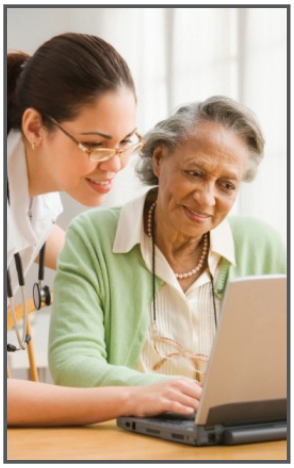

Center for
Technology and Aging

Technologies for Remote Patient Monitoring in Older Adults

Position Paper
Discussion Draft
December 2009

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Executive Summary

A majority of older adults are challenged by chronic and acute illnesses and/or injuries. Eight out of ten older Americans are living with the health challenges of one or more chronic diseases.[1] In addition, falls are the most common cause of nonfatal injuries and of hospital admissions for trauma among older adults. Remote patient monitoring (RPM) technologies have been shown to be effective in helping to manage chronic disease, post-acute care, and monitoring the safety of the older adult population. RPM technologies can help older adults slow progression of chronic disease and ensure continued recovery after being discharged from an acute care setting. RPM technologies can also alert caregivers and prompt intervention when a vulnerable older adult is injured or in harms way.

A number of remote patient monitoring technology-enabled innovations can improve the health and independence of older adults. The paper discusses two areas of opportunity for remote patient monitoring in this population: 1) Chronic Disease Management and Post-Acute Care Management and 2) Patient Safety. In alignment with the mission of the Center for Technology and Aging, this paper will focus on technology-enabled innovations predominantly aimed at improving the health of older adults and promoting independent living in community-based, home, and long-term care settings. Such technologies are used by patients and caregivers to principally improve self-management of care and enhance communication of patient information to clinicians. The technologies described in this report should be viewed as a limited sample and not an exhaustive list.

The U.S. health care system could reduce costs by nearly $200 billion during the next 25 years if remote monitoring tools were utilized in congestive heart failure, diabetes, chronic obstructive pulmonary disease (COPD), and chronic wounds or skin ulcers.[2] While chronic disease, post-acute care and injuries are not limited to this population, older adults are disproportionately affected by such problems. Greater access to proven remote patient monitoring technologies can lead to safer, more effective monitoring of health and safety among older adults. While remote patient monitoring solutions that reduce the cost and burden of illness among older adults currently exist, most are still widely underutilized. This paper discusses the benefits of broader diffusion of proven RPM technologies for older adults with chronic health conditions, their family caregivers, the long-term care workforce, and society at large.

Introduction

The Center for Technology and Aging is devoted to helping California and the nation more rapidly implement technologies that help older adults lead healthier lives and maintain independence. Of the many potential technology areas, this paper focuses on advancing technologies that improve Remote Patient Monitoring (RPM).[3] In January 2010, the Center will launch its Remote Patient Monitoring Initiative, which includes the Center's Remote Patient Monitoring Diffusion Grants Program.

The Center's Remote Patient Monitoring Initiative aims to increase use of technologies that:

- Reduce the use of emergency department and hospital services by older adults (60+ years old).
- Enable independent living and the ability to live in the setting of one's choice.
- Lead to improvements in the cost and quality of care.
- Reduce the need for older adults to move to more intensive, high-cost care settings.
- Reduce the burden on formal and informal caregivers.
- Work in the home, as well as in long-term and post-acute care settings.

These technologies include integrated and standalone remote monitoring devices for chronic disease management, post-acute care management, and patient safety monitoring for wandering and falls.

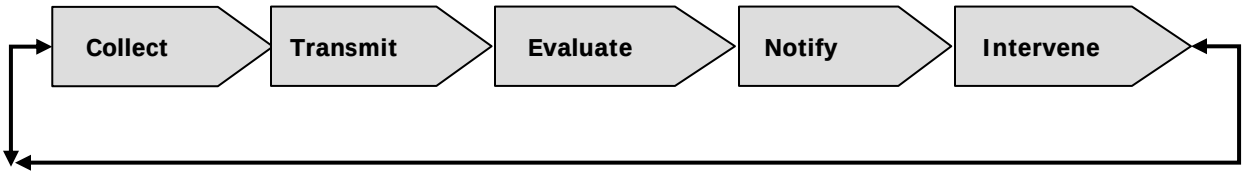
This paper identifies and describes issues and opportunities for the Remote Patient Monitoring Diffusion Grants Program and related initiatives. It provides an overview of the remote patient monitoring process, and discusses two areas of opportunity for remote patient monitoring in older adults: 1) Chronic Disease Management and Post-Acute Care Management and 2) Patient Safety. Example technologies that support each area are also described. The Center believes that examples help to transform the abstract into the concrete. However, the technologies mentioned in this report should be viewed as a limited sample and not an exhaustive list.

Many research sources informed and guided this work, including articles published in peer-reviewed journals, research and position papers from government and non-government websites, views expressed in expert panels and informant interviews, and pre-existing research reports from the Health Technology Center and the New England Healthcare Institute. The Center views this position paper as a starting point for discussion, and expects to build on this foundation by collaborating with and learning from stakeholders who bring their extensive knowledge, experience, and innovative ideas to the collaboration process.

Overview of Remote Patient Monitoring

Remote Patient Monitoring (RPM) refers to a wide variety of technologies designed to manage and monitor a range of health conditions. Point-of-care monitoring devices, such as weight scales, glucometers, implantable cardioverter-defibrillators, and blood pressure monitors, may individually collect and report health data. They may also become part of a fully integrated health data collection, analysis, and reporting system that communicates to multiple nodes of the health system. Such integrated systems provide alerts when health conditions decline, allowing patients, caregivers, and clinicians to intervene and modify treatment plans as needed.

