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Patient, Caregiver, and Clinician Experience with a Technologically Enabled Pillbox: A Qualitative Study

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Abstract

Objectives   As part of a study to assess whether a technologically enabled pillbox prescribed to patients at hospital discharge can improve medication safety, we sought to assess participant experiences with the intervention.

Methods   We conducted a series of semi-structured phone interviews with patients, patient caregivers, and inpatient and outpatient clinicians who participated in the Smart Pillbox Transition Study. We developed an interview guide using the Systems Engineering Initiative for Patient Safety (SEIPS) framework, which included the *a priori* domains of (1) barriers to implementation, (2) facilitators of the intervention, and (3) general feedback regarding experience with the intervention. Within these domains, we employed SEIPS-informed themes of environment and organization, logistics and tasks, personnel and patients, and technology and tools. Interviews were conducted between May 2018 and January 2019. We used content analysis to interpret findings.

Results   We interviewed 6 patients, 2 caregivers, and 5 inpatient and 2 outpatient clinicians. Patient-endorsed barriers in the theme of technology and tools included signal issues, inappropriate alarms, and portability. Barriers in the theme of logistics and tasks included coordination with pharmacists in the event of a prescription change. Barriers mentioned by clinicians included patients who were poor fits for the intervention (theme: personnel and patients) and competing demands at discharge (theme: logistics and tasks). Facilitators that were frequently mentioned by patients and caregivers in the theme of technology and tools included useful alarms and ease of use. Clinicians stated that communication with pharmacy and study staff helped facilitate the intervention (theme: personnel and patients).

Conclusion   We identified several key barriers and facilitators from patients, caregivers, and clinicians to successful implementation of this intervention. Reconciling these sometimes contrasting viewpoints will be crucial if the Smart Pillbox or similar health information technology interventions are to be adopted as tools to improve medication safety during care transitions.

Keywords
► discharge planning
► patient self-care
► home care and e-health
► wireless devices
► adverse drug event
► medication adherence

Background and Significance

The period immediately after hospital discharge is an especially vulnerable time for patients.[1] This transition of care is especially fraught as there is a high risk of postdischarge adverse drug events (ADEs) or injury due to medications within 30 days of hospital discharge. Research suggests postdischarge ADEs make up 70% of all postdischarge adverse events, at a rate of 0.30 ADEs per patient.[2] Further, approximately one-fifth of patients suffer a postdischarge ADE, two-thirds of which are potentially preventable or mitigatable.[2–5] These postdischarge ADEs may lead to adverse medication effects, hospital readmission, or mortality.[6–8]

Health information technology (HIT) interventions hold promise in minimizing medication discrepancies and ADEs.[9–11] One such class of HIT interventions are "smart pillboxes." Smart pillboxes are technologically enabled pillboxes that have a range of capabilities, including the ability to transmit audible and digital alerts, track patient medication adherence, and generate adherence reports to clinicians.[12–14] Several studies to date have touted the success of such interventions in reducing medication discrepancies and, in some cases, improving chronic disease control in the ambulatory setting for a wide range of conditions such as hypertension,[15,16] diabetes,[15,17] human immunodeficiency virus (HIV),[12,18–24] tuberculosis (TB),[18,25] multiple myeloma,[26] and post–kidney transplantation.[15] Additionally, and importantly given the novelty of smart pillbox devices, several studies have also explored user perspectives of this technology, the majority of which have focused on patient[19,22,27–36] rather than clinician[32,35,37] perspectives.

Given the novelty of smart pillbox devices and their potential in reducing medication discrepancies, it is important to gain a better understanding of their use during care transitions. Specifically, it is crucial to identify barriers and facilitators of implementing such an intervention in this unique setting, to guide successful implementation in the postdischarge care transition.

Objectives

The purpose of this study is to provide patient, patient caregiver, and clinician perspectives on the implementation of a novel smart pillbox intervention to reduce medication discrepancies and improve medication adherence after hospital discharge from an academic medical center. Primary outcomes of the trial reporting the impact of the smart pillbox on medication adherence and chronic disease control and a report on the challenges of deploying a complex HIT intervention will be published separately.[38]

Methods

Study Setting
We conducted this qualitative study as a component of the Smart Pillbox Transitions Study (clinicaltrials.gov identifier: NCT03475030). The Smart Pillbox Transitions Study was a cluster-randomized clinical trial in which patients were

randomized to receive a technologically enabled pillbox (TowerView Smart Pillbox) or usual care at discharge from an acute hospitalization. The Smart Pillbox is a technologically enabled device that houses prefilled weekly medication trays and sends medication administration reminders via device chimes and illumination, phone, and text and/or e-mail to patients and caregivers (►Fig. 1). Additionally, the Smart Pillbox detects if medications are removed from the corresponding tray and generates adherence reports accessible by patient clinicians via a secure online platform.

