Older Adults and Management of Medical Devices in the Home: Five Requirements for Appropriate Use

Sara C. Keller, MD, MPH, MSHP,^{1,2} Ayse P. Gurses, PhD, MS, MPH,² Nicole Werner, PhD,^{3,4} Dawn Hohl, RN, PhD,⁵ Ashley Hughes, MS,⁶ Bruce Leff, MD,⁶⁻⁸ and Alicia I. Arbaje, MD, MPH^{6,9}

Abstract

Medical devices, or instruments or tools to manage disease, are increasingly used in the home, yet there have been limited evaluations of how older adults and caregivers safely use these devices. This study concerns a qualitative evaluation of (1) barriers and facilitators of appropriate use, and (2) outcomes of inappropriate use, among older adults at the transition from hospital to home with skilled home health care (SHHC). Guided by a human factors engineering work system model, the authors (1) conducted direct observations with contextual inquiry of the start-of-care or resumption-of-care SHHC provider visit, and (2) semi-structured interviews with 24 older adults and their informal caregivers, and 39 SHHC providers and administrators. Five requirements for the appropriate use of home medical devices were identified. A systems approach integrating the hospital with the SHHC agency is needed to make the use of home medical devices safer.

Keywords: medical devices, home health, human factors, elderly, geriatrics, hospital discharge

Introduction

WITH EMPHASIS on decreasing hospital stays, patients increasingly use complicated medical devices in the home. Medical devices are defined by the Food and Drug Administration as instruments, machines, implants, or other articles intended to diagnose, treat, or prevent disease or disability.¹ In hospital settings, inappropriate device use can cause harm.² Medical devices may be more difficult to use in the home,³⁻⁵ particularly for older adults who may struggle with impaired mobility, eyesight, hearing, or cognition.⁶ Home environmental factors (eg, background noise,^{7,8} sanitary practices, lighting, pets, vermin, temperature variations, clutter^{6,9-12}) also affect device use.

Older adults may have their first experience with a home medical device after hospital discharge. During the transi-

tion from hospital to home, older adults are at increased risk for suboptimal care and unplanned health care utilization.^{13,14} Although home medical devices may facilitate older adults remaining at home,¹⁵ it is unclear how the inappropriate use of home medical devices may contribute to the overall challenges of older adults in transitioning home after hospital discharge.

Skilled home health care (SHHC) services often support older adults' transitions home.¹⁶ Almost 5 million Americans were discharged from SHHC services in 2013.¹⁷ Skilled home health care providers (SHHCPs; nurses, rehabilitation therapists, and others) deliver home-based services on a short-term, intermittent basis. These services include provision of and training in the use of home medical devices, such as mobility aids, infusion pumps, ventilation devices, and home oxygen. Little work has focused on older adults' postdischarge

¹Division of Infectious Diseases, Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, Maryland.

²Armstrong Institute of Patient Safety and Quality, Johns Hopkins University School of Medicine, Baltimore, Maryland.

³Living Environments Laboratory, Department of Industrial and Systems Engineering, Center for Quality and Productivity Improvement, College of Engineering, Wisconsin Institutes for Discovery, University of Wisconsin—Madison, Madison, Wisconsin.

⁴Geriatrics Research Education and Clinical Center, William S. Middleton Memorial Veterans Hospital, Madison, Wisconsin.

⁵Johns Hopkins Home Care Group, Baltimore, Maryland.

⁶Division of Geriatric Medicine, Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, Maryland.

⁷Department of Health Policy and Management, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland.

⁸Department of Community and Public Health, Johns Hopkins School of Nursing, Baltimore, Maryland.

⁹Department of Clinical Investigation, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland.

use of home medical devices from the perspectives of those directly involved in the hospital to SHHC (hospital/SHHC) transition.^{4,15}

Human factors engineering (HFE) applies information about human abilities and limitations to the design of tools, systems, tasks, jobs, and environments.¹⁸ HFE may provide insight into older adults' use of home medical devices by explaining the system in which people perform processes to produce outcomes.¹⁹ HFE models, such as the Systems Engineering Initiative for Patient Safety (SEIPS) 2.0,¹⁹ have been used extensively in inpatient settings to improve medical device safety.^{6,19–22} Limited published research has taken a HFE approach to describe the system¹⁹ of older adults' use of home medical devices.¹⁵ The objectives of this paper are to use a HFE approach to (1) characterize barriers and facilitators to older adults' successful use of home medical devices during the hospital/SHHC transition, and (2) characterize outcomes of inappropriate use.

