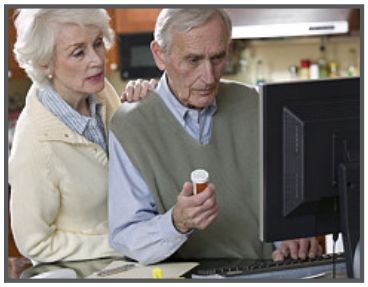

Center for
Technology and Aging

Technologies for Optimizing Medication Use in Older Adults

Position Paper
October 2009

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List of Abbreviations

A1c ..... Glycated hemoglobin or HbA1c
ADEs..... Adverse drug events
APHID ..... Automated Patient History Intake Device
CCD..... Continuity of care document
CCR ..... Continuity of care record
CDA ..... Clinical document architecture
CMS ..... Centers for Medicare & Medicaid Services
EHR..... Electronic health record
HL-7 ..... Health Level 7 (a medical information interface standard)
IHI..... Institute for Healthcare Improvement
INR ..... International Normalized Ratio
IOM ..... Institute of Medicine
IV..... Intravenous (administration of medications)
LTC ..... Long term care
MMSE ..... Mini-mental state examination
MTMP..... Medication Therapy Management Program
NGO..... Non-governmental organization
Part D ..... Medicare's prescription drug program
PHR..... Personal health record
PT ..... Prothrombin time
RFID..... Radio-frequency identification
The Center .... Center for Technology and Aging
VA..... United States Department of Veterans Affairs
VHA ..... Veterans Health Administration
VNA ..... Visiting Nurse Association

Executive Summary

Medication use is ubiquitous among older adults, with 90% of older adults using one or more prescription medications per week.[2] While medications are widely appreciated, commonly used, and help many older adults lead longer, healthier, and more productive lives, there is still great room for improvement in medication use.

The paper provides an overview of the medication-use process, and discusses three areas of opportunity for medication optimization for older adults: 1) medication reconciliation, 2) medication adherence, and 3) medication monitoring. Medication-use problems can occur at different phases in the medication-use process. To help pinpoint where medication-use problems occur, what opportunities exist to solve these problems, and which technologies may be beneficial in the process, it is helpful to visualize the medication-use process as a series of five steps or phases: assess, prescribe, dispense, administer, and monitor.[3-5] Medication reconciliation problems mainly present in the Assess and Prescribe phases of the medication-use process, whereas medication adherence problems commonly occur in both the Dispense and Administer phases.

A number of technology-enabled interventions can mitigate medication-use problems, optimize process step efficiency, and improve the health and independence of older adults. In alignment with the mission of the Center for Technology and Aging, this paper will focus on technology-enabled interventions predominantly aimed at improving the health of older adults while promoting independent living in community-based, home, and long-term care settings. Patients and caregivers primarily use these technologies to improve self-management of care and enhance communication of medication information to clinicians. The technologies described in this report should be viewed as a limited sample and not an exhaustive list.

> The New England Healthcare Institute estimates that $290 billion of healthcare expenditures could be avoided if medication adherence were improved.[1]

Medication optimization solutions that reduce the cost and burden of illness among older adults are urgently needed. While medication-use problems are not limited to older adults, older adults are disproportionately affected by such problems. Greater access to proven medication optimization technologies can lead to safer, more effective medication use among older adults.

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, the Center is focusing first on advancing technologies that improve ("optimize") medication use among older adults.[6] In September 2009, the Center launched its Medication Optimization Initiative, which includes the Center's Medication Optimization Diffusion Grants Program.

The Center's Medication Optimization Initiative aims to increase use of technologies that:

- Help improve medication use in older adults (60+ years old) with chronic health conditions
- Enable independent living and the ability to live in the setting of one's choice
- Will lead to improvements in the cost and quality of care
- Reduce the need to move to more intensive, higher-cost care settings
- Reduce the burden on formal and informal caregivers
- Improve medication reconciliation, medication adherence, and/or medication monitoring
- Are used in the home, as well as other long-term and post-acute care settings
- Include medical devices and information and communications technologies

This paper identifies and describes issues and opportunities for the Medication Optimizaton Diffusion Grants Program and related initiatives. The paper provides an overview of the medication-use process, and discusses three areas of opportunity for medication optimization in older adults: 1) medication reconciliation, 2) medication adherence, and 3) medication monitoring. 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 Medication Use in Older Adults

Medication use is ubiquitous among older adults. According to surveys, 90% of older adults use one or more prescription medications per week,[2] 41% of older adults take five or more medications,[7, 8] and 12% use 10 or more medications per week.[2]

Medication-related problems are not limited to older adults. But older adults are disproportionately affected by such problems because so many use medications. Medication-use problems are also exacerbated by conditions that are inherent to aging. Such conditions include the high prevalence of co-morbid illness and polypharmacy use. To further compound the challenge of medication problems among older adults, information about appropriate dosing and the risk of adverse reactions in segments of this population are often unavailable. Frail, older adults with multiple health challenges are often excluded from clinical drug trials—clinicians' primary source of information about the effects of particular medications.