Figure 1: Remote Patient Monitoring Process



This diagram describes the remote patient monitoring process in five steps: Collect, Transmit, Evaluate, Notify, and Intervene. RPM Technologies can collect data actively or passively by interacting with the patient. Data can include vital signs, blood glucose levels, responses to specific health condition questions and general health questions as well as patient location. Data is then packaged, delivered, and received by providers, family caregivers, and third parties via different modes of communication. Algorithms and/or healthcare workers review the data and determine if there are any areas for concern. If needed, family caregivers, clinicians, third parties or the patients themselves are notified of a potential problem through either the device itself or an intermediary healthcare worker. They can then take action if an intervention is needed. For the purposes of the paper and the RPM Diffusion Grants Program, the Center is interested in technologies that complete the full RPM process by providing end-to-end communication between the patient, caregivers, health care professionals and/or third parties. See Appendix A for a detailed review of the RPM process and optimal outcomes for each step.

Information and communication are the glue that holds the RPM process together, helping to ensure successful outcomes. The process depends on accurate, complete and timely information. If valuable information is inaccessible or ignored, the ability to respond appropriately and optimize the treatment regimen can be hampered.

Opportunities for Remote Patient Monitoring

A majority of older adults are challenged by chronic and acute illnesses and/or injuries. Hence, chronic disease management, post-acute care management, and safety monitoring are three important applications of remote patient monitoring (RPM) technologies for the older adult population. RPM technologies can help slow progression of chronic disease and ensure continued recovery after being discharged from an acute care setting. RPM technologies can also alert caregivers and prompt intervention when a vulnerable older adult is injured or in harms way.

After providing a high-level snapshot, each of these opportunity areas will be described, along with several respective example technologies. Note that these opportunities and example technologies should serve as a starting point for consideration, and are not meant to represent all possibilities and technologies for remote patient monitoring.

Chronic Disease Management

Chronic diseases, such as diabetes, asthma, heart disease, and chronic obstructive pulmonary disease, are pervasive, burdensome, and costly in the older adult population.

- Eight out of ten older Americans are faced with the health challenges of one or more chronic diseases (CDC).[4]
- Chronic disease is responsible for 60% of deaths worldwide.[5]
- Chronic disease accounts for three-quarters of America's direct health expenditures.[6]
- People with chronic disease cost 3.5 times as much to serve compared to others, and account for 80% of all hospital bed days and 96% of home care visits.[6]

Many people have the potential to live long, active lives despite the presence of a chronic health condition. If detected early, managed and monitored diligently, many can avoid serious health complications and avoid the attendant costs. Because of the significant opportunity to maintain independence, prevent health complications and reduce expenditures, chronic disease management has been the focus of many recent health and home care innovations. Remote Patient Monitoring (RPM) technologies have enabled or supported many of these innovations. According to Coye et al. 2009, RPM technologies can facilitate six components of chronic disease management: (1) early intervention—to detect deterioration and intervene before unscheduled and preventable services are needed; (2) integration of care—exchange of data and communication across multiple co-morbidities, multiple providers, and complex disease states; (3) coaching—motivational interviewing and other techniques to encourage patient behavioral change and self-care; (4) increased trust—patients' satisfaction and feelings of "connectedness"

with providers; (5) workforce changes—shifts to lower-cost and more plentiful health care workers, including medical assistants, community health workers, and social workers; and (6) increased productivity—decreased home visit travel time and automated documentation.[7] This suggests that RPM technologies can play six functional roles in chronic disease care as seen in Figure 3.

Figure 2: Roles and Benefits of RPM Technologies in Chronic Disease Management

(Source: Adapted from Coye et al 2009)[7]

Functional Role	Benefits
Early Warning System	Prompts early intervention when health status deteriorates
Care Integrator	Integrates a complex web of caregivers that might not otherwise communicate and collaborate for the health of an older adult.
Progress Tracker	Promotes evidence-based health care and self-care. Reduces duplication of health services.
Confidence Builder	Reinforces self-efficacy and confidence that selected health behaviors will lead to selected health goals.
Capacity Builder	Increases the capacity of individuals (patients and lower-skilled informal and formal caregivers) to provide more highly skilled care. Enables less centralized and more distributed care.
Productivity Amplifier	Increases the ability to do more with less and to avoid duplication of services.

Post-Acute Care Management

Post-acute care management, such as care management after a hospital stay, is in need of improvement. Without the home-care tools and understanding, and the ability to navigate a complex web of care providers and care settings, many recently hospitalized older adults do not recover as expected. This perfect storm of home- and self-care challenges too often results in hospital readmissions within weeks after discharge, greater utilization of health care than necessary, and reductions in independence.

Because of the significant opportunity for improvement, hospital readmissions rates are currently a key focus area for health systems and health policy initiatives. According to a recent MedPac study, 17.6 percent of all Medicare hospital admissions are readmissions, and a majority of these

are avoidable. Readmissions cost $15 billion annually. If successfully prevented, Medicare could save $12 billion of the $15 billion in readmissions costs.[8]

Factors that contribute to excessive hospital re-admissions include service fragmentation and poor communication among and between health care settings and care providers, and poorly delivered and/or understood discharge instructions and follow-up.

Personal health records and remote patient monitoring technologies support or enable care models that reduce avoidable readmissions rates, by improving coordination across the continuum of care and promoting seamless transitions from the hospital to home, skilled nursing care, or home health care. Similar to applications in chronic disease management, RPM technologies enable better post-acute care self-management, early intervention, and other improvements mentioned in the previous section.

Chronic Disease and Post-Acute Care Remote Patient Monitoring Technologies

Remote patient monitoring devices have been shown to increase the patients' role in the management of their own health, improved chronic disease management, and reduced acute episodes. Using a variety of integrated or standalone RPM devices, up-to-date information on patients' chronic disease and/or post-acute care status (including vital signs, heart rate, blood glucose levels, medication management, mental health, physical and cognitive fitness) and other data can be transmitted to family caregivers, providers, and other third parties. Clinicians or other properly trained individuals can then intervene by providing coaching or adjusting the course of treatment.