Methods

Design

A qualitative analysis of older adults' hospital/SHHC transitions was performed. Participants were older adults and their caregivers (any nonpaid individual who participated regularly in the older adult's care), SHHC administrators, and SHHCPs (nurses and physical therapists). The study approach consisted of (1) a contextual inquiry of the first SHHCP visit after hospital discharge, during which researchers observed work being performed and asked questions to uncover unarticulated aspects of SHHCP work²³ and (2) semi-structured interviews with SHHC administrators, older adults, caregivers, and SHHCPs. Data collection took place at the SHHC agency and in the home.

Settings and participants

Data collection occurred at 2 sites affiliated with 1 large nonprofit urban SHHC agency. A combination of purposive and network sampling²⁴ were used to identify adults ≥65 years of age who would be receiving SHHC services after hospital discharge. Older adults were approached in person before hospital discharge, or by telephone the day after discharge. Written consent was obtained from the older adult (or his or her legally authorized representative) as well as the SHHCP visiting the older adult. This study was approved by the Johns Hopkins School of Medicine Institutional Review Board and participating site review boards.

Data collection and analysis

Contextual inquiries and interviews were guided by the SEIPS 2.0 model¹⁹ and explored barriers and facilitators to hospital/SHHC transitions.¹⁹ The model depicts an integrated feedback system in which elements of the health care work system (here, the system of home medical device use) interact to perform work through processes (here, processes required for the appropriate use of home medical devices), and outcomes of these processes (for the older adult, the SHHCP, and the organization).¹⁹

Two investigators conducted contextual inquiries and interviews between June and August 2015. In each of 24

contextual inquiries, 1 or 2 investigators observed a start of care (the SHHC agency's first visit to the older adult's home) or resumption of care (the first postdischarge visit by a SHHC agency that had provided prior services) visit. Investigators asked clarifying questions and took handwritten notes describing what was seen and heard from the time the SHHCP arrived at the home to the conclusion of the visit.

Semi-structured interviews occurred immediately after the visit. Older adults and caregivers (if present) were interviewed in the home (24 interviews), and SHHCPs were interviewed outside of the home (34 interviews). These interviews took approximately 45 minutes. SHHC administrator interviews occurred privately in conference rooms or offices and lasted 30 minutes (5 interviews). All interviews were audio-recorded and transcribed. Thematic saturation was reached for the findings presented.²⁵

Directed content analysis²⁶ was guided by the SEIPS 2.0 model.¹⁹ A preliminary coding template was created after review of 3 randomly-selected transcripts from each of (1) SHHC administrator interviews, (2) SHHCP interviews, (3) older adult interviews, and (4) notes from contextual inquiries. This coding template was revised as subsequent transcripts were reviewed, with changes being applied retroactively. Both a priori codes developed from the SEIPS 2.0 model¹⁹ and themes developed in vivo were used around barriers and facilitators to home medical device use and outcomes of inappropriate use of home medical devices. At least 2 investigators reviewed each transcript independently. Differences were discussed and reconciled by consensus.

Content analyses of these codes led to the development of major themes and subthemes. These themes were either (1) commonly mentioned by respondents, or (2) findings thought to be particularly novel, insightful, or surprising. Although the analysis was guided by SEIPS 2.0,¹⁹ the identification of emergent themes also was allowed. The results are presented as a conceptual description (themes developed from the data or existing theories) and an interpretive explanation (transformation of the data through linkages between categories).²⁷ In reviewing the coded data, the study team determined that the codes could be further grouped into key requirements for the appropriate use of home medical devices. Analysis was facilitated with ATLAS.ti software (ATLAS.ti Scientific Software Development, Ver. 7, Berlin).

Results

Description of the population

Of the 24 older adults interviewed, the mean age was 71 years, and half (50%) had caregivers present for the contextual inquiry and interview. Five (21%) were white, 8 (33%) were African American, and 8 (33%) were Hispanic who did not identify with any race.

Of the 39 SHHCPs interviewed, almost all were women ($N=36$, 92%); the mean age was 48 years. The SHHCPs were primarily registered nurses (80%) and included 5 SHHC administrators. Sixteen SHHCPs (41%) were white, 18 (46%) were African American, and 6 (15%) were Hispanic. These SHHCPs had spent a mean of 17 years in the home care industry.

Description of findings

Figure 1 presents the older adult and SHHCP's work system of obtaining and using a home medical device during the hospital/SHHC transition, including outcomes of inappropriate use, and was created by applying the SEIPS 2.0 model to the data.¹⁹ The study team created a meta-work system that includes the work systems of the older adult and caregiver as well as the SHHCP. In reviewing the codes and identifying barriers and facilitators to home medical device use at the time of the hospital/SHHC transition, 5 key requirements for the appropriate use of home medical devices emerged. Barriers and facilitators to these requirements are detailed in Table 1.