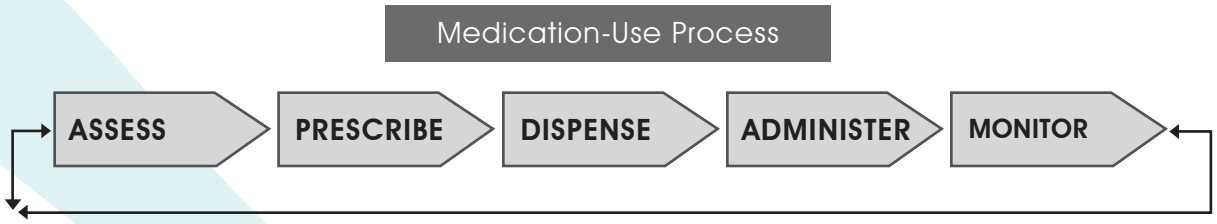
Suboptimal medication use can increase the burden of illness and result in higher costs to families and society:

- Adverse drug events are a leading cause of morbidity and mortality. According to the Institute of Medicine (IOM), more than 2 million serious adverse drug events and about 100,000 deaths occur annually due to medication problems.[4]
- In one study, the risk of hospitalization was twice as high in chronically ill individuals who did not take their medications as directed, compared to chronically ill individuals who did.[9]
- The New England Healthcare Institute estimates that $290 billion of healthcare expenditures could be avoided if medication adherence were improved.[1]

While medications are widely appreciated, commonly used, and help many people lead longer, healthier, and more productive lives, there is still great room for improvement in medication use. Medications are too often underused, overused, or misused.[4, 10]

Medication-use problems can occur at different phases in the medication-use process. To help pinpoint where such medication-use problems occur, what opportunities exist to solve these problems, and which technologies may be useful to support such solutions, it is helpful to visualize the medication-use process as a series of steps or phases.[3-5]

The diagram below describes the medication-use process in five steps: assess, prescribe, dispense, administer, and monitor. Underuse of medications tends to occur at the prescribe and administer phase of the medication-use process. In the prescribe phase, underuse includes the failure to prescribe medications for which there is an evidence base for reduction in morbidity and mortality.[4]



Underuse in the administer phase can occur because of forgetfulness, which is unintentional, or an intentional decision to stop using a medication because of side effects or other reasons. Underuse in the administer phase often falls under the rubric of "medication nonadherence."

Overuse of medications occurs in the prescribing phase when there is no evidence base for reduction in morbidity and mortality, but a prescription is issued anyway. Overuse is best documented in the use of antibiotics for treatment of colds, upper respiratory infections, and bronchitis.[4] Overuse by individual patients can also occur in the administer phase when forgetfulness leads to double dosing.

Misuse of medications is the inappropriate use of medications. Misuse can include unintentional errors in administration that lead to adverse reactions. Misuse also includes intentional overuse to harm oneself or to satisfy an addiction. In the context of this paper, misuse will refer to suboptimal medication adherence, which includes failure to follow treatment recommendations, i.e., not picking up the right drug once it is dispensed, and not administering it on time, in the right dose, and for the right length of time. Failing to follow instructions, missing doses, taking double doses, and taking medication at the wrong time are all adherence-related misuses. Another important "misuse" of medications that is highlighted in this paper, is inadequate monitoring.

Information and communication are the glue that holds the process together, helping to ensure successful outcomes. The process of assessing patient needs and prescribing, dispensing, administering, and monitoring medications often depends on accurate, complete and timely information. If members of the medication-use social system (patients, physicians, pharmacists, etc.) ignore important information or do not have access to important information, the opportunity to respond to patient needs and optimize the treatment regimen will be lost.

Opportunities for Medication Optimization

Significant opportunities to improve medication use exist in the following three areas: medication reconciliation, medication adherence, and medication monitoring. Interventions in these three opportunity areas can address medication-use problems that are important, widespread, and potentially addressable by technology-enabled innovations. Medication reconciliation problems mainly present in the assess and prescribe phases of the medication-use process, while medication adherence problems commonly occur in the dispense and administer phases.

After providing a high-level snapshot, each opportunity area will be described, along with example technologies that may support each of these opportunities. Note that these opportunities and example technologies serve as a starting point for consideration, and are not meant to represent all possible opportunities and technologies for medication optimization.

Chart 1 provides a high-level view of the medication-use phases, and the goals associated with each. A limited set of example technologies is also shown. These example technologies both support each of the phases and goals and align with the mission and goals of the Center for Technology and Aging. For a broader look at the process steps, goals, and supportive technologies, see Appendix A.

Chart 1. The Medication-Use Process:
Process Step Goals and Example Technologies for Patients and Caregivers

Medication Reconciliation		Medication Adherence		Medication Monitoring
Assess	Prescribe	Dispense	Administer	Monitor
Goals • Patient history includes a complete and accurate medication list • Patient needs are accurately conveyed and understood	**Goals** • Medication orders are documented and shared with patients	**Goals** • Medication is made available • Medication picked up by patient • Patient and caregivers understand medication instructions	**Goals** • Individual dose dispensed • Individual dose taken by patient (on time, in the right dose, and for the right length of time)	**Goals** • Routine dosing and tracking of medication • Reports and trending information from medication log generated • Clinician adjusts medication as needed • Prescriptions refilled
Example Technologies • Medication List Software • Personal Health Records	**Example Technologies** • Medication List Software • Personal Health Records	**Example Technologies** • Teleconsultations • Online Patient Education • Cognitive Assessment Tools • Pharmacy Kiosks	**Example Technologies** • Medication Adherence Devices (integrated and standalone, simple and advanced function)	**Example Technologies** • Personal Biometric Testing Device • Wireless Communication Devices • Personal Health Records

Opportunities for Medication Optimization

Medication Reconciliation

Medication reconciliation is the process of creating an accurate list of all medications a patient is taking and comparing that list against new physician orders. The five main steps of the process are: 1) developing a list of current medications; 2) developing a list of medications to be prescribed; 3) comparing the medications on the two lists; 4) making clinical decisions based on the comparison; and 5) communicating the new list to appropriate caregivers and to the patient.[11]