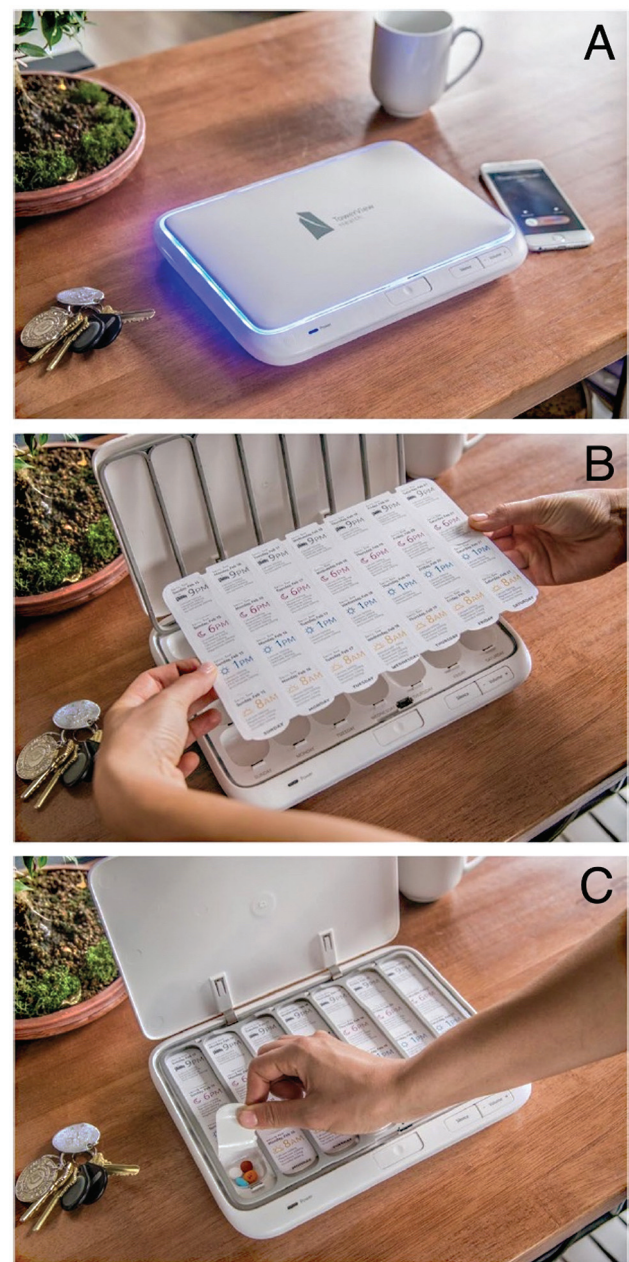The Mass General Brigham Institutional Review Board approved this study.

Fig. 1 The TowerView Smart Pillbox. (**A**) The pill box (note the *blue illumination alarm* around the device margin). (**B**) Insertion of the blister pack into the pill box. (**C**) A patient opening one of the wells. Keys and a smartphone are shown for scale.

Study Participants

Eligible patients for the Smart Pillbox Transitions Study included hospitalized patients with a plan of discharge home from the medical, cardiology, or oncology services at Brigham and Women's Hospital, a 793-bed tertiary academic medical center in Boston, MA. Other inclusion criteria included being prescribed five or more chronic medications, having a primary care provider at a hospital-affiliated clinic, and being primarily English or Spanish speaking. Cluster randomization was performed at the primary care practice level and completed prior to patient enrollment. The trial was performed between January 2017 and December 2018.