Description of the work system model

The older adult and SHHCP work system of obtaining and appropriately using a home medical device on hospital/SHHC transition includes interactions between tools and technologies (eg, device, cognitive aids), tasks, person (older adult, caregiver, SHHCP), organization (SHHC agency, hospital), and the physical environment, in the setting of an external environment (eg, insurance, regulations) (Fig. 1). The immediate processes resulting from the failure of the work system of acquiring and using the medical device, and intermediate outcomes of inappropriate completion of processes are then described. Intermediate outcomes lead to outcomes of inappropriate use categorized based on (1) who experienced the outcome (ie, older adult, SHHCP, the organization) and (2) the type of outcome (ie, perception and attitude, clinical). Older adult outcomes included perceptions and attitudes related to their experience (ie, stress, fear,

withdrawal, not feeling valued, negative perception of health care), and clinical outcomes (ie, threats to safety, health care utilization, complications, mobility issues). SHHCP outcomes included perceptions and attitudes related to their experience (ie, stresses, fear, frustration, not feeling valued). Organizational outcomes included perceptions and attitudes related to the experience (organizational morale).

Requirement 1: The older adult must have the right device at the right time. To have the right device at the right time, the device must be available when needed and delivered appropriately. The study team presented barriers and facilitators to having the right device at the right time based on the codes (Table 1). Several key barriers and facilitators emerged (Table 2). First, interprofessional collaboration was critical to ensuring the appropriate use of medical devices. Many SHHCPs appreciated when a SHHCP from a different professional background evaluated the same older adult, as this allowed them to codevelop a plan of care. One nurse, describing an older adult seen earlier that day, noted that this collaboration allowed her to better understand what older adults might need:

"That [home environment] kind of worries me and I'm so glad [a physical therapist] came in today because [the physical therapist] will be able to pick up different things and us working together will help get things set up for [the patient]. And [the patient] definitely is going to need equipment."

Second, organizational policies and procedures may have had unintended consequences that created a barrier to the appropriate use of medical devices. In particular, organizational policies occasionally led to a delay in the older adult receiving the medical device on arrival home. SHHCPs

FIG. 1. Older adult and SHHCP work system around use of home medical devices at the time of the transition from hospital to skilled home health care. SHHCP, skilled home healthcare provider.

TABLE 1. THE FIVE REQUIREMENTS FOR APPROPRIATE USE OF HOME MEDICAL DEVICES, INCLUDING BARRIERS TO AND FACILITATORS OF OPTIMAL USE

<i>Requirement for appropriate use of home medical device</i>	<i>Subtask needed for requirement</i>	<i>Barriers to meeting requirement</i>	<i>Facilitators to meeting requirement</i>
1. The older adult must have the right device at the right time.	<ul style="list-style-type: none"> • Device available in a timely fashion • Device delivered appropriately 	<p>Task barriers</p> <ol style="list-style-type: none"> 1. Task confusion among SHHCP <p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulty accessing a physician 3. Organizational policies with unintended consequences 4. Lack of organizational protocols <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult 2. Lack of caregiver presence <p>Physical environment</p> <ol style="list-style-type: none"> 1. Geographic challenges <p>External environment</p> <ol style="list-style-type: none"> 1. Insurance challenges <p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulty accessing a physician 3. Organizational policies with unintended consequences 4. Lack of organizational protocols 5. Difficulties coordinating across many people <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult 2. Older adult hesitation to bother others 3. Functional impairment in older adult 4. Older adult health beliefs 5. Lack of older adult education 6. Lack of caregiver presence <p>External environment</p> <ol style="list-style-type: none"> 1. Insurance challenges 2. Older adult/local culture of not seeking help 	<p>Tool/technology facilitators</p> <ol style="list-style-type: none"> 1. Cognitive aids <p>Organizational facilitators</p> <ol style="list-style-type: none"> 1. Cohesive teamwork 2. Organizational protocols 3. Positive organizational dynamics 4. Continuity of care <p>Person facilitators</p> <ol style="list-style-type: none"> 1. High socioeconomic status of older adult 2. Education of older adult
2. The older adult and caregiver must receive proper training and ongoing support in using the device.	<ul style="list-style-type: none"> • Older adult and caregiver trained in using the device • Supervision available for older adult and caregiver in using the device • Help is available when needed to use the device, including troubleshooting 	<p>Tool/technology facilitators</p> <ol style="list-style-type: none"> 1. Cognitive aids <p>Task facilitators</p> <ol style="list-style-type: none"> 1. Older adult task clarity <p>Organizational facilitators</p> <ol style="list-style-type: none"> 1. Collaborative teamwork 2. Positive organizational dynamics 3. Organizational support for clinician 4. Continuity of care <p>Person facilitators</p> <ol style="list-style-type: none"> 1. Positive family dynamics 	

(continued)