Medication Reconciliation	
Assess	Prescribe
Goals • Patient history includes a complete and accurate medication list • Patient needs are accurately conveyed and understood	**Goals** • Medication orders are documented and shared with patients
Example Technologies • Medication List Software • Personal Health Records	**Example Technologies** • Medication List Software • Personal Health Records

Since most medication errors are made at the "interfaces of care," the Joint Commission asserts that medication reconciliation should be done at every transition of care, including changes in setting, service, practitioner, or level of care. A change in a patient's condition is also a critical point when medication reconciliation is needed.[12]

When care transitions occur, the complete and reconciled list of medications should be communicated to the patient's known primary care provider, or the original referring provider, or a known next provider of service. When a patient transitions from a service organization to home, a complete and reconciled list of the patient's medications should be provided directly to the patient (and the patient's family as needed). When appropriate, the list should be explained and the communication should be documented.[13] Patient assessment is also an important component of the medication reconciliation.

A primary goal of medication reconciliation is to avoid adverse drug events (ADEs) and the associated increases in health problems, hospitalizations, and emergency room visits. While not all ADEs are due to medication reconciliation errors, the data below suggest that such errors may play an important role.

- Approximately 20% of patients discharged from the hospital to their home experienced an adverse event in one study. More than 66% of these adverse events were medication related[14]
- Medication discrepancies were the most common drug-related problem at the time of hospital discharge in one study and the cause of half of all preventable adverse drug events 30 days after discharge[15]

Opportunities for Medication Optimization

Medication Reconciliation

- Another study found that half of previously hospitalized patients who were receiving continuing care from their primary care physician experienced at least one medication error within two months of discharge from the hospital[16, 17]

According to the Institute for Health Improvement (IHI), a well-designed medication reconciliation process has the following characteristics:

- Uses a patient-centered approach
- Makes it easy to complete the process for all involved
- Helps people understand the benefits of medication reconciliation
- Minimizes the opportunity for drug interactions and therapeutic duplications by making the patient's list of home medications available when physicians prescribe medications
- Provides the patient with an up-to-date list of medications
- Ensures that other providers who need to know have information about changes in a patient's medication plan[18]

Physicians are often legally responsible for medication reconciliation errors.[17] However, the patient is the one constant in the continuum of care. Hence, patients, family members, or other informal caregivers should be encouraged to carry a current medication list to all medical encounters and settings.[17] As electronic health records (EHRs) remain absent in most care settings and systems, patients (and caregivers) should take an active role in the medication reconciliation process. Even if a care provider has an EHR system, patients need to actively check the accuracy of medication data. In a recent study of medication discrepancies, 70% of medications recorded in patients' electronic medical records were no longer being taken.[19]

Opportunities for Medication Optimization

Medication Reconciliation Technologies

Patients and caregivers can utilize technologies to help mitigate medication reconciliation problems. Using a variety of online programs and technologies, patients or caregivers can provide complete, up-to-date patient medication histories. There are several models for medication lists. Some online medication lists only allow one-time entry of medication information, while others electronically store information for continuous updates. Most lists require patients to enter drug, dose, and other medication information, which can leave room for error. Electronic lists in this form are often only accessible to patients and caregivers. In order for clinicians to access this medication list, patients must bring a printout of the list with them to the medical exam.

Examples of one-time entry medication lists are listed below. See IHI.org and ntocc.org for additional examples.

Name	Organization	Description
My Medication Log	Cardiovascular and Public Health Detailing Programs	A medication log for use in the Cholesterol Action Kit http://www.ihi.org/IHI/Topics/PatientSafety/MedicationSystems/Tools/MyMedicationLog.htm
Universal Medication Form	McLeod Health in Florence, SC	A form where patients can enter medications used, allergies, and immunization records
Health and Safety Passport	California Pacific Medical Center, San Francisco, CA	Patients list their medications, health history, and other relevant information
Med List	A statewide, collaborative initiative in Massachusetts	Medication list to keep track of patient medications and supplements. Also offers tips for using medications wisely.
My Medicine List	American Society of Health-System Pharmacists (ASHP)	A tool where patients can develop and manage their own medication list. The tool can be found on the ASHP Foundation website and on http://www.safemedication.com/meds/medForm.cfm
Pill Card	Agency for Healthcare Research and Quality (AHRQ)	Information on how to develop an easy-to-use "pill card" for patients, parents, or anyone who has a hard time keeping track of their medicines at http://www.ahrq.gov/qual/pillcard/pillcard.htm
My Medicine Record	Food and Drug Administration (FDA)	Patients list prescription medicines, over-the-counter medicines and dietary supplements. http://www.fda.gov/cder/consumerinfo/my_medicine_record.htm

Opportunities for Medication Optimization

Medication Reconciliation Technologies

Movement toward continuous electronic medication lists begins to offer increased clinician access, while interoperability opportunities emerge to pull information from prescription records and integrate with personal health records (PHRs) and EHRs. PHRs are a set of technologies through which patients can access and manage their own health information, regardless of care setting. The contents of PHRs vary, but can include at a minimum diagnosis/problems, medications, allergies, and past medical history. Additionally, PHRs can have a provider/clinician portal, where providers can enter and maintain information. Common across many of these systems are support for the Continuity of Care Record (CCR) as outlined by the American Society for Testing and Materials (www.ccrstandard.com) and/or the Continuity of Care Document (CCD) outlined by HL7 (www.hl7.org). Both standards provide a core data set of the most relevant administrative, demographic, and clinical information facts about a patient's healthcare. There are currently hundreds of different PHR offerings, including services from Google and Microsoft as well as a non-profit/for-profit partnership collaborative: Dossia (www.dossia.org). In addition, many health systems and large clinics have developed their own PHRs that integrate with their EHRs. In the long term, many providers will have access to integrated PHRs and EHRs. Their EHR/PHR's will be able to accept CCR/CCD information from other providers on an automatic or on-demand basis. Most provider organizations will have added portal functions to their PHR to provide improved access, self-service, continuity of chronic care, and remote care.