Currently, several different types of integrated RPM devices exist. These devices act as an aggregator of information from multiple peripheral devices (e.g., blood pressure cuff, scale, glucose monitor, pulse oximeter, prothrombin time/international normalized ratio (PT/INR) meter, thermometer, electrocardiogram ECG, peak flow meter, stethoscope, pedometer) that transmit or plug directly into integrated technologies. Many integrated devices are activated daily by the patient or caregiver. They ask patients to answer a series of questions, collect and report peripheral device data, provide educational information, and even support audio or visual contact with clinicians for real-time intervention or assistance.

Some instruments can also self-activate and alert patients and caregivers that a test or medication must be taken. Data are subsequently transferred to health care professionals, where they are triaged through patient-specific algorithms to categorize risk and alert appropriate caregivers and clinicians when answers and/or data exceed predetermined values. Many of these tools store previous test results through a specific device program or a web-based program. RPM

devices also provide patient education via reading or hearing health tips. Devices can be a conduit of communication between patients and healthcare professionals through audio and/or visual settings allowing for real-time intervention, coaching, and patient education.

Patients have highly varied needs for remote patient monitoring technologies. Some patients want a simple, inexpensive, portable technology while others may require an expensive, integrated, home-based technology. There is a wide spectrum of technologies in between, from simple to complex, that meet the needs of nearly all patient segments in the most appropriate way.

The ability to augment patient self-management tools and skills is critical to the value of integrated RPM devices. This can be accomplished in a variety of ways, as described in Figure 3.

Figure 3: Self Management Capabilities in RPM Devices[9]

RPM capabilities	Resultant Support via Technology
Managing therapeutic processes	- Disease knowledge - Vital signs and self-reporting - Take medication - Rules of conduct - Physiotherapy
Managing health and preventive behavior	- Nutrition - Physical exercise - Cognitive exercise - Social interaction - Stress reduction
Managing the role of the chronically ill patient	- Dynamics of health status and disease progress - Navigating the health care system - Relationship to health care professionals - ”Action plans”
Managing daily life	- Maintain autonomy in daily life - Deal with disease related implications - Support in daily life by friends, family members and informal helpers
Managing Crises	- Be prepared for crises - Recognize crises - Call for help

Numerous health care organizations are now fielding RPM-enabled programs for chronic disease management. Examples for this paper are drawn from Kaiser Permanente, Group Health of Puget Sound, and the Veterans Health Administration (VHA). The VHA has broadly deployed a range of RPM technologies in 50 different health management programs across 18 Veterans Integrated Service Networks[10] and conducted various studies showing improved chronic disease management, cost savings, and reduced hospital admissions and ED visits. Since 2000, they have

conducted numerous studies evaluating the use of the Health Buddy varying in study design, patient population, and size.

Findings from comparative studies conducted on 17,025 patients enrolled in the VHA CCHT (Care Coordination/Home Telehealth) program in 2006 and 2007 show a 25% reduction in bed days of care, 20% reduction in numbers of admissions, and mean satisfaction score rating of 86%.[11] Figure 4 shows the percent decrease in healthcare utilization by chronic condition. The cost of the program is $1,600 per patient per annum. This compares with direct cost of VHA's home-based primary care services of $13,121 per patient per annum, and market nursing home care rates that average $77,745 per patient per annum.[11]

The VHA's underlying health information infrastructure, coupled with a strong commitment to standardized work processes, policies and training, have combined to support an increase in CCHT patients from 2,000 to 31,570 from 2003 to 2007. VHA plans to increase its non-institutional care (NIC) services 100% above 2007 levels to provide care for 110,000 patients by 2011, or 50% of its projected NIC needs. VHA's experience is that an enterprise-wide remote patient monitoring implementation is an appropriate and cost-effective way of managing chronic care patients in both urban and rural settings.

Figure 4: Outcomes: VHA Care Coordination/Home Telehealth 2004-2007[11]

Condition	# of Patients	% Decrease Utilization
Diabetes	8,954	20.4
Hypertension	7,447	30.3
CHF	4,089	25.9
COPD	1,963	20.7
PTSD	129	45.1
Depression	337	56.4
Other Mental Health	653	40.9
Single Condition	10,885	24.8
Multiple Conditions	6,140	26.0

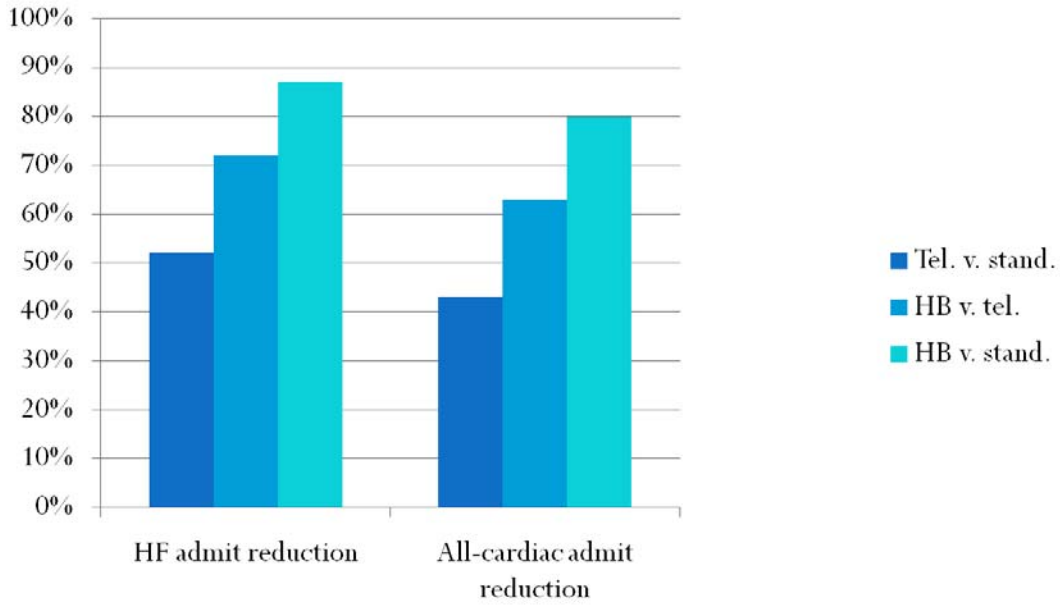
The use of RPM technologies for post-acute patients with the goal of reducing readmissions has also been studied and evaluated. In patients released from the hospital with heart failure, the