TABLE 1. (CONTINUED)

<i>Requirement for appropriate use of home medical device</i>	<i>Subtask needed for requirement</i>	<i>Barriers to meeting requirement</i>	<i>Facilitators to meeting requirement</i>
3. The device must fit the older adult's size and physical abilities.	<ul style="list-style-type: none"> • Choosing the appropriate device • Device customized for the older adult • Device is easy for older adult to use 	<p>Task barriers</p> <ol style="list-style-type: none"> 1. Task confusion among SHHCP <p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulties coordinating across many people 3. Difficulty accessing a physician 4. Organizational policies with unintended consequences <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult 2. Lack of caregiver presence <p>External environment</p> <ol style="list-style-type: none"> 1. Insurance challenges 2. Older adult/local culture of not seeking help 	<p>Tools/technology facilitators</p> <ol style="list-style-type: none"> 1. Cognitive aids <p>Organizational facilitators</p> <ol style="list-style-type: none"> 1. Organizational protocols 2. Positive organizational dynamics 3. Contingency plans 4. Communication between SHHCP <p>Person facilitators</p> <ol style="list-style-type: none"> 1. High socioeconomic status of older adult 2. Positive family dynamics 3. SHHCP adaptability
4. The device must function properly.	<ul style="list-style-type: none"> • Device manually functions • Device is appropriately maintained 	<p>Task barriers</p> <ol style="list-style-type: none"> 1. Need for more time <p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulty accessing a physician 3. Organizational policies with unintended consequences 4. Lack of organizational protocols <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult 2. Health beliefs of older adult 3. Lack of older adult education 4. Lack of caregiver presence <p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulty accessing a physician 3. Organizational policies with unintended consequences <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult <p>Physical environmental barriers</p> <ol style="list-style-type: none"> 1. Physical environment of the home 	<p>Task facilitators</p> <ol style="list-style-type: none"> 1. Cognitive aids <p>Organizational facilitators</p> <ol style="list-style-type: none"> 1. Organizational protocols <p>Person facilitators</p> <ol style="list-style-type: none"> 1. Older adult requests for support
5. The device must physically fit in the home environment	<ul style="list-style-type: none"> • Device is located where it can be accessed by older adult 	<p>Organizational barriers</p> <ol style="list-style-type: none"> 1. Ineffective teamwork 2. Difficulty accessing a physician 3. Organizational policies with unintended consequences <p>Person barriers</p> <ol style="list-style-type: none"> 1. Cognitive impairment in older adult <p>Physical environmental barriers</p> <ol style="list-style-type: none"> 1. Physical environment of the home 	<p>Task facilitators</p> <ol style="list-style-type: none"> 1. Cognitive aids <p>Organizational facilitators</p> <ol style="list-style-type: none"> 1. Positive organizational dynamics

SHHCP, skilled home healthcare provider.

TABLE 2. SUMMARY OF LESSONS LEARNED ABOUT THE APPROPRIATE USE OF HOME MEDICAL DEVICES

1. Interprofessional collaboration is critical to ensuring the appropriate use of medical devices.
2. Organizational policies and procedures may have unintended consequences that create a barrier to the appropriate use of medical devices.
3. Uncertainty around insurance coverage of home medical devices is common.
4. Training older adults and caregivers in use of the devices is essential, as many medical devices are not intuitive.
5. Older adults apply lessons from their own experiences and learned experiences from others when choosing and modifying medical devices for their individual needs.
6. Difficulties accessing physicians creates a barrier to the appropriate use of medical devices.
7. Direct observation of the home environment is necessary when choosing appropriate medical devices.

commented that hospitals no longer discharged older adults with home medical devices as it was too costly. Similarly, as SHHC administrators explained, SHHC policies also had changed in response to financial losses, preventing SHHCPs from providing home medical devices until after the older adult's arrival home:

"And [we] no longer really...try to [give supplies] the day [of discharge] because plans change, people don't go home, people at the last minute to go a subacute [facility], some people die, some people decide to go with family. So now you've got an oxygen tank, now you got supplies that [are] in the wrong place. We ate enough of the supply costs to say 'let's wait until they get there.'"

Third, uncertainty around insurance coverage of home medical devices is common. Based on prior experiences, many SHHCPs worried that if they ordered needed medical devices and the older adult's insurance policy did not fully cover these devices, or if the older adult had not yet met their insurance deductible, the older adult would be financially liable:

"I hope that insurance will cover a percent of [a shower chair], the challenge [with] her is sometimes they don't cover for it and at the end of the day, the patient might be the one who's going to be...paying for it."