Walgreen's currently provides pharmacy patients access to their medication history through online tools. Patient drug and dose information input errors can be reduced as prescription information and filling history is automatically pulled into the list. Like other medication lists, patients often fail to share this information with the clinician. Walgreens has recently partnered with Microsoft® HealthVault™, a web-based PHR platform, giving Walgreens pharmacy patients the ability to upload their medication history into HealthVault and share this information with caregivers, clinicians, and others. Medication information will be automatically updated daily in HealthVault, allowing patients to share their most up-to-date health information while avoiding manual entry of data.[20]

Opportunities for Medication Optimization

Medication Reconciliation Technologies

Check-in medication kiosks, piloted at the Veterans Health Administration (VA), have patients and caregivers review and adjust their medication history, pre-populated from their EHR. The VA developed the Automated Patient History Intake Device (APHID) for use in the ambulatory setting, where patients review and update their medication histories before their appointments. APHID pulls medication lists from the VA's electronic health record and has patients review the name, dose, frequency and pictorial representation of the medications. Patients have the opportunity to input information from non - VA clinician visits into the kiosk, which can then be used on subsequent visits. Providers then review the updated medication history during the appointment, looking for possible drug interactions and duplicate therapies. During the pilot of APHID, a study found that older adults thought the kiosk was simple to use (75.4%) and navigate (66.7%), and that the medical information was easy to understand (94.2%). APHID's utilization of EHR and patient input on medication history prior to medical appointments also has the potential to reduce clinician reconciliation work and streamline work processes. While the reconciliation process cannot be completely replaced by technology, kiosks reduce the time clinicians spend entering medication information while engaging patients and caregivers in managing the patient's health.

Opportunities for Medication Optimization

Medication Adherence

The World Health Organization defines adherence as "the degree to which the person's behavior corresponds with the agreed recommendations from a health care provider."[9] Non-adherent patient behaviors occur at two main points in the medication-use process (Dispense and Administer). A significant portion (12%) of patients will not take possession of dispensed medications.[8] Of the patients that do pick up the dispensed prescription, 40% will not administer the medications correctly.[21] Medication adherence problems can also arise in the Monitor phase of the process, as patients may self-adjust their medications inappropriately, or stop altogether because of side effects.

Medication Adherence	
Dispense	Administer
Goals • Medication is made available • Medication picked up by patient • Patient and caregivers understand medication instructions	**Goals** • Individual dose dispensed • Individual dose taken by patient
Example Technologies • Teleconsultations • Online Patient Education • Cognitive Assessment Tools • Pharmacy Kiosks	**Example Technologies** • Medication Adherence Devices (integrated and standalone, simple and advanced function)

Suboptimal medication adherence can have negative consequences for individuals, families, and society, as medication non-adherence significantly increases the cost and burden of illness.[8] The New England Healthcare Institute estimates that $290 billion of health care expenditures could be avoided each year if medication adherence were improved.[1]

Medication non-adherence is considered responsible for:

- 33%-69% of medication-related hospital admissions
- 23% of all nursing home admissions
- Increased use of expensive, specialized medical resources
- Unneeded medication changes
- Unexplained treatment failures
- Repeat office visits[8]

Opportunities for Medication Optimization

Medication Adherence

Poor medication adherence has many root causes. Adherence is influenced by prior experiences, cultural factors, personal beliefs, treatment side effects, patient-provider relationships, and financial constraints.[22] Medication adherence can be especially difficult for older adults. Physical, cognitive, and sensory health often decline with age. Mobility difficulties, forgetfulness, and diminished sight and hearing make it more difficult to acquire medications, understand instructions, remember to take medications on time, and read and hear medication-taking instructions. Because medication adherence is considered an instrumental activity of daily living, the ability to manage medications successfully is an important factor in maintaining independence in the older adult population.[23]

Because medication adherence is multi-factorial, many clinicians believe that a multi-faceted approach is most effective at improving adherence. Many also believe that adherence interventions must be customized to the individual's needs. Such interventions include:

- Simplifying the patient's medication regimen, e.g., changing from dosing three times a day to twice a day
- Identifying if the medication has untoward effects, e.g., causes side effects or financial burden
- Better motivating the patient to persist in taking their medications. (This is particularly important in chronic illnesses that are asymptomatic, such as hypertension)
- Providing cues or reminders to take medications as prescribed

According to Logue (2002) there are several ways to measure the outcomes from medication adherence interventions.