Specialized Primary and Networked Care in Heart Failure disease management program (SPAN-CHF I) conducted a randomized control trial evaluating a nurse-run disease management (DM) program to prevent readmission of heart failure patients. A follow-up study, SPAN-CHF II, investigated the use of DM along with an automated home monitoring (AHM) system to further evaluate reduction in readmissions. The study found that in-home monitoring (AHM) and coaching (DM) after hospitalization for CHF reduced rehospitalizations for heart failure by 72 percent, and all cardiac-related hospitalizations by 63 percent.[12,13]

The AHM utilized an interactive scale, blood pressure cuff, text messaging system, and the Bosch Health Buddy device. The Health Buddy is a stationary integrated RPM device that utilizes peripheral devices including scale, blood pressure monitor, glucose meter, pulse oximeter, and peak flow meter readings. Additionally, it contains a series of questions and dialogues addressing the patient's mental, physical, and cognitive health. Appropriate risk intervention dialogues can be assigned based on individual patient needs. Health Buddy has received NCQA certification for 10 programs: asthma, cancer, coronary artery disease, congestive heart failure (CHF), chronic obstructive pulmonary disease, chronic pain, depression, diabetes, hypertension, and pediatric asthma.

The Health Buddy is one of seven major integrated devices currently on the market, all of which are summarized in Figure 6.

Figure 5: Preventing Readmissions: SPAN-CHF I and II Studies [12,13]



Integrated devices are expected to grow in capabilities and scope to include monitoring from sensors and other streams of continuous data. Information regarding environmental safety, such as the temperature of a patient's home, monitoring appliances for activity, and security systems, are beginning to be merged with patient monitoring in integrated devices. Behavioral safety devices, including sensors to monitor falls and location devices to track wandering, can also stream data into integrated devices. These expanded combinations offer patients and caregivers access to a broader array of both patient and environmental data.

Figure 6: Examples of Integrated Home Health Monitoring Devices

(adopted from the NEHI FAST Detailed Technology Analysis: Home Telehealth Report)[14]

Device	Organization	Description
Health Buddy	Bosch	Over 30 programs where patients answer a series of questions about their health and wellbeing. Data transmitted via telephone line or Ethernet connection to a secure data center. The data is then available for review on the web-based Health Buddy Desktop. Patient responses are color-coded by risk level as High (red), Moderate (yellow), and Low (green) prompting intervention when needed. Care managers can send texts straight to the device under 150 characters. Peripheral devices include: scale, glucose meter, peak flow meter, blood pressure cuff, pulse oximeter.
Telestation	Philips	Patients answer health assessment survey questions. Data is transmitted from wireless peripheral devices to the telestation. Information is then transmitted through the phone line to health care professionals. Peripheral devices include: scale, blood pressure meter, glucose meter, pulse oximeter, rhythm strip recorder.
Genesis DM	Honeywell	Web-based system with customizable subjective disease-related queries for patients. Two-way audio allows healthcare professionals and patients to communicate. Peripheral devices include: stethoscope, scale, blood pressure meter, glucose meter, pulse oximeter, thermometer, PT/INR meter, peak flow meter.
Intel's Health Guide PHS6000	Intel	Combines in-home patient device with an online interface. Patients and caregivers inteact using two-way audio and video. A multimedia education library can be found on the system. Peripheral devices include: blood pressure monitors, glucose meters, pulse oximeters, peak flow meters, weight scales.
LifeView	American TeleCare	Combines patient monitoring and interactive video allowing healthcare professionals to monitor the status of the patients. Data is collected from peripheral devices and the LifeView Patient Monitors, which is then transmitted through telephone line or broadband connection. Two-way audio/video allow clinicians and patients to communicate. Peripheral devices include: stethoscope, scale, blood pressure meter, glucose meter, pulse oximeter, thermometer, PT/INR meter.

Ideal LIFE Pod	Ideal Life	Data is collected from peripheral devices and the Ideal LIFE Pod, which then transmits data through an analog phone line. Peripheral devices include: blood pressure meter, glucose meter, scale pulse oximeter, peak flow meter, pedometer, chair scale.
Healthanywhere	Healthanywhere Inc.	Platform offered in various devices including a home tablet, kiosk, and smartphone application. Data from peripheral devices is transmitted using bluetooth. Additional features include calendars, reminders, questionnaires, and two-way video through kiosks that link patients with healthcare professionals. Data can be viewed by healthcare professionals and users and is also integrated with Microsoft's HealthVault. Peripheral devices include: blood pressure cuffs, glucose meter, and scales.

While there are an increasing number of integrated devices, many RPM devices effectively function independently. One of the most prevalent forms of standalone RPM devices are physiological cardiac devices, like Pacemakers, Implantable Cardioverter Defibrillators (ICDs), and Cardiac Resynchronization Therapy devices (CRTs). These devices can provide continuous, real-time tracking and analysis of patients' heart rhythms as well as device components, like battery life and lead function. Physiological cardiac RPM devices have demonstrated many benefits, including reduced in-person clinic visits, early detection of health problems, increased patient satisfaction, and potential cost savings.[15] A comparison of six representative continuous cardiac remote patient monitoring technologies is presented in Figure 7.