Requirement 2: The older adult must receive training and ongoing support in using the device. To meet this requirement, the older adult needs training in using the device, supervision when first using the device, and ongoing assistance including troubleshooting (Table 1). As one physical therapist explained, based on her experience:

"...after you leave, they tend to...not use the device [in the way] you talked about So...on the next visit I'm going to try to see [if] she [is] using the appropriate ambulatory device [as] instructed. If not, then a lot of reinforcement has to be done...to make sure that she doesn't get into any accident[s]...."

Uncertainty around whether an older adult's insurance policy would cover medically necessary home medical devices or home health services was common (Table 2).

SHHCPs noted that waiting for insurance approval would delay training. Based on these experiences, they provided training without being assured reimbursement:

"So if it's somebody who cannot wait, let's say, somebody goes home with a trach[eostomy], and the insurance did not give an approval yet [for SHHC] and the family did not have a chance to be taught how to suction the patient, then they have two choices. Send them back to the hospital, or we go there and teach the family, because there can be [airway mucous] plugging, then that would not be good."

In addition, training older adults and caregivers in the use of medical devices is essential, as many medical devices are not intuitive. For example, one nurse noted that an aide caring for an older adult had failed to lock a walker to prevent it from collapsing. There had been no easy way to identify that such a lock existed:

"The walker, [the aide] didn't know how [to lock it], that means all this time this patient's been walking around with a walker that's not locked. Scary."

Requirement 3: The device must fit the older adult's size and physical abilities. For the device to fit the older adult's size and abilities, the proper device must be chosen, the device must be customized for the older adult, and the device must be easy to use (Table 1). A major theme emerged (Table 2): Older adults apply lessons from their own experiences and learned experiences from others in choosing and modifying medical devices for their individual needs. One older adult added an extra railing to her steps based on a personal experience: "Once I was going to fall on the stairs and I tore my ligament in my ankle..."

Older adults also learned from the experiences of others in choosing home medical devices that they could customize. One was particularly struck not by his experience, but by a book he had read:

"I read a book about Harry Truman, the President. And he was in excellent health until he fell in the bathtub. And that impressed me. That all you need is one bad fall.... That's...one of the main reasons I put those [grab bars] up there...you just need a little soap on that floor and you can take a bad spill. ...that's...real...terrifying. So...the bars are very handy, holding on and getting out of the tub."

Requirement 4: The device must function properly. For the device to be used properly, the device must manually function and be maintained (Table 1). It was noted here as well that difficulty accessing physicians created a barrier to the appropriate use of medical devices (Table 2). One nurse recounted her experience spending 2 months trying to get a prescription to repair an older adult's oxygen concentrator, during which time the older adult was hospitalized 3 times:

"I was...calling the doctor...and...calling the company...trying to find out what needs to be done to have somebody come by here to service her oxygen concentrator. They told me that the doctor has to send a prescription with...four different things that the doctor had to specify.... I called the doctor's office numerous times. I even sent a letter with [the patient] the last time that she went [to her doctor's office]... I never got a chance to follow up because she was rehospitalized. So her oxygen concentrator, it's still shutting off, [and her] portable oxygen tank...is just about on empty..."

Requirement 5: The device must physically fit the home environment. Barriers and facilitators to the device physically fitting the home environment were identified (Table 1). The study team also learned that direct observation of the home environment is necessary in choosing equipment (Table 2), as many devices ordered by hospitals did not fit the physical layout of the home. Instead, SHHCPs described their experience with recommending devices after visiting homes:

“[With] her case in particular, [we will] have some issues with her bathroom because it’s a small environment.... So in that case we really have to figure out the proper equipment. She has the bench, but it’s too big given the size of the...tub and the location of the toilet, which is side by side.... Usually the hospital...staff does not really picture the actual bathroom.”

Needing to directly observe the home prior to choosing appropriate devices often resulted in increased work for the SHHCP and caregiver from devices being redelivered, and the home being rearranged, as well as a delay in the older adult’s receiving the appropriate device. One older adult–caregiver pair even suggested that their home be visited prior to discharge, although this was not the practice of the SHHC agency:

Older Adult: “[The physical therapist] did look at all the equipment and he feels it’s not the right one....”

Caregiver: “Well, because [the physical therapist] actually is here.”

“He saw it, you know.”

“I asked [the inpatient staff] if somebody could come to the house to look at the bathroom.... And they said, no they don’t do that. It would make sense to me that it would save all this shifting around of equipment.”

Discussion

A HFE-informed approach was used to identify barriers and facilitators to the appropriate use of home medical devices and outcomes of inappropriate use during older adults’ hospital/SHHC transition. These findings may guide interventions to improve older adults’ use of home medical devices.

This study expanded on literature focused on inpatient medical devices and hospital/SHHC transitions to include home medical device use during hospital/SHHC transitions. Unlike prior studies of home medical devices, the present study included SHHCPs and focused on older adults.

