		$7,140
Average yearly cost of long-term care paid by Medicaid in Missouri ($152/day)*	$55,480	
1.7 years long-term care		$94,316
Cost savings per person		$87,176

* Missouri DHSS, 2015

costs are relatively small compared to the average cost of nursing home care paid by Medicaid. For comparison purposes, the average Medicaid cost in Missouri was used (Missouri DHSS, 2015).

Discussion/Recommendations

Key findings from this analysis are important for the application of technological solutions to assist older adults to age in place, in the least restrictive environment of their choice. Increasing LOS, from an average of 2.6 years for residents of TigerPlace to 4.3 years through proactive use of health alerts, is an appealing opportunity to help older adults and health care staff make early assessments of impending health status change, particularly when the health alerts are generated by automated algorithms interpreting environmentally embedded sensors that do not require that people actively "do something" with technology. Having an early alert system to "pay attention" for a potential health problem appears to enhance the current care coordination delivery model at TigerPlace because those living with sensors had longer LOS than those who did not.

When conducting the research to develop the early health status change alerts, care coordinators told researchers that they thought the technology could enhance their decision-making (Rantz et al., 2010; Alexander et al., 2011). Both groups benefit from the usual care at TigerPlace that is based on research about RN care coordination from the Sinclair School of Nursing AIP research in the community (Marek et al., 2006; Marek et al., 2010; Rantz et al., 2014b). The evaluations of clinical outcomes and costs at TigerPlace demonstrated the effectiveness of the care model (Rantz et al., 2011; Rantz et al., 2014a). The care coordination model at TigerPlace appears to improve LOS for those *living without sensors* (2.6 years) as compared with the national median of 22 months (1.8 years) in residential senior housing (Caffrey et al., 2012). This finding adds to the evidence of the effectiveness of the care delivery model (Rantz et al., 2014b); however, the LOS *is even longer for those living with the sensors* (4.3 years).

The clinicians and research team envisioned being able to enhance the effectiveness of the care model with sensor technology (Rantz et al., 2010), but the technology was not anticipated to effect LOS to the apparent extent (from 2.6 to 4.3 years) that these longitudinal data reveal. It is unknown if simply adding sensors technology without coupling it with the care coordination model will have the same or similar effect. Care coordinators suggest that the sensors inform and enhance their decision-making and are likely best used in this way.

Applying the results for potential cost savings reveals opportunities for consumers and overall health care to reduce costs by remaining at home or in independent housing longer later in life. This is likely appealing to older adult consumers, their families, and public policy makers (Rantz, Popejoy, Musterman, & Miller, 2014).

Results must be interpreted with caution. This is a limited population of seniors, although representative of many seniors who live in residential senior housing. The sample is one of convenience because all who move to TigerPlace can choose to participate in the sensor research or not. Although groups were tested for homogeneity, the sample was not random. Future studies should address these issues, and a larger randomized study testing in-home sensor technology is currently underway in 12 assisted living facilities measuring more health and cost outcomes.

Undertaking technology research in a real-world setting where people live has many challenges, especially when the sensors are refined and tested, data collection and use moves to real time because clinicians want to use the information to inform clinical decision-making, and research and development are on-going! There are competing interests of goals for the technology from interdisciplinary team members. Clinicians want easy, fast use of the data within their workflow; students want interesting projects that will enable meeting their course of study requirements; researchers want preliminary data for designing larger scale studies or the opportunity to make an innovative technological advance even in the absence of an obvious apparent health care need; families and residents want the benefits of new technological advances that will enable better health and function with minimal to no interruption in daily life. The research is usually slow and iterative, making continual small improvements in programming, but sometimes it takes a major leap forward with a technological advancement that enables a new approach to a problem the team has been trying to solve for months or years.

The key essential ingredient for successfully undertaking this type of research is an interdisciplinary team of researchers who are committed to working together to solve some persistent problems. Our team of researchers includes several who are also clinicians in practice (nursing, physical therapy, medicine), engineers (computer and electrical, health management and informatics, and others), and the clinical staff (nurses and social worker) who work in the real-world environment of the elders who help the team by consenting to live with the sensors embedded in their apartments. Most members of our team have been working together for >10 years and are highly committed to solving some of the persistent problems of aging through early detection of changes in health.

Conclusions

Although a gross longitudinal outcome measure, LOS for older adults living with environmentally embedded sensor systems was significantly longer (4.3 years) than LOS for those who chose to not live with sensors (2.6 years). Technologically enhanced care coordination holds much promise for improving the health status and function of older adults and has potential cost saving benefits. It is envisioned that RN Care Coordination coupled with sensor technology in senior housing and private homes offers new, beneficial, cost-effective services for the future.

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