Eligible participants for the qualitative aspect of the study included patients enrolled in the intervention from the primary study (i.e., patients who had received the smart pillbox intervention). We contacted all patients who received the intervention ($n = 24$) via phone. If patients were interested in participating ($n = 6$), we obtained verbal consent and scheduled the interview. If a patient also had a caregiver actively involved with medication management, we then asked if the caregiver would be willing to be scheduled for a separate interview. To identify potential clinician participants, we identified the discharging interns/physician assistants (PAs), inpatient attendings, and outpatient attendings of patients who received the intervention. We then used a random number generator to randomly identify 10 discharging interns/PAs, 5 inpatient attendings, and 5 outpatient attendings. These clinicians were then e-mailed inviting them to participate in an interview. Clinicians who replied were then scheduled for interviews.

Study Design

We developed an interview guide (►**Supplementary Appendix 1**, available in the online version) based on the Systems Engineering Initiative for Patient Safety (SEIPS) framework, which is a theoretical model from the human factors and systems engineering fields that expands upon the Donebedian structure-process-outcome model to depict how the health care environment work system affects processes and patient outcomes.[39,40] The work system is further comprised of several components, including interactions between person, organization, technologies and tools, tasks, and environment.

We framed the interview guide based on three *a priori* domains:

- Barriers to implementation.
- Facilitators/points of success of the intervention.
- General feedback on the intervention.

Within these domains, we ensured the interview guide targeted additional themes within components of the SEIPS model work system, including environment and organization, logistics and tasks, personnel and patients, and technology and tools (►**Fig. 2**). Additional subthemes within these themes are listed in ►**Supplementary Appendix 2** (available in the online version). We collected additional participant responses within the domain of general feedback and impressions on the intervention, which included asking participants about potential barriers identified by the research team during the development of the interview guide, and suggestions for improvement. Within this domain, gen-
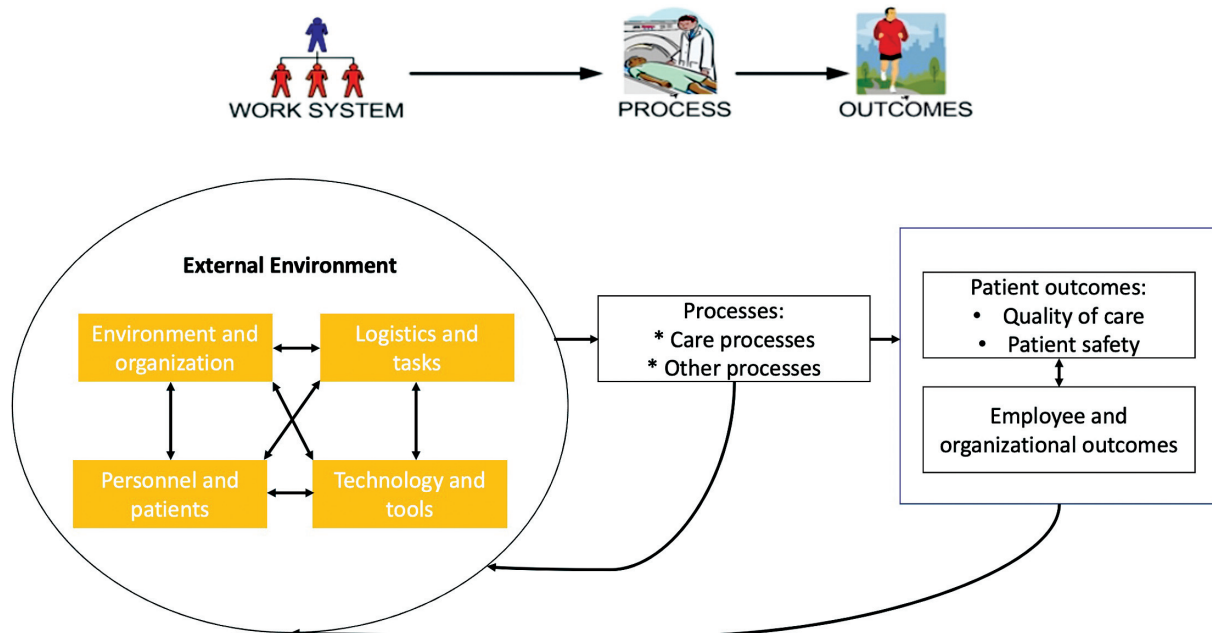

Fig. 2 Adaptation of Systems Engineering Initiative for Patient Safety (SEIPS) model.[39,40] The interview guide targeted themes within adapted components of the SEIPS model work system, including environment and organization, logistics and tasks, personnel and patients, and technology and tools. Components of the original SEIPS model work system include organization, physical environment, tasks, person, and technology and tools. (Reproduced with permission of Carayon et al.[39])

eral feedback impressions of intervention components were categorized as "positive," "neutral," and "negative."