This study revealed that SHHCPs collaborated to ensure the appropriate use of home medical devices. SHHCPs described interprofessional collaboration as a necessary element of the appropriate use of home medical devices in their experience, as it is in other aspects of hospital/SHHC transitions.²⁸ In this study, SHHCPs codeveloped care plans, where insights from, for example, nurses and physical therapists might be incorporated into one older adult’s plan of care. In addition, SHHCPs had shared situational awareness (ie, a common understanding of the older adult’s care plan),²⁹ leading to an improved use of home medical devices. In this study, because they worked in the same SHHC agency, SHHCPs benefited from knowing each other and from being able to use the same medical records system, and they spoke to each other directly about their concerns. The

SHHCPs found this ability to communicate with colleagues in the same SHHC agency to be useful. However, codeveloping plans and creating a shared situational awareness might be done in a more formal way, such as with weekly multidisciplinary rounds discussing each older adult among all SHHCPs. Care plans could be drafted by all SHHCPs involved in the care of the older adult prior to finalization of the care plan. Collaboration and coordination between SHHCPs from different professions, whether informal as shown in this study, or with more formal rounds, is an important component of home medical device use.

This study also found that hospital and SHHC policies created barriers to obtaining home medical devices. By delivering home medical devices after discharge (and not before, as had been done in the past), the SHHC agency prevented financial loss if discharge plans changed. Meanwhile, hospitals lost money when they sent medical devices home with patients, and had stopped this practice. The combination of these 2 policies to reduce financial loss meant that older adults did not always have home medical devices upon arriving home. Furthermore, even when home medical devices were present, they did not always fit the home. Although others have described characteristics of the home environment that may impact home medical devices,^{6–12} research has not focused on devices physically fitting into the home. One caregiver even suggested that SHHCPs visit the home prior to ordering medical devices. Other alternatives could include caregivers taking images of the areas where home medical devices might be needed (ie, bathroom, bedroom) to assist in ordering home medical devices, or the SHHC providing multiple home medical devices of differing sizes on the delivery vehicle. These interventions would require hospitals and SHHCs to collaborate on early notification of discharge plans.

Many SHHCPs had experiences with older adults’ insurance policies either not fully covering medically necessary home medical devices, or not covering training older adults in their use (including caregiver training in how to suction a tracheostomy). Unfortunately, information about coverage decisions often did not come until after the device or training was needed. If the device or service was not covered, older adults might be financially liable for the costs of these medically necessary devices or services. Although conversations should occur between ordering providers, SHHCPs, and older adults and their caregivers about whether a medically necessary home medical device or service might require out-of-pocket payments, the uncertainty about insurance coverage of devices and services makes shared decision making difficult. The role of insurance coverage uncertainty as a barrier to home medical device provision has been suggested in conceptual models,¹⁵ but has not yet been demonstrated in research.

This work supported other studies in showing that training and ongoing support in home medical devices is needed for the appropriate use of these devices, based on experiences of patients, caregivers, and SHHCPs. Even health care workers may feel that their own training and ongoing support in in-hospital medical device use may be insufficient.³⁰ In the home, training materials provided by manufacturers may be inadequate^{4,30,31} or unavailable: some training materials are so confusing that SHHCPs prefer to not distribute them.⁴ Older adults may need more

training in complicated home medical devices.³¹ This study showed that this training should occur with the actual devices older adults would be using, and should be ongoing as skills may decay.³² Training materials should be designed based on HFE principles and tested for ease of comprehension and use.

Accessing physicians was important in appropriately using home medical devices, as SHHCPs experienced. As shown in other studies, communication between inpatient and outpatient physicians and SHHCPs is key^{33–38}; the inpatient physician may no longer be following the patient, and the outpatient physician may not have a clear understanding of hospital events. Future initiatives focusing on handoffs between inpatient and outpatient physicians should involve SHHCPs.

In addition, older adults used their experiences to choose medical devices that fit their needs. Other studies also have shown that patients can provide insights into home medical device design.^{39,40} Manufacturers and providers should incorporate the perspectives of older adults in designing home medical devices.

This research addresses home medical device use as an important but underrecognized component of older adults' hospital/SHHC transitions. The study team garnered a deep understanding of the home medical device work system through contextual inquiry of SHHCP visits and through interviews with older adults, SHHCPs, and SHHC administrators.

This study had several limitations. First, it focused on the experiences of older adults in one large American city, so the findings may not reflect the experiences of all patients. As this is a qualitative study, the focus was not on generalizability, but rather hypothesis generation and guiding intervention development. Second, this study did not interview certain key stakeholders, such as hospital-based clinicians or primary care providers, as these stakeholders were not directly involved in home medical device use during the hospital/SHHC transition. Third, this study focused specifically on the hospital/SHHC transition period as this is a period during which older adults are at high risk of readmissions,¹⁴ so the findings may not reflect what happens during other periods of home medical device use. Challenges with home medical device use may change over time.