Most large cardiac physiological monitoring device manufacturers use RFID to wirelessly transmit data from the device to a base station, which can be stationary or mobile. Such transmissions are either manually requested by a patient using a wand tool, or automatically uploaded to the base station without patient involvement. Base stations then transmit data via an analog phone line ("landline") or Global System for Mobile Communications network (GSM or cellular phone networks) to the clinician. Transmission to the clinician can occur daily or on a scheduled basis. Acute events, like shock administration by the device, trigger an alert to the clinician. Clinicians can receive alerts via SMS text messaging, e-mail, fax or phone. Clinicians can then investigate patient data to decide whether the patient should come into the hospital or stay at home. Some devices have the ability to create specific alerts for individuals, accessing and configuring alerts online, and stratifying risk. Other unique features include measuring lung fluid levels and generating alerts (Medtronic CareLink), using wireless peripheral devices like weight scales and blood pressure cuffs (Boston Scientific Latitude), and exporting data directly into EHRs (Boston Scientific Latitude).

Figure 7: Comparison of Continuous Cardiac Remote Patient Monitoring Technologies (adapted from Burri and Senouf, 2009)[16]

	Biotronik Home Monitoring	Medtronic CareLink	Boston Scientific Latitude	St Jude Merlin.net
Wireless communication with implanted device	Radiofrequency	Radiofrequency	Radiofrequency	Radiofrequency
Data Transmission	GSM network	Analog phone line	Analog phone line	Analog phone line
Transmitter	Mobile	Stationary	Stationary	Stationary
Frequency of transmissions	Daily FU; Alert events	Scheduled FU; Alert events	Scheduled FU; Alert events	Scheduled FU; Alert events
Physician Notification	SMS, e-mail, fax	SMS, e-mail	Fax, phone	Fax, e-mail, SMS
Special Features	Alerts fully configurable online Wireless PMs	Optivol lung fluid status alert Configurable red and yellow alerts	EHR data export capability Optional wireless weight scales and blood pressure cuffs	Alerts fully configurable online Possibility of sending automated phone calls to patients

According to the American College of Cardiology (ACC)/American Heart Association (AHA)/Heart Rhythm Society (HRS) guidelines, patients obtain many benefits from the use of standalone cardiac RPM devices.[17] Preliminary results from the TRUST trial, which analyzed remote monitoring of patients using Biotronik ICDs, found that remote monitoring reduced the number of in-person clinic visits by 43%.[18] The trial also demonstrated no significant difference in terms of patient safety between in-person clinic visits and remote monitoring. Reduction of in-person visits depends on the severity of the patient's illness and the implanted device. Given the nature of patients' conditions who use CRTs a reduction of in-person clinic visits may not be appropriate for this population.

Continuous Cardiac RPM technologies will increase automation processes and accessibility of data to patients and clinicians. The Biotronik device is the first to allow for automatic upload of patient data to the clinician. This automation will ensure transmission of data at appropriate intervals, and allow for increased frequency of transmission. The portable base station, which can be worn by patients, and the use of GSM networks to transmit data can improve the frequency of

transmission as patients are not required to be in the same location as the stationary base station and/or landline ports.

In the future, closed loop systems will permit devices to administer or adjust treatment based on sensor readings. Improved sensor development will create a more robust and accurate data set. Many continuous cardiac devices are capable of becoming closed loop systems. Such systems will emerge as algorithms and alert systems mature, error signals decrease, and remote overview by physicians becomes seamless. As the number of older adults implanted with cardiac devices grows, device communications and capabilities will mature.

Patient Safety Monitoring and Injuries

To promote safety and prevent injuries among older adults, many technology developers are focusing their attention on remote patient monitoring technologies that detect and ultimately prevent falls and wandering. The incidence of falls among older adults is high, as are the associated health care costs. Additionally, older adults with dementia are at increased risk of both falling and wandering. In a study of 100 people with dementia, patients fell over 400 times per year and estimates of wandering ranged from 6 to 100% (Tully, 2006). Unsafe wandering and elopement have many negative consequences, including injury to oneself or others, and even death.

According to Lohr, "Falls are so harmful to the elderly and so costly to society that if falling were a disease, it would be deemed an epidemic."[19]

- Hip fractures are a major contributor to death, disability, and diminished quality of life among older adults.
- In 2004, falls were the leading cause of injury deaths among older adults and were responsible for about 14,900, or almost 43%, of all unintentional injury deaths in this age group.[20]
- Fall-related death rates rose sharply with increasing age and the greatest increase occurred after age 79.[20]
- Falls are the most common cause of nonfatal injuries and of hospital admissions for trauma among older adults.[20]
- Over 1.8 million seniors were treated in US hospital emergency departments for fall injuries, and one out of four was subsequently hospitalized.[20]
- Getting help quickly after a fall reduces risk of hospitalization by 26%[21] and death by over 80%.[22]
- Those who fall are 2-3 times more likely to fall again.[23]

Patient Safety Monitoring Technologies

Fall detection, fall prevention, and location tracking technologies monitor patients in terms of their location, balance, and gait. Such devices allow caregivers and other parties to assess patient mobility and safety. Fall detection technologies actively or passively evaluate whether a fall has taken place and alert others that an individual has fallen. Fall detection technologies include personal emergency response systems (PERS) and passive sensors. Fall prevention technologies measure gait and balance in order to predict the likelihood of falls. Many fall prevention technologies are currently in the developmental stage and utilize pressure and other types of sensors embedded in the user's shoe, cane or other assistive technology. Location

tracking technologies enable caregivers and others to locate older adults that are prone to wandering. Location tracking technologies employ numerous tracking techniques, including Wi-Fi, GPS, cellular networks, and radio frequency located in a device worn or occupied by the user. Tracking devices vary by tracking technique, signal activation, involvement of third parties, and level of acuity for device activation. The key to success for these safety technologies are the patient specific alert mechanisms and support services.[24]