- Objective symptom assessment and physical examination, e.g., vital signs, lung and heart auscultation
- Direct indicators, e.g., blood glucose level
- Indirect indicators, e.g., pill counts, filling/refilling of prescriptions, pill diaries
- Subjective reports, e.g., patient or family statements
- Frequency of visits to emergency departments[24]

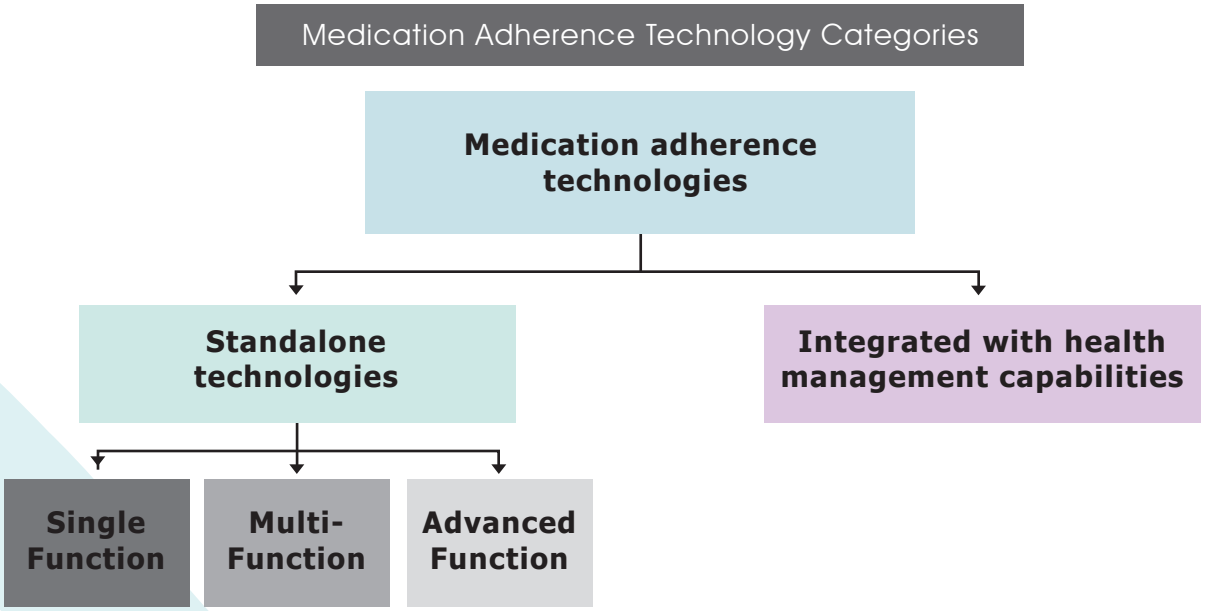
In a recent comparison of methods to assess medication adherence and classify nonadherence, patient self-report, pharmacy refill records, and use of electronic pill container lids all provided similar estimates of overall adherence. But refill records and data from the electronic pill containers were in highest statistical agreement.[21]

Opportunities for Medication Optimization

Medication Adherence Technologies

In dispensing medication to the patient, cognitive assessments can assist in determining a patient's capability for medication adherence. Specific cognitive abilities including memory, literacy, executive abilities and general cognitive status all relate to different aspects of medication adherence.[25] Common cognitive assessment tests like the Mini-Mental State Exam (MMSE) have been shown to correlate with medication adherence, especially in the elderly. Lower scores indicate lower cognitive function making patients less likely to take their medication correctly.[26] Work is currently underway to computerize cognitive assessment tests for online access by patients in the home, physician's office, community-based or long-term care setting.[27] The regular use of computerized cognitive assessments can establish a clear baseline of cognitive function and can set the stage for continuous assessment and/or assessment after injury.[28] Should cognitive assessment scores begin to fall in certain areas, medication regimes and use of more complex adherence dispenser devices can be adjusted accordingly.

Medication adherence technologies have been expanding in both variety and sophistication. Technologies can assist patients and caregivers with obtaining proper medication information, patient education, medication organization, dispensing, dose reminders, and safeguard against an overdose. Such technologies can be classified as standalone or integrated technologies. Standalone technologies tend to be less complicated and can be single-function, multi-function or have advanced functions. Integrated technologies are more complex and integrate medication management with other health management capabilities such as general health monitoring, sensors, or health information storage.



Opportunities for Medication Optimization

Medication Adherence Technologies

A technology can potentially provide one or more functions to an individual patient under a "medication administration continuum," including:[29]

1. Fill: provides patient with information and/or instructions about the drug
2. Remind: reminds patients to take medications – audibly, visually, or both
3. Dispense (e.g., in the home): automatically dispenses medications, usually at certain times/intervals
4. Ingest: detects whether or not a patient has ingested his/her medications
5. Metabolize: detects whether or not a patient has metabolized his/her medication
6. Report: logs date and time when medication is taken and reports to clinician/caregiver
7. Adjust: adjusts medication automatically if needed

Ingest, metabolize, and adjust can be considered "advanced functions" because these capabilities are still largely in development. A technology that performs one function currently available within the medication adherence technology spectrum is a single-function technology while a device that performs two or more functions currently available within the spectrum are referred to as multi-function technology. Advanced function technologies perform one or more of the currently available spectrum functions and can also perform one of the more advanced functions including detection of medication ingestion, metabolism, or adjustment.

Standalone technologies are the simplest and easiest to use; however, they lack the functionality for more comprehensive health management. Examples of standalone technologies include medication information devices, medication reminders, a medication dispenser, or a device that combines informing, reminding, and dispensing. Many standalone technologies are currently available on the market. Additional standalone technologies are being developed, including those with advanced functions. Rex the talking pill bottle is a single-function standalone device that assists visually or cognitively impaired patients with accessing recorded medication information. The pill bottle contains a speaker with recorded information from the pharmacist stating the name of the drug, what it is used for, dose, frequency, duration, side effect warnings, and refill instructions. Kaiser Permanente has implemented this technology in over 140 facilities.