Data Collection

All interviews were conducted by phone by one of two experienced study team members (EMS or JLS) between May 2018 and January 2019. The interviews were 15 to 45 minutes in length. All interviews were audio-recorded, transcribed, and uploaded to NVivo v12 (QSR International, Doncaster, Australia) for analysis and retrieval.

Data Analysis

Study team members met regularly following data collection to review transcripts. Interview transcripts were independently coded by two study team members (EMS and JLS) using the analytic framework based on the domains from the interview guide, and content analysis to interpret findings within the SEIPS-based themes. We used a combination of inductive and deductive approaches, starting with the SEIPS-based themes (deductive), and then using an inductive approach to draw on emerging subthemes from the interviews. Following independent coding, we met for comparative reflection and discussion to identify emerging themes and resolve discrepancies through consensus. Through this iterative process, themes and subthemes were refined and redundancies were reconciled.

Results

Fifteen participants were interviewed, including 6 patients, 2 patient caregivers, and 7 clinicians (2 inpatient attendings, 2 outpatient attendings, 2 inpatient interns, and 1 inpatient PA). Characteristics of the patient and clinician participants are summarized in ►Table 1.

The qualitative results are presented in the following sections under each domain, theme, and subtheme, as well as summarized in ►Tables 2 and 3.

DOMAIN 1: Barriers to Implementation

Theme 1: Environment and Organization
We identified several environmental and organizational barriers to implementation of the Smart Pillbox at both the hospital and pharmacy levels. Hospital-related barriers, endorsed solely by clinicians, were mostly related to competing priorities, such as early discharge, which could potentially reduce institutional commitment to this intervention. Pharmacy-related barriers that impacted clinician participants pertained to the pharmacy's hours of availability and insurance coverage issues. Patient participants also experienced delays in medications when the contracted pharmacy for this study transitioned to a different pharmacy.

Theme 2: Logistics and Tasks
Within the theme of logistics and tasks, we identified several subthemes including insufficient training, device setup at discharge, interdisciplinary communication, and availability

Table 1 Characteristics of interview patient and clinician interview participants

Characteristic	Number (%)
Patients	**6**
Female	5 (83)
Age, (y) median (range)	63.5 (26–88)
Race/ethnicity	
Hispanic Black	1 (17)
Non-Hispanic White	5 (83)
Highest educational attainment	
Graduate school	1 (17)
College	4 (67)
High school/GED	1 (17)
Employment status	
Employed full time	1 (17)
Retired	4 (67)
On disability	1 (17)
Marital status	
Married	3 (50)
Widowed	1 (17)
Single/never married	2 (33)
Lives alone	3 (50)
Caregiver helps with ADLs/IADLS[a]	1 (20)
Someone helps with medications	3 (50)
Cell phone access	5 (83)
Daily Internet use	6 (100)
Pillbox use prestudy	4 (67)
Morisky scale[b]	
High (>8)	2 (33)
Medium (6–8)	3 (50)
Low (<6)	1 (17)
sTOFHLA score[b]	
Adequate (23–36)	5 (83)
Inadequate (0–16)	1 (17)
Clinicians	**7**
Medical resident	2 (29)
Physician assistant	1 (14)
Inpatient attending	2 (29)
Outpatient attending	2 (29)
Female	5 (71)
Years in practice, median (range)	9 (1–21)

Abbreviations: ADL, activity of daily living; GED, general educational development; IADL, instrumental activity of daily living; sTOFHLA, short test of functional health literacy in adults.
[a]Data missing for 1 respondent.
[b]The Morisky scale is a score of medication adherence; sTOFHLA is a score of patient health literacy.