Fall Detection Technologies

The primary goal of fall detection technologies is to distinguish falls from activities of daily living (ADL) and then contact authorities who can quickly assist the individual. Fall detection systems can be active, passive or a combination. Active systems, such as PERS, are devices that users must activate to obtain assistance, most commonly by pushing a button or pulling a cord. Passive systems involve the use of sensors to continuously monitor movement, while utilizing specific algorithms and alert systems to inform caregivers and others of potential falls. Users do not need to activate passive systems as they automatically detect a fall and contact help. Motion and pressure sensors can be placed around the living facility on walls, ceilings, and floorboards while location and position sensors, like accelerometers and gyroscopes, can be placed on older adults themselves. Some passive systems contain a backup active system where users can activate the device for assistance.

Many types of personal emergency response systems require patients to activate an alarm for assistance. Devices can be stationary (pull cords and emergency buttons) or portable (necklaces or bracelets). After activation, the device communicates with a transmitter, which relays the information, often through the phone line, to a third party vendor at a monitoring center. Here, third parties assess the situation, contact appropriate parties for further assistance, and often initiate audio communication with the older adult through the telephone or another portable or fixed transmitter device,. Users typically pay for the monitoring equipment as well as a monthly service plan for access to third party support. User activation, especially with stationary PERS, can cause difficulties if an older adult falls and is not within reach of the device. Similarly, portable systems can pose a challenge to activate if an individual falls or becomes incapacitated. Portable PERS also require that the older adult always wear the device. Dementia or other cognitive ailments may cause the user to forget to wear or activate the device. Bulky, less attractive systems also discourage the user from wearing it as they may be uncomfortable or embarrassing.

Passive fall detection technologies utilize a variety of sensors including motion and pressure sensors, accelerometers, and gyroscopes to monitor location, position, immobility, speed of

motion, and distance covered. Passive sensor technologies automatically detect falls and promptly alert the appropriate parties. Different types of sensors can be used to detect movement, including motion sensors affixed to the walls of users' homes, accelerometers and gyroscopes attached to the user, and pressure sensors in the floorboards underneath carpet.[25] Algorithms are utilized to set thresholds for alert notification tailored to each older adult by monitoring patterns of movement and behavior. This data pattern can assist with detecting urinary tract infections through frequency of bathroom visits at night or throughout the day. Such technology can also signal that an individual may need to move to a higher acuity setting or that they should consider using mobility assistive technologies if patterns change and mobility begins to deteriorate. System dashboards integrate individual and multiple user data in an easy to monitor format. Dashboards can stratify alert notifications based on severity, which can be particularly valuable for assisted or independent living communities that monitor several people at once.

Sensitivity and specificity of passive fall detection technologies is increasing. One study found that use of an accelerometer device can discriminate between falls and ADLs with a sensitivity of 97.5% and a specificity of 100%.[26] More recently smart phone applications, such as Android's iFall, have emerged for fall detection. The Android phone contains a tri-axial accelerometer, which is used to monitor the user's location and position given. While older adults must carry the device at all times, threshold-based algorithms; user information on height, weight, and level of activity; and unique user phone movements are taken into account when evaluating whether a fall occurred.[27] If a potential fall occurs, iFall sends a notification to the user. If there is no response from the user, the system sends a text message to pre-specified contacts. Upon response from the contact, iFall automatically turns on the user's speakerphone and contacts medical help if needed.

As algorithms and sensor technologies mature in fall detection technologies, patterns may emerge that correlate to an immediate likelihood of falling. This could potentially predict when a fall will occur moments before one does and can alert caregivers or the individual themselves for further assistance. Representative fall detection and prevention systems are presented in Figure 8.

Figure 8: Fall Detection and Prevention Systems

Fall Detection Systems	Active or Passive	Description	Examples
Alarm with fixed or portable	Active	Personal Emergency Response systems require older adults to activate a call button, which can	Stationary: Pull cords, stationary emergency buttons.

receiver and transmitter		either be stationary in a room or portable worn by the user. Some devices activate third party audio communication with the patient to address the situation and can contact the appropriate parties for further assistance.	Portable: Emergency necklaces, bracelets. Philips Lifeline, MedicalAlarm.com
Location and position sensors with algorithms	Passive	Sensors, like accelerometers and gyroscopes, are connected to the user and detect user's location and position in relation to the ground. Preset algorithms determine if movement is out of the scope of ADL and is considered a fall. Software alerts third party or caregiver to potential fall.	Android Application iFall, Speedy
Motion Sensors and pressure sensors with algorithms	Passive	Motion sensor units are placed around the user's house or apartment on the walls or on the ground. Sensors continuously track user's motion. Preset algorithms determine whether user has fallen by analyzing immobility where users remain still in one area for longer than the allotted time. Software alerts third party or caregiver to potential fall.	GE's QuietCare, myhalo
Fall Prevention Systems	**Active or Passive**	**Description**	**Examples**
Gait and balance monitors with algorithms	Passive	Pressure and motion sensors, accelerometers, and gyroscopes are used in devices attached to users or assistive technologies to monitor gait and balance. Sensors detect patterns in movement, establishing threshold based fall risk algorithms. Software alerts third party or caregiver to fall risk potential.	Smart cane, ishoe

Fall Prevention Technologies

Aside from in-person and video visits to observe gait patterns and diagnose mobility issues, most of the gait and balance technologies are in the development phase and have not been thoroughly evaluated or experienced widespread deployment. Such technologies are expected to predict likelihood of falls by passively observing movement and gait patterns as well as pressure distribution.