A multi-function standalone technology, Philips Medication Dispensing Service, organizes and dispenses 10-30 days worth of medication (depending on the dose frequency) by individualized doses into plastic cups. Patients are reminded to take their medication based on verbal and auditory reminders. To safeguard against double dosing or missed doses the system will lock away the dispensed medication after 90 minutes if it has not been removed

from the device. It will then alert up to four caregivers, including health care professionals, that a dose was missed. Alert and dispensing history are uploaded daily to a web-support system allowing caregivers and clinician review. In a study comparing the Philips Medication Dispensing Service with plastic medication boxes, Philips Medication Dispensing Service was shown to reduce hospitalization rates, emergency room visits, and (where appropriate) decrease the number of medications taken by the patient. Staff at the Johnston County VNA, where the Philips Medication Dispensing Service machines were installed and where the study was conducted, thought the greatest success with the Philips Medication Dispensing Service was seen in patients on warfarin therapy or those who had mental and cognitive health issues.[30]

	Philips Medication Dispensing Service	**Medi-Set Medication Boxes**
Hospitalization per patient	0.09	0.42
Emergency Department visits per patient	0.18	0.42
Prescriptions per patient	7.62	8.65

Advanced function standalone medication technologies using direct measures, such as detecting if a patient ingested his/her medication or whether they have metabolized the medication, are mostly in development and not yet available on the market. A few examples include MagneTrace and Xhale's SMART™. The "ideal" technology would continue to improve the patient's medication adherence, and start to integrate monitoring features like automatically adjusting medication doses.

Developed more recently, integrated medication adherence technologies integrate pill dispenser and reminder systems with general health monitoring or health information storage. For example, InforMedix's Med-eMonitor System is a portable electronic medication-dispensing device, holding one month's supply of up to 25 different medications, with add-on health management features. Once dispensed, the system asks the patient to confirm they have taken the medication while recording the date and time the medication was delivered. Patients are then asked a series of health related questions about their blood pressure, blood glucose level, and signs concerning stroke. If a health problem is reported, or if no response is received over a certain period of time, the system will attempt to contact the patient, caregiver, physician or emergency services as needed. Use of the InforMedix' Med-eMonitor System was associated with improved mean medication adherence rates of over 92% compared to a 40% baseline medication adherence rate.[31] Use of the system was also associated with a reduction in Hemoglobin A1c levels in individuals with Type 2 diabetes—by an average of 18.5% in a 3-month period.

Opportunities for Medication Optimization

Medication Adherence Technologies

Integrated technologies can primarily be medication management devices with add-on health management features or home health devices with add-on medication management features. While these integrated technologies allow for more comprehensive health management, they can be more expensive and complicated than their standalone counterparts, making them more difficult to use. These integrated technologies often use a service-based pricing model (compared to a one-time fee for standalone technologies). Some integrated solutions are currently available on the market, while others are in development.

Patients have highly varied needs for medication adherence technologies. Some patients want a simple, inexpensive technology while others may have a condition requiring an expensive, integrated technology as well as a spectrum of technologies in between. There is a need for a large portfolio of technologies, from simple to complex, in order to meet needs for all patient segments in the most appropriate way.

Opportunities for Medication Optimization

Medication Adherence Technologies

Table 3: Medication Adherence Technologies

Category	Description	Sample Techs	Pros	Cons	Market Stage	Economics	Categories in Medication Adherence Spectrum
Single-Function	Performs one function currently available within the medication adherence technology spectrum	• iGuard • Timex messenger • Rex Pill bottle • Gentle Reminder	Simplest and easiest to use technologies	• Lacks greater functionality for more comprehensive health management	Many technologies out on the market and currently used	• Usually a one-time purchase • Prices can vary widely • Relatively inexpensive	Fill, Remind or Dispense
Multi-Function	Performs two or more functions currently available within the medication adherence technology spectrum	• EMMA • Philips Medication Dispensing System • MedSignals • uBox • Dispense-a-Pill	• Mostly easy to use • Integrates multiple functions for better health management	• May be complex or require greater caregiver involvement • Lacks functionality for more comprehensive management	Many technologies out on the market and currently used	• Usually a one-time purchase • Prices can vary widely (less than $100 to $1000+)	Fill, Remind, Dispense, and Report
Advanced Function	Performs one or more of the currently available spectrum functions and can also perform one of the more advanced functions	• MagneTrace • Xhale's SMART	• Advanced technologies allow actual tracking/ adjustment/ ingestion of medication • Integrates multiple functions	• Considerably more complicated than single/ multi function without clear benefit understanding • In some cases, may lack comprehensive management functionality	Most technologies still in development	• Currently unclear - most technologies still in development • May be relatively expensive	Advanced functions: Ingest, Metabolize, and Adjust
Integrated with Health Management Capabilities	Technologies that integrate medication administration with other health-related management functions (i.e. monitoring, sensors, independent living assistance)	• Med-eMonitor • HealthHero • Home HealthPoint • Zume Life Zuri • Intel HealthGuide	• Combined offering allows for broad patient management • Many devices likely to move towards integration of health tracking/ monitoring	• Relatively complicated, may require caregiver involvement • May require greater tech knowledge	• Some techs currently on market and used • Other techs in development	• Usually upfront cost plus a monthly fee (service-oriented model) • Upfront cost can be relatively high	Fill, Remind, Dispense, and Report

Opportunities for Medication Optimization

Medication Monitoring

In the context of this paper, medication monitoring primarily refers to the process of monitoring a patient's response to a medication. Secondarily, medication monitoring can also reveal whether a patient is taking a medication, or taking an appropriate dosage at the appropriate times. Monitoring information includes biometric data, administrative data (e.g., whether a prescription was filled), subjective reports, and health service utilization data.