A HFE-informed approach was used to identify systematic barriers, facilitators, and outcomes of older adults' home medical device use during the hospital/SHHC transition. The study findings emphasize 5 requirements for the appropriate use of home medical devices that can guide the development of interventions. The care of older adults in the home likely will become more complex over time, as more tasks previously provided in inpatient settings are moved to the home. New developments in technology will add to this complexity. Future investigations could focus on a deeper understanding of the challenges during hospital/SHHC transitions and other transitions involving the use of medical devices.

Author Disclosure Statement

Drs. Keller, Gurses, Werner, Hohl, Leff, and Arbaje, and Ms. Hughes declare that there are no conflicts of interest.

This work was supported by funding from the Johns Hopkins University School of Nursing Center for Innovative Care in Aging, the Johns Hopkins Clinical Research Scholar grant (#KL2TR001077), the National Patient Safety Foundation, and the Agency for Healthcare Research and Quality (grant # 1K08HS022916). Dr. Keller receives funding from a Johns Hopkins Clinical Research Scholar KL2 Award KL2TR001077, as well as the Sherrilyn and Ken Fisher Center for Environmental Infectious Diseases Discovery Program.

Acknowledgments

We would like to extend our gratitude to the home health care agencies for their ongoing support of this research, and to all of the providers, older adults, and their caregivers who participated in this work.

References

- Food and Drug Administration. Is the Product a Medical Device? 2014. www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/Overview/ClassifyYourDevice/ucm051512.htm Accessed May 23, 2016.
- Food and Drug Administration Center for Devices and Radiological Health Office of Device Evaluation. Applying Human Factors and Usability Engineering to Medical Devices. 2016. www.fda.gov/ucm/groups/fdagov-public/@fdagov-meddev-gen/documents/document/ucm259760.pdf Accessed August 29, 2016.
- Beer JM, McBride SE, Mitzner TL, Rogers WA. Understanding challenges in the front lines of home health care: a human-systems approach. *Appl Ergon* 2014;45:1687–1699.
- Abts N, Hernandez A, Caplan S, Hettinger AZ, Larsen E, Lewis VR. When human factors and design unite: using visual language and usability testing to improve instructions for a home-use medication infusion pump. *Proc Int Symp Hum Factors Ergonom Health Care* 2014;3:254–260.
- Kortum P, Perez SC. Evaluation of home health care devices: remote usability assessment. *JMIR Hum Factors* 2015; 2:e10.
- Story MF. Medical devices in home health care. In: Olsen S, ed. *The role of human factors in home health care: workshop summary*. Washington, DC: National Academies Press, 2010:145–172.
- Ingadottir TS, Jonsdottir H. Technological dependency—the experience of using home ventilators and long-term oxygen therapy: patients' and families' perspectives. *Scand J Caring Sci* 2006;20:18–25.
- Thomson R, Martin JH, Sharples S. The psychosocial impact of home use medical devices on the lives of older people: a qualitative study. *BMC Health Serv Res* 2013; 13:467.
- Charness N. The people who receive and provide home health care. In: Olsen S, ed. *The role of human factors in home health care*. Washington, DC: National Academies Press, 2010:9–28.
- Bitterman N. Design of medical devices—a home perspective. *Eur J Intern Med* 2011;22:39–42.
- Sanford J. The environments of home health care. In: Olsen S, ed. *The role of human factors in home health care: workshop summary*. Washington, DC: National Academies Press, 2010:47–66.
- Drury C. Home health care tasks and tools. In: Olsen S, ed. *The role of human factors in home health care: workshop*