Researchers at MIT created the iShoe insole, which uses pressure sensors and an algorithm to monitor patient balance and gait to predict likelihood of falls.[28] The device was originally created to monitor balance in astronauts returning from space. Researchers are also looking to develop a closed loop system where a given pressure distribution can be modified through the shoe causing the individual to lean or move in a slightly different direction. Another device in the developmental stage utilizes a wearable 3D accelerometer and 2D gyroscope. Results from a study found that falls can be detected 700 ms before the impact occurs with 100% specificity and 95.2% sensitivity.[29] Immediate detection right before a fall occurs promotes the use of fall impact reduction systems like inflatable airbags for hip protection.[30]

Fall prevention monitoring technologies affixed to assistive technologies can provide additional information on appropriate use of assistive devices. Improper use of assistive technologies, like canes and walkers, accounts for a large proportion of falls. The SmartCane System is an example of an assistive technology combined with gyroscopes, accelerometers, and pressure sensors to monitor proper use of canes and evaluate fall potential among older adults.[31] The sensors wirelessly transmit data via Bluetooth capabilities to monitoring devices like PDAs. Spotting misuse early and providing real-time feedback to users, caregivers, and clinicians may lead to fall prevention. Preliminary data has shown that data from these sensors along with the wireless transmission is capable of measuring and analyzing older adults cane use.[31]

Location Tracking Technologies

Location tracking technologies enable providers and family caregivers to locate older adults that are prone to wandering, such as those with Alzheimer's disease and other cognitive impairments. These technologies vary by range and accuracy of location due to selected tracking techniques, signal type (active vs. passive), signal activation methods, and technology support systems. Costs for location tracking technologies include the cost of the device, plus a monthly monitoring support fee.

Currently, several location tracking devices utilize different types of tracking techniques, such as GPS, Wi-Fi (Wi-Fi Positioning Service WPS), cell towers, Zigbee, Bluetooth, and Radio Frequency. Some tracking techniques work well outdoors and are less accurate indoors (GPS), while others cover a wide range or are limited in range (Bluetooth). GPS technology location systems utilize satellites to locate individuals and can be worn directly by users or can be placed in cars or other modes of transportation. GPS technologies are limited in the range they are able to effectively cover as signals are often lost or depleted in areas of high density overgrowth, inside buildings, and in places with less satellite coverage. Integration of GPS with mobile phones and other devices is becoming commonplace and making this tracking technique an attractive option.

Google's Latitude is a software product utilizing GPS, Wi-Fi, cell phone towers or a combination of all three, which can be used on many cell phones. This system provides passive monitoring after the initial setup of the program, allowing people to locate users without interacting with a third party vendor or the police.

Passive location tracking technologies provide an automatic constant stream of the user's location, while active devices require remote activation of the device by third parties or caregivers. The Alzheimer's Association has supported Omnilink's Comfort Zone program as their preferred location tracking technology. The Comfort Zone program uses Radio Frequency (RF) to provide a continuous stream of data given that the RF signal is within the range of the transmitter. The signal can be activated by friends and family members and does not require third party vendors or police involvement. Users do have the option of contacting third parties and the police if they need additional help locating the individual. Technologies that give providers and family caregivers the ability to continuously view the location of the older adult have the added benefit of monitoring mobile behavior.

Location information can be available directly to providers and family caregivers or may only be available to third party vendors and/or the authorities. Some location tracking devices require activation through the vendor, who then provides law enforcement personnel with location information of the older adult. Other devices provide algorithms with set alerts to notify providers, neighbors, family, and friends when the older adults leaves a certain area. Some devices, such as the Comfort Zone can supply real-time information of users' location without contacting third party support as seen with the Comfort Zone Program from Omnilink. The Comfort Zone Program also offers the option to contact third party support if needed. Other devices like EmFinders and LoJack SafetyNet require activation by the vendor. The signal of the missing individual is then provided to the police.

Figure 9: Location Tracking Devices for Wandering

Location Tracking Device	Description	Tracking Technology
Google Tracker – Latitude	▪ Portable location-tracker mobile phone application available on many phones ▪ Caregivers and others can view user location from the computer or compatible phone device. ▪ Google Location Alerts can trigger a text message alert if user goes to a strange location	GPS, cell phone towers, Wi-Fi connections
Omnilink's Comfort Zone program www.alz.org/comfortzone	▪ Uses GPS and cellular technologies integrated with a web-based application for online mapping to track people. ▪ Families access a secure website and establish safety zones for user and receive email or text message alerts within 15-30 minutes ▪ Families can receive user location update every two minutes for one hour through web-based application	Cell towers, GPS
LoJack® SafetyNet™	▪ User wears portable Personal Locator Unit (PLU) that emits radio frequency signals. ▪ Public safety agencies and local enforcement officials use LoJack when a user goes missing. ▪ Lojack's caregiver support organization is accessible by phone and email	RFID
Quest Guard SOS GPS tracking system	▪ Real-time GPS tracking device integrated with web-based software provides families with user's current and past locations. ▪ Caregivers can create safety zones and set curfew requirements. If the person wanders from the assigned safety zone, an immediate alert is sent to the caregiver.	GPS
GPSTN http://www.gpstn.net/Elderly_Tracking.htm	▪ GPS device installed in cars to monitor user's speed and location ▪ Caregivers access device through computer application ▪ Email alert sent if the person is speeding or has entered a restricted area	GPS
EmFinders www.emfinders.com	▪ Wearable device using cellular network to locate user ▪ Once triggered by the caregiver, local enforcement officials can track the person through the cellular based locator system	Cellular Network

Discussion

The Center for Technology and Aging is committed to encouraging wider use of viable technologies that compare favorably on the following criteria: population applicability, health and economic outcomes, workforce relief, stakeholder readiness, and policy relevance.[32] Many remote patient monitoring technologies have been discussed. Most have potential to benefit a large portion of the older adult population and to benefit from favorable policy developments.