Table 2 Domains, themes, and additional illustrative examples from participant experience with the Smart Pillbox intervention

Domain	Theme	Illustrative example (subtheme in parentheses)
Barriers to implementation	Environment and organization	"The next competing new thing, right? Like do you need to learn about it or to integrate it into your practice? Like are we doing virtual visits or annual wellness visits or do we need to increase like the number of whatever X things that we bill for it's just like, that checklist of new things…" (*competing priorities*)—Outpatient clinician
	Logistics and task	"I mean I don't know anything about what the patient is seeing or handling" (*insufficient training*)—Inpatient clinician
	Personnel and patients	"I'm hearing impaired and I never seemed to be handy when they [alarms] went off" (*patient poor fit due to physical limitations*)—Patient
	Technology and tools	"…[it] went a little bit haywire at one point where I would take my medication and it would constantly be texting me and alerting me that I need to take my medication" (*false-positive/false-negative alarms*)—Patient
Facilitators/ points of success of intervention	Environment and organization	"All of my doctors were very supportive when I got set up" (*sufficient institutional engagement*)—Patient
	Logistics and task	"You know the thing is everyone was very cooperative, and I found everyone was working toward the same goal, which was getting the pillbox filled correctly and getting it out to me and making sure that the medication was correct. So, I had a good experience with it" (*interdisciplinary communication between pharmacy and patient*)—Patient
	Personnel and patients	"To me it seems like an excellent intervention for people who have a hard time with medications, like remembering to take them, who have complicated regimens, and need help sticking to it" (*positive outcome expectancy*)—Outpatient clinician
	Technology and tools	"If I took my medication, I was fine, and if I didn't, I knew the lights were on and it's time for me to go grab them" (*useful alarms*)—Patient
General feedback on the intervention	Suggestions for improvement	"If someone wanted to do like a 20-minute teaching or in-service on it, I think it'd be really an eye-opener, to kind of know what's going on in people's homes with this and know how we could even recommend it" (*changes to training*)—Inpatient clinician
		"Maybe a way to make like a travel size version or something easier to take with you" (*changes to pillbox and technology*)—Patient

Table 3 General feedback and impressions of intervention component illustrative examples, categorized as positive, neutral, or negative, from patients/caregivers and clinicians

General feedback sentiment	Patient/caregiver	Clinician
Positive	"To keep track of everything rather than having a lot of different, individual medicine bottles around, so, that's kind of what I thought it would be the benefit, just organizing the pills"	"I think it was just great knowing that my patient is leaving with their meds in their hands… with an intervention that would help them actually take them"
Neutral	"I would say no, I thought it [would work] pretty well"	"The clinical concerns, I didn't really have any. I, you know, was thinking sort of through logistically, how is this going to get implemented? How are the people going to get set up with it in the right time frame?"
Negative	"I guess I thought that it was, you know, clever but unnecessary"	"I mean thinking about the amount of medications as people who have advanced age, medical complexity, not only do they have so many pills, there are sometimes TID or QID, so the frequencies and like drug interactions, like not to take one when the other one is being administered"

Abbreviations: QID, quater in die (four times daily); TID, ter in die (three times daily).

of assistance. Several clinicians and patients/caregivers identified that they did not receive sufficient training, had unclear goals and expectations regarding the intervention, or were unaware of several of the core features of the Smart Pillbox.

The greatest reported barrier endorsed by inpatient clinicians pertained to elements regarding the setup at discharge. Specifically, all the interviewed inpatient clinicians relayed the rushed nature and timing of discharge as a significant barrier to implementing the Smart Pillbox. Additionally, the fact that use of the Smart Pillbox required earlier discharge medication reconciliation in combination with unpredictability of final discharge prescriptions contributed to barriers related to setup at discharge. As one inpatient attending stated:

> "…that lag time between knowing that the patient is being discharged and then… getting the patient the box, I think is probably the biggest barrier."

There were fewer reported barriers related to the subthemes of interdisciplinary communication and availability of assistance, but these subthemes were still observed: one patient reported difficulties in reaching the product support line; another patient and his caregiver reported difficulties communicating with pharmacy staff members.

Theme 3: Personnel and Patients

Within the theme of personnel and patients, one concentrated subtheme for clinicians was a lack of, or negative, outcome expectancy (i.e., not expecting the intervention to work, including not being able to see if it was successful). As one inpatient PA explained:

> "I never get to see the follow-up to see how it would have impacted her adherence, or did it save her from missing doses she should have received."