- summary. Washington, DC: National Academies Press, 2010: 29–46.
13. Naylor MD, Hirschman KB, O'Connor M, Barg R, Pauly MV. Engaging older adults in their transitional care: what more needs to be done? *J Comp Eff Res* 2013;2:457–468.
 14. Arbaje AI, Wolff JL, Yu Q, Powe NR, Anderson GF, Boulton C. Postdischarge environmental and socioeconomic factors and the likelihood of early hospital readmission among community-dwelling Medicare beneficiaries. *Gerontologist* 2008;48:495–504.
 15. Henriksen K, Joseph A, Zayas-Caban T. The human factors of home health care: a conceptual model for examining safety and quality concerns. *J Patient Saf* 2009;5:229–236.
 16. Older Americans 2010: key indicators of well-being. Washington, DC: Federal Interagency Forum on Aging-Related Statistics, 2010.
 17. Harris-Kojetin L, Sengupta M, Park-Lee E, et al. Long-term care providers and services users in the United States: data from the National Study of Long-Term Care Providers, 2013–2014. National Center for Health Statistics. Hyattsville, MD, *Vital Health Stat* 2016;3:4.
 18. Chapanis A. To communicate the human factors message, you have to know what the message is and how to communicate it. *Hum Factors Soc Bulletin* 1991;34:1–4.
 19. Holden RJ, Carayon P, Gurses AP, et al. SEIPS 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients. *Ergonomics* 2013;56:1669–1686.
 20. Pennathur PR, Thompson D, Abernathy JH, III, et al. Technologies in the wild (TiW): human factors implications for patient safety in the cardiovascular operating room. *Ergonomics* 2013;56:205–219.
 21. Gurses AP, Ozok AA, Pronovost PJ. Time to accelerate integration of human factors and ergonomics in patient safety. *BMJ Qual Saf* 2012;21:347–351.
 22. Carayon P, Wetterneck TB, Rivera-Rodriguez AJ, et al. Human factors systems approach to healthcare quality and patient safety. *Appl Ergon* 2014;45:14–25.
 23. Beyer H, Holtzblatt K. Contextual design: defining customer-centered systems. San Francisco, CA: Morgan Kaufmann Publishers, 1998.
 24. Crabtree BF, Miller WL. Doing qualitative research. Washington, DC: Sage Publications, 1999.
 25. Ando H, Cousins R, Young C. Achieving saturation in thematic analysis: development and refinement of a codebook. *Comp Psychol* 2014;3:1–7.
 26. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Educ Today* 2004;24:105–112.
 27. Sandelowski M, Barroso J. Classifying the findings in qualitative studies. *Qual Health Res* 2003;13:905–923.
 28. Pesut B, McLean T, Reimer-Kirkham S, Hartrick-Doane G, Hutchings D, Russell LB. Educating registered nursing and healthcare assistant students in community-based supportive care of older adults: a mixed methods study. *Nurse Educ Today* 2015;35:e90–e96.
 29. Endsley MR. Towards a theory of situation awareness in dynamic-systems. *Human Factors* 2015;37:32–64.
 30. Doyle PA, Gurses AP, Pronovost PJ. Mastering medical devices for safe use: policy, purchasing, and training. *Am J Med Qual* DOI: 10.1177/1062860616645857
 31. Lehoux P. Patients' perspectives on high-tech home care: a qualitative inquiry into the user-friendliness of four technologies. *BMC Health Serv Res* 2004;4:28.
 32. Kluge A, Frank B. Counteracting skill decay: four refresher interventions and their effect on skill and knowledge retention in a simulated process control task. *Ergonomics* 2014;57:175–190.
 33. Bell CM, Schnipper JL, Auerbach AD, et al. Association of communication between hospital-based physicians and primary care providers with patient outcomes. *J Gen Intern Med* 2009;24:381–386.
 34. Kripalani S, LeFevre F, Phillips CO, Williams MV, Basaviah P, Baker DW. Deficits in communication and information transfer between hospital-based and primary care physicians: implications for patient safety and continuity of care. *JAMA* 2007;297:831–841.
 35. Oduyebo I, Lehmann CU, Pollack CE, et al. Association of self-reported hospital discharge handoffs with 30-day readmissions. *JAMA Intern Med* 2013;173:624–629.
 36. Sheu L, Fung K, Mourad M, Ranji S, Wu E. We need to talk: primary care provider communication at discharge in the era of a shared electronic medical record. *J Hosp Med* 2015;10:307–310.
 37. Press MJ, Gerber LM, Peng TR, et al. Postdischarge communication between home health nurses and physicians: measurement, quality, and outcomes. *J Am Geriatr Soc* 2015; 63:1299–1305.
 38. Lyngstad M, Hofoss D, Grimsø A, Hellesø R. Predictors for assessing electronic messaging between nurses and general practitioners as a useful tool for communication in home health services: a cross-sectional study. *J Med Internet Res* 2015;17:e47.
 39. Fung CH, Igodan U, Alessi C, et al. Human factors/usability barriers to home medical devices among individuals with disabling conditions: in-depth interviews with positive airway pressure device users. *Disabil Health J* 2015; 8:86–92.
 40. Lang AR, Martin JL, Sharples S, Crowe JA. The effect of design on the usability and real world effectiveness of medical devices: a case study with adolescent users. *Appl Ergon* 2013;44:799–810.

Address correspondence to:

Sara C. Keller, MD, MPH, MSHP

Division of Infectious Diseases

Department of Medicine

Johns Hopkins University School of Medicine

1600 N, Wolfe Street, Brady Building Room 523

Baltimore, MD 21287

E-mail: skeller9@jhmi.edu