Population Applicability:
Most of the discussed technologies are potentially beneficial to a significant population of older adults who are at-risk for moving to a higher level of care. Technologies may also be instrumental in enabling people with high-burden disabilities and chronic illnesses to better self-manage their health conditions and thereby prevent complications and injuries.

Environmental Design: Future development of the Smart Home concept will combine multiple patient monitoring systems including devices that monitor patient's health, safety, and their environment. Many vendors like Intel and Motorola are involved in smart home studies. Continued integration of monitoring devices will give older adults and caregivers the support to help keep older adults independent longer.

Health and Economic Outcomes: Credibly demonstrating improvements in health and economic outcomes is one of the largest challenges facing remote patient monitoring. Randomized, controlled trials are the gold standard for demonstrating such improvements. However most technologies have been studied with less robust methods, e.g., pre-post observation studies. On the positive side, well-known and well-respected organizations, such as the Veterans Administration and Kaiser Permanente, have increasingly demonstrated "in practice" the benefits of remote patient monitoring technologies.

Workforce Relief: In the medium- to long-term, some technologies may reduce demands on the ever-stretched workforce that cares for older adults—by encouraging greater self-management and other efficiencies. Expanding use of such technologies in the short term, however, may place extra burdens on this home care and health care workforce as well as caregivers. Many remote patient monitoring technologies, for example, will require someone to train the patient or informal caregiver. Until the patient and caregiver can operate the technology without assistance, it is likely that a home or health care worker will be relied upon to lead the way.

Stakeholder Readiness: Standalone technologies may achieve more rapid adoption because they do not require buy-in from a complex web of stakeholders, nor do they require interoperability. Technologies that interface with multiple medical devices and information technologies may be adopted more slowly as they often require EHR to store and keep track of patient data. However, more complex, interoperable solutions may be needed, especially where breakdowns in communication are at the heart of the problem.

Policy Relevance: The $787 billion American Recovery and Reinvestment Act of 2009, which included $19.2 billion for health information technology (HIT), has brought electronic medical records to the forefront of the health care technology discussion. EHR adoption will be pivotal for use of integrated chronic disease remote patient monitoring technologies. The massive amounts of data collected from these technologies needs to reside in an EHR to be accessed by clinicians and other health care professionals. Many third party vendors have created data storage solutions, but integration within delivery systems in the long-term will require EHR adoption.

Payment issues remain a powerful barrier to adoption and diffusion of remote patient monitoring technologies. The Medicare Telehealth Enhancement Act (H.R. 2068), introduced into the US House of Representativies in May 2009, would expand Medicare coverage of remote patient management services and establish a fee schedule for home health remote patient management services.[33] Some provisions of HR 2068 have also been included in Congress's health reform bill.[34]

Appendix A: Remote Patient Monitoring Detailed Process

Phase	Key Steps	Optimal Step Outcome
Collect	Monitoring Device Activated for Use	Patient, caregiver, clinician or third party activates or initiates device for passive data collection
	Device Obtains Information	Activated device passively or actively collects information
	Device Records Information	Information from device is recorded and stored for viewing and/or delivery
Transmit	Data Packaged	Data packaged in appropriate format for transmittal
	Data Delivered	Data transmitted via internet, telephone, short message service (SMS) text
	Data Received	Appropriate providers, caregivers, third parties, and/or the patient receive patient data information
Evaluate	Indicators Programmed	Indicators of thresholds and normal results programmed into algorithm or noted if reviewed by a healthcare worker
	Data Reviewed	Indicators are used to screen data for areas of possible concern. An algorithm can compile these results, or a healthcare worker can tabulate the information.
Notify	Alert Preparation	Device, intermediary software, or healthcare worker prepare the alert for transmission to care team via phone, text, pager, or email. In acute events alert sent according to structured hierarchy of the patient's health team.
	Alert Sent to Responder	Alerts sent to designated responders including, but not limited to, the patient, family, caregiver, direct care worker, clinician, emergency responders, etc.
Intervene	Responder contacts patient, caregiver or family	Responder contacts those who can provide assistance to the patient
	Intervention Occurs	Clinicians, emergency response, patient, caregiver, family, third party or the device intervenes in patient activity providing assistance if needed; Clinicians adjusts treatment
	Education	Teach patient/caregiver/family about incident, how to avoid it, and how to handle it in the future

Appendix B: Acronyms

ACC	American College of Cardiology
ADL	Activities of Daily Living
AHA	American Heart Association
AHM	Automated Home Monitoring
CAD	Coronary Artery Disease
CCHT	Care Coordination/Home Telehealth
CHF	Congestive Heart Failure
COPD	Chronic Obstructive Pulmonary Disease
CMS	Centers for Medicare & Medicaid Services
CRT	Cardiac Resynchronization Therapy
DM	Disease Management
ECG	Electrocardiogram
ED	Emergency Department
EHR	Electronic Health Record
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HRS	Heart Rhythm Society
ICD	Implantable Cardioverter Defibrillator
INR	International Normalized Ratio
IOM	Institute of Medicine
NCQA	National Committee for Quality Assurance
NIC	non-institutional care
PERS	Personal Emergency Response System
PT	Prothrombin Time
RFID	Radio-frequency Identification
RF	Radio-frequency
RPM	Remote Patient Monitoring
SMS	Short Message Service
WPS	WiFi Positioning Service

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About the Center for Technology and Aging

Supported by a generous grant from The SCAN Foundation, the Center for Technology and Aging is devoted to helping California and the nation more rapidly implement technologies that improve home and community-based care for older adults, and help older adults lead healthier lives and maintain independence. The Center identifies promising strategies to promote the adoption and diffusion of technologies and provides grant funding to test selected strategies. In collaboration with grantees and key stakeholders, the Center will disseminate best practices and lessons learned from grant making initiatives. The Center serves as a state and national resource for those engaged in the promotion and implementation of successful technology diffusion strategies.

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