"Poor fit" was likewise identified within the theme of personnel and patients as a barrier among some patients; examples of poor fit included frequent travel, functional limitations (physical and cognitive), language barriers, medication regimen complexity, having medications outside the pillbox, poor adherence and follow-up, resistance to accepting help, and periods of illness and hospitalizations. One caregiver's response was particularly illustrative:

> "I would say, another issue that she had is because she was taking them (medications) at four different times a day. The first pill would be before she got out of bed and then her 10 a.m. say and her 5 p.m. would be on the first floor and her bedroom was on the second floor and then her bedtime pills, she preferred to take them upstairs getting ready for bed on the second floor, so she would have to take them out of the container and bring some of them upstairs with her…and sometimes she didn't hear the phone ring"

Theme 4: Technology and Tools

Barriers within the theme of technology and tools were reported primarily among patients and caregivers and included false-positive/false-negative or annoying alarms, signal issues, and the number and size of wells. One patient had difficulty finding a location in their home with adequate signal:

> "Well, I guess my original pillbox they thought something was wrong with it…we tested it and said it had moved to a new location in my apartment and it looked like it wasn't getting a good signal."

DOMAIN 2: Facilitators/Points of Success of the Intervention

Theme 1: Environment and Organization

Within the theme of environment and organization, clinicians commented on there being adequate support from the hospital and that the intervention aligned with other hospital priorities. Some clinicians stated that the hospital outpatient pharmacy was generally available when necessary, in contrast to others who noted pharmacy availability as a barrier (as above). Patients endorsed that their outpatient clinicians were supportive of their involvement in the study and were pleased that multiple clinicians across the health care system were able to monitor their progress.

Theme 2: Logistics and Tasks

In contrast to the barriers mentioned earlier, within the theme of logistics and tasks, some clinicians felt that their training on intervention implementation and understanding of the goals and expectations was adequate. Additionally, interdisciplinary communication and availability for assistance was regarded favorably, especially communication between patients and the pharmacy and communication between study staff and the inpatient team. One patient's caregiver was especially praiseful of pharmacy staff members:

> "I talked several times with people on the phone there, the pharmacy… there was a pharmacist … she was just, stellar in what she did."

Although inpatient clinicians rarely commented that the discharge medication setup process was easy, one resident stated:

> "…in some ways, it also saved time the next day because it, the meds were already sent, and then also you didn't have to spend time like calling the pharmacy and making sure like all the medications were there and available."

Theme 3: Personnel and Patients

Within the theme of personnel and patients, while some patients and clinicians expressed barriers related to a pessimistic outcome expectancy (as above), many interviewees

endorsed a positive outcome expectancy, that is, belief that this intervention would end up being effective. One outpatient attending stated:

> "My impression was that it would be a great tool for some patients."

Similarly, in contrast to the barriers outlined earlier, patients and clinicians also identified that a patient being a "good fit" for the intervention was a facilitator.

Additional subthemes that emerged included patients having adequate support from family and home services, patients having few or no medications outside the pillbox (such as inhalers or insulin), and patients having a language difference that could be bridged by the technology. Regarding language differences, one outpatient attending commented:

> "You know she has limited English proficiency, so you know the visual acuity, like the visual cues and the sound cues help when there's a language barrier right?"

Theme 4: Technology and Tools

Within the theme of technology and tools, patients generally expressed high regard for many of the technological aspects of the Smart Pillbox. In particular, all of the patients and their caregivers stated that they found the alarms to be useful. As one patient commented:

> "I would forget, and then I hear, I'd have my phone and I would hear the alert or I would be in my room and I would see the lights flashing, so I know, "Wait a minute, I gotta [sic] go take my medications," and you open the pillbox and there you are, you know exactly what you're taking… there's no way you can make a mistake, with your, when you have that pillbox. There's no way."

Other aspects of the technology and tools that patients positively endorsed included ease of use, portability, lack of obtrusiveness, and lack of signal issues.

DOMAIN 3: General Feedback on the Intervention

General impressions of intervention components that were considered "positive," "neutral," or "negative" are summarized in ►Table 3. Most general impressions were positive and were related to the perceived usefulness of having medications prepackaged and of the alerts. The research team also asked patients about several potential barriers developed *a priori* by the research team; all of these were ultimately not endorsed by the patients, including potential confusion around having as-needed medication outside of the pillbox or concern about having young children who might try to access it.

Both patients and clinicians also offered suggestions for improvement in different aspects of the intervention, including the themes of environment/organization, logistics/task, personnel/patients, and technology/tools. For example, regarding suggestions for improvement for the organization, one inpatient PA

suggested incorporating discussion about setting up the device as part of morning interdisciplinary rounds and care coordination. Clinicians also suggested more careful consideration of which patients would benefit the most from and should receive the intervention. Patients also offered suggestions for improving the pillbox, such as first doing a home signal test, making the device less bulky, incorporating a password or lock device, and developing an associated smartphone application.