Monitor

Goals

- Track patient response to medication
- Respond to tracking information when needed
- Clinician adjusts medication as needed
- Prescriptions refilled

Example Technologies

- Personal biometric testing devices
- Wireless communication devices
- Personal Health Records

Inadequate monitoring is a natural target for quality improvement.[32] According to a study of ambulatory Medicare beneficiaries, adverse drug events occurred at a rate of 50 per 1000 person-years, with a rate of 14 preventable adverse drug events (ADEs) per 1000 person-years. Suboptimal monitoring was involved in 61% of the preventable adverse drug events.[2] Monitoring problems that were associated with ADEs tended to fall into the categories of monitoring too infrequently or not responding adequately to signs, symptoms, or laboratory test indications of drug toxicity.[2]

The following emphasizes monitoring in the case where a patient is at risk for adverse reactions. But medication monitoring can also be used to keep a patient motivated, e.g., measuring blood pressure to affirm that anti-hypertensive medications and a low-sodium diet are working as expected. If diet or a lower dose of medication is not enough to reach targeted goals, medication adjustments based on monitoring information can be made.

Medications that place patients at risk for adverse reactions are especially important to monitor. Warfarin is an exemplar in this case. Warfarin (an oral anticoagulant) is widely used to prevent deep vein thrombosis, and problems associated with atrial fibrillation and prosthetic heart valves.[33] While warfarin's effectiveness for these conditions is widely acknowledged, warfarin use must be closely monitored. Adverse reactions that are serious enough to send someone to the emergency room are common with warfarin. In one study, anticoagulants were second on the list of adverse drug events presenting to the emergency department, with 6.2% attributable to anticoagulants.[34, 35] (Adverse drug events associated with insulin topped the list with an 8% incidence rate.) Bleeding is the most serious and common complication of warfarin use.[36] Most bleeding problems are clinically minor,[36] but fatal hemorrhagic events claim the lives of 1% of patients each year.[32]

Opportunities for Medication Optimization

Medication Monitoring

Age is the main risk factor for bleeding[36] and this is a concern because many older adults are on warfarin therapy. In one study of ambulatory older adults, 7% were using warfarin.[2] Warfarin use among nursing home residents may be as high as 12%, according to some authors.[37] Research suggests that for every 10 year increase in age above 40, the risk of major bleeding increases 46%.[36]

Warfarin can be safely used if therapeutic monitoring is done well. The risk of bleeding can be assessed via a blood test of prothrombin time (PT) International Normalized Ratio (INR). Warfarin dosage can be adjusted down if the patient's INR is too high.[36] However, a dose of warfarin that is too low can place the patient at increased risk of stroke or other thomboembolic event. Hence, frequent monitoring is needed to decide on the optimum dosing level.

Convenient, drop-in prothrombin time testing clinics have been available for decades. At-home or near-home prothrombin testing devices are widely available and Medicare payment coverage is available for beneficiaries who are using warfarin to prevent problems from chronic atrial fibrillation, venous thromboembolism, and heart valves.

Opportunities for Medication Optimization

Medication Monitoring Technologies

Point-of-care testing devices are available to monitor blood pressure, peak flow (for asthma), blood glucose (for diabetes), and a host of other health conditions. Many devices can interface with a personal computer, and increasingly with home monitoring devices. Data can also be uploaded to a clinician's portal or other remote site.

Returning to the example of home monitoring of warfarin, point-of-care testing devices have increased patients' role in the management of their health, reducing visits to warfarin clinics. Many studies have shown effective home and self-management of anticoagulation therapy.[38, 39] Communication tools and devices to streamline medication dose adjustments are also becoming more sophisticated and reliable. In a proof-of-concept study, clinicians successfully used a decision support tool to calculate dose modifications and relayed the changes through an interactive voice response system.[40] An internet-based medication adjustment tool (using an algorithm and clinician supervision) was associated with better patient anticoagulation control (74% time in therapeutic range) compared to an anticoagulation management service (58.6% time in the therapeutic range) for home warfarin monitoring.[40]

Wireless communication devices including cell phones, computers, point of care testing devices and automated dispensing devices enable continuous, real-time data collection and transmission of medication results and biometric data. Currently, mobile phone applications are available that allow users to personally manage their medications, with reporting and trending features. These applications are available from devices like Apple's iPhone and Research in Motion's Blackberry. Development of applications are growing for warfarin monitoring, and glucose and insulin dosage monitoring. Some applications have additional health management information like food intake and exercise. Biosensors, which collect and wirelessly transmit biometric data are in development to measure ingestion and metabolism of medication. Please refer to the advanced function standalone medication adherence technologies for further information on developing technologies in the field.

Point-of-care testing devices to monitor medication are becoming more prevalent and accurate with wireless capabilities. The increased ability to store, view, and trend data by patients, caregivers, and clinicians can improve management of patients' medication programs.

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.[6] Many medication optimization 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: Because so many older adults use medications, 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 injuries and complications.

Health and Economic Outcomes: Credibly demonstrating improvements in health and economic outcomes is one of the largest challenges that medication-use technologies face. Randomized, controlled trials are the gold standard for demonstrating such improvements. But most technologies, if tested at all, 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 medication optimization technologies.

Workforce Relief: In the medium- to long-term, some technologies may reduce demands on the ever-stretched work force that cares for older adults—by encouraging greater self-managment 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. Many in-home medication-use technologies, for example, will require someone to train the patient or informal caregiver.

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. However, more complex, interoperable solutions may be needed, especially where breakdowns in communication are at the heart of the problem (e.g., as in medication reconciliation).