Discussion

In our SEIPS-informed qualitative analysis of patient, patient caregiver, and clinician experience with the implementation of a novel smart pillbox intervention to reduce medication discrepancies and improve medication adherence after hospital discharge, we were able to identify key barriers and facilitators of successful intervention as well as several suggestions for improvement. Patients and their caregivers identified barriers related to the technology, including inappropriate alarms, connectivity, and portability issues, in addition to issues with logistics and task as they related to contacting the pharmacy and ensuring medications were accurate and delivered in a timely manner. Clinicians endorsed key barriers, mostly pertaining to the hospital environment and organization and logistics and tasks, especially the rushed nature, competing priorities, and unpredictability of the discharge process that conflicted with the additional time required to set up the pillbox for use. Overall, these findings provide a useful assessment for barriers and facilitators of a technologically enabled pillbox to improve medication adherence at discharge, many of which likely apply to similar HIT interventions during this crucial transition of care.

Our study is a novel contribution to the literature as it is the first, to our knowledge, that provides qualitative insight into the barriers and facilitators of the implementation of a HIT intervention for medication safety at hospital discharge. Further, it is among the first that purposefully integrates a patient safety framework (SEIPS) to develop an interview guide and identify themes and subthemes. This process will help facilitate the incorporation of lessons learned from this intervention to other similar interventions.

Our study's focus on implementation of technologically enabled pillboxes at the time of hospital discharge adds to existing qualitative studies in the ambulatory setting.[19,22,27–36] These studies have examined the use of a smart pillbox in a variety of geographic locations (e.g., U.S. academic medical centers, clinics in sub-Saharan Africa, urban clinics in India) for a variety of conditions. Similar to what we found in our study, these studies also identified technology and tools as a prominent barrier to implementation. Patients identified issues with device connectivity[19,31] and with alarms being either inappropriate or obtrusive.[27,35,37] Other qualitative studies also highlight patient-reported issues with device portability during commuting or travel.[22,27,30,32,33,35,36] Our study adds barriers not previously noted in the literature, including patient concerns regarding medication complexity and having multiple medications in the pillbox wells given multiple medical

conditions, different from other studies that were largely disease specific. This feedback is particularly important when considering utilization of the smart pillbox technology within a more complex clinical setting involving a broader cohort of patients.

Our study adds insight into barriers of implementation from clinician perspectives during challenging workflows in the hospitalization-to-home transition of care, which also involves a transition of patient responsibility from the inpatient to outpatient clinician. The limited existing data on clinician perspectives largely support our findings, including lack of available personnel to implement the device,[37] insufficient training, medication dispensing, and communication with pharmacists and product support[35] as major barriers to implementation.

As with identified barriers, many of the facilitators that patients identified for the smart pillbox intervention were similar to other qualitative research of technologically enabled pillboxes in the outpatient setting. This was especially true within the theme of technology and tools, where our study supported the findings of other studies that found the pillbox was easy to use,[19,27,31,35,36,41] that the alarms were useful,[19,27,31,35,36,41] and there were limited signal issues.[31] Other literature also identified that having family members available to help in medication management facilitated the intervention.[27,32,33,35] Although fewer existing studies examined the domain of logistics and task (specifically patient communication with pharmacists, product support, or clinician staff members), one international study did find that patients appreciated having health care clinicians contacting them in the case of missed medication doses.[35] Within the theme of personnel and patients, several studies highlight clinicians' positive outcome expectancy as a facilitator of implementation,[35,37] supported by our findings. Our study adds to this existing literature as it evaluates facilitators to implementation within the unique setting of transition from hospital to home, which necessitates involvement and collaboration between multiple types of personnel, including product support, pharmacists, inpatient and outpatient clinicians, and study staff members.

Some comments we received from patients and clinicians were contradictory (e.g., some patients found device portability to be problematic, while others found it sufficiently portable; some clinicians believed training was inadequate, while others thought training was sufficient), likely due to natural differences in opinions and lack of standardized training on device implementation. Given this, future attempts to incorporate such a device into the hospitalization-to-home care transition should include more robust early-stage input from various stakeholders, including patients, caregivers, clinicians, pharmacists, staff, and hospital administrators, to ensure these perspectives are integrated into implementation planning.

Based on the findings from this study, when taken in the context of limited existing literature on this topic, there are several key recommendations within the SEIPS-based themes that we present to optimize the likelihood for a smart pillbox intervention to be successfully implemented at the hospitaliza-

tion-to-home care transition. Within the theme of environment and organization, the hospital system and associated pharmacies should have sufficient awareness and sponsorship of the intervention to ensure that sufficient resources are devoted to support the intervention's infrastructure. Within the theme of logistics and tasks, clinicians should have adequate training about the device and its potential to improve patient care, to improve clinician adherence and buy-in. A standardized and internally validated training about the device and its capabilities for all clinicians and supporting staff could be considered to improve clinician buy-in. Given the logistic complexity of patient discharge for inpatient clinicians who are often overloaded with other tasks, there may be a role for dedicated discharge coordinators or pharmacists to ensure that device setup is completed in a thorough and timely manner. Within the theme of personnel and patients, when considering which patients have the highest likelihood of benefit from such an intervention, we would recommend selecting patients with medical complexity (i.e., multiple comorbidities), but with relatively stable medication regimens and dosages, with a limited number of medications outside the pillbox (e.g., as needed medication, insulin, inhalers, controlled substances), who have caregivers invested in their successful medication management and with limited cognitive or functional limitations. It is crucially important to monitor the sociodemographic profile of patients who receive a smart pillbox and compare this to the general profile of a health care system to ensure that the intervention does not exacerbate a "digital divide."[42] Finally, within the theme of technology and tools, the smart pillbox itself must be user-friendly, portable, unobtrusive, safe, and have robust connectivity capabilities. We recommend that developers of similar devices particularly focus on device portability. We believe if these critical themes and subthemes are addressed, HIT interventions such as this have a reasonable possibility of being successfully implemented.[43]

Limitations

We acknowledge several limitations of this study that should be considered. First, we hoped to achieve theme saturation after completion of the participant interviews, but it is unclear if this was achieved. This was in part due to the relatively low number of subjects enrolled in the trial and low number of clinicians who responded to requests for interview. While we did not include pharmacists in this qualitative study, perspectives from this key group are shared in an accompanying manuscript.[38] Second, our study was performed at a single, well-resourced academic medical center in the Northeast United States as part of a randomized trial. Additionally, the majority of patients included were Whites and college educated with high medical literacy. Some of our findings may not therefore be generalizable, especially in lower-resource settings that may lack the infrastructure, personnel, and funding to support this intervention. However, we are reassured that many of the themes identified were shared with studies performed in different clinical (i.e., ambulatory) and geographic (i.e., international, urban/rural) settings. Third, although we purposefully chose a validated framework for understanding how the health

care environment work system affected processes and patient outcomes in the SEIPS model, it is possible that by using this framework we did not identify other important domains. There is also some overlap between our identified themes and subthemes, which is a consequence of the SEIPS framework's emphasis on interactions between its components. However, we are reassured that while ours is the first to purposefully use the SEIPS framework in this context, many of the domains and themes we identified were shared with other studies. Fourth, we did not include a formal test of interrater concordance. Finally, our study is subject to the same biases as other qualitative research, including selection, acquiescence, and confirmation bias. Selection bias derives from selecting our patient sample from the pool of participants who completed the intervention arm of the study. Thus, the opinions expressed may not be representative of all smart pillbox users. We purposefully conducted the interviews to avoid sources of interviewer biases.

Conclusion

In this qualitative study based on the SEIPS framework on the implementation of a novel smart pillbox intervention to reduce medication discrepancies and improve medication adherence after hospital discharge, we identified key barriers and facilitators to intervention implementation endorsed by patients and clinicians. Whereas patients and their caregivers generally appreciated the smart pillbox and its technological capabilities as well as support from study staff, inpatient and outpatient clinicians endorsed key barriers, mostly within the theme of logistics and tasks. Reconciliation of perspectives from key stakeholders is crucial for a smart pillbox or similar HIT interventions to be successful.

Clinical Relevance Statement

Technologically enabled pillboxes are generally well-received by patients and have the potential to reduce posthospital discharge ADEs. It is important to ensure that the technology is functioning appropriately and that workflows to provide patients with such a device during the discharge process are streamlined if such an intervention is to be successfully implemented.

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