Discussion

Policy Relevance: Many current and emerging policies seem to favor medication optimization solutions. The Centers for Medicare and Medicaid Services (CMS) have taken a leading role in improving medication use for older adults and others that are eligible for Part D Medicare coverage of prescription drugs. For example, CMS is in the process of instituting improvements in Medication Therapy Management Programs (MTMP) that are currently offered by Part D sponsors (CMS contracts with "Part D sponsors" to provide prescription drug coverage for Medicare beneficiaries). To maintain status as a Part D sponsor, organizations must provide MTMP services for selected Medicare clients, i.e., those who have multiple chronic illnesses, use multiple medications, and incur high drug costs. According to a recent CMS call letter, MTMP services will soon have to meet more stringent standards, such as quarterly, targeted medication reviews to assess drug use and monitor any problems.[41]

Non-governmental organizations (NGOs) are also leading high-visibility initiatives to improve medication use. Medication reconcilation improvement is a high-priority goal for the Joint Commission and the Institute for Healthcare Improvement, for example.[13, 18]

Appendix A:

Medication Optimization Opportunities in Context

This paper has discussed three medication optimization opportunities (Medication Adherence, Medication Reconciliation, and Medication Monitoring) in the context of the mission and goals of the Center for Technology and Aging. The following table places these opportunities into a broader context, and highlights in yellow those areas that are most relevant to the Center's Medication Optimization initiatives.

Mapping the three medication optimization opportunities to the medication-use process provides the opportunity to identify solutions that optimize outcomes. First the three opportunities map to five process phases, which categorize the main actions of medication management: assess, prescribe, dispense, administer, and monitor. (Note that phases vary by care setting, health care professional role, and patient involvement). Phases can be further divided into process steps, starting from patient identification and medication history, and progressing to routine dosing, tracking, and reporting of patient medication use. A number of technology innovations can optimize process step efficiency, mitigate medication-use problems, and improve the health and independence of older adults. Technology solutions range from standalone to integrated technologies and are utilized by patients and caregivers, clinicians, or both.

Medication Optimization Opportunities in Context
Adapted from A Guide for Health Care Payers to Improve the Medication Management Process (pgs 9-11)[5]

Opportunity	Phase	Key Steps	Optimal Step Outcome	Technologies
Medication Reconciliation	Assess (physician's office, hospital)	Patient Identification	Identified patient information including name, address, birth date, gender	RFID (Radio-frequency identification) Barcoding
		Medication History	Obtained complete list of previous and current medications used by patient	Medication list software Personal Health Records (PHR)
		Diagnosis	Clinician accurately diagnoses patient problem	
	Prescribe (physician's office, hospital)	Medication Selection	Optimal medication for patient selected by clinician. Pulled from lists specific to diagnosis, commonly prescribed, etc	Clinical decision support tools EHR
		Safety Check	Patient medication selection passes safety check and does not interfere with patient allergies, other drugs or medical conditions, taking into account patient body size and pharmacokinetics for proper dose	Clinical decision support tools EHR
		Formulary and Benefits Check	Patient medication selected from pharmacy benefit list, has prior authorization, with the lowest possible co-pay	Clinical decision support tools EHR
		Medication Ordered	Electronic or hand written medication orders from clinician transmitted seamlessly to dispenser	e-prescribing CPOE
		Ordered Medication Documented	Medication order documented where patients can access the information	Medication list software PHR
Medication Adherence	Dispense (medication packing facility)	Evaluate/Approve Order	Medication order reviewed and approved to dispense	CPOE
		Medication Preparation	Medication order identified, prepared and packaged for delivery to dispensing location	RFID service robots
		Medication Distribution	Medication delivered to dispensing location	
	Dispense (pharmacy, hospital)	Patient and Medication Identification	Health care professional identifies and verifies patient and medication order	Barcoding, RFID
		Safety Check	Patient medication passes safety check and does not interfere with patient allergies, other drugs or medical conditions, taking into account patient body size and pharmacokinetics for proper dose	Clinical decision support tools
		Patient Education and Cognitive Assessment	Patient educated on medication use, dosing, side effects, and contraindications. Cognitive assessment determines patients' ability to adhere to medical regime.	TeleConsultations Online patient education Cognitive Assessment tools
		Medication Dispensed to Clinician	Medication order dispensed and picked up by clinician	Robotic dispensers and carousels
		Medication Dispensed to Patient	Medication order dispensed and picked up by patient	Pharmacy kiosk
	Administer (hospital, LTC facility, patient home)	Medication Information Identification (by clinician)	Clinician identifies and verifies correct patient and medication	Barcoding RFID
		Medication Information Identification (by patient or caregiver)	Patient identifies correct medication by reviewing drug name, dose, time of day, drug interactions	Talking pill bottles
		Dispense Individual Dose (by clinician)	Accurate individual medication dose (pill, IV bag, shot or liquid) properly dispensed to clinicians	IV Smart pumps Service robots
		Dispense Individual Dose (by patient)	Accurate individual medication dose (pill) properly dispensed to caregivers or directly to patient	Automated dispenser devices
		Take Dose	Patients takes proper dose at the right time	Reminder alert devices
Medication Monitoring	Monitor (LTC facility, patient home, hospital)	Routine Dosing and Tracking	Patient/caregiver routinely takes proper medication dose and records time medication is taken or not taken	Automatic dispenser devices
		Reporting and Trending	Caregiver/patient/clinician receives overview and trending of medication log and outcomes	Wireless communication devices Automatic dispenser devices PHR
		Refill prescriptions, contact clinician	Patient/caregiver refills medication or contacts clinician to adjust	Prescription reminder systems

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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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