Understanding hazards for adverse drug events among older adults following hospital discharge: Insights from frontline care professionals

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Abstract

Objectives.—Care transitions pose high risk for adverse drug events (ADEs). We aimed to identify hazards to medication safety for older adults during care transitions using a systems approach.

Methods.—Hospital-based professionals from 4 hospitals were interviewed about ADE risks following hospital discharge among older adults. Concerns were extracted from the interview transcript, and for each concern, hazard for medication-related harms was coded and grouped by its sources according to a human factors and systems engineering model that views post-discharge ADEs as the outcome of professional and patient home work systems.

Results.—Thirty-eight professionals participated (five hospitalists, 24 nurses, four clinical pharmacists, three pharmacy technicians, and two social workers). Hazards were classified into six groups, ranked by frequencies of hazards coded: (1) medication tasks related at home, (2) patient and caregiver related, (3) hospital work system related, (4) home resource related, (5) hospital professional-patient collaborative work related, and (6) external environment related. Medications most frequently cited when describing concerns included anticoagulants, insulins, and diuretics. Top coded hazard types were complex dosing, patient and caregiver knowledge gaps in medication

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management, errors in discharge medications, unaffordable cost, inadequate understanding about changes in medications, and gaps in access to care or in sharing medication information.

Conclusions.—From the perspective of hospital-based frontline healthcare professionals, hazards for medication-related harms during care transitions were multi-factorial and represented those introduced by the hospital work system as well as defects unrecognized and unaddressed in the home work system.

Keywords

transitional care; medication errors; patient safety; safety management; qualitative research; ergonomics; human factors

Introduction

The transition to community settings, such as patient homes, following a hospital discharge is a high risk period for adverse drug events (ADEs), especially among older adults.[1,2] Understanding contributors to post-discharge ADEs, in comparison to inpatient settings, is challenging because of multiple work systems involved in transitional care.[3] The term "work system" is used to describe a collective of social and technical elements of a system which influence care processes and outcomes.[4] Although the work system concept has been used primarily in studies of professional work, it has been extended to studies of health related tasks performed by patients and caregivers outside of formal healthcare settings including patient homes.[5] Following hospital discharge, as medication management tasks are transitioned to the patient home work system, the patient and caregivers interact with multiple, often fragmented professional work systems.[6] These systems are distributed organizationally across hospitals, community pharmacies, primary care offices, and patient homes. Some patients also interact with home health professionals.[7] In recent years, the field of human factors has advanced concepts for studying such complex systems, in particular from the perspective of the patient as he or she moves across and interacts with different care teams.[8–11] Previous studies of medication safety during care transitions identified risk factors for ADEs in terms of diseases or demographics that are frequently not modifiable.[1,2] The concept of hazard has been used in safety science to identify defects, especially those hidden, in underlying systems for improvement.[12] To use an analogy, pothole as hazard in a road is not a traffic accident by itself, but either individually or, in most cases, in combination with other hazards, it has a potential to lead to traffic accidents. Some hazards may be latent and very hard to detect, waiting to cause harms. Seemingly insignificant hazards may be amplified in their consequences under certain conditions, and may have cascading effects as they move through different work systems.

We conducted an interview study with frontline clinicians to capture their insights into what makes it hazardous when a patient is transitioning out of acute care in a hospital to home. We defined hazard as a condition or a set of circumstances presenting a potential for harm based on patient safety literature.[12] Our targeted harm was post-discharge ADEs, and the targeted conditions or circumstances were based on a socio-technical approach to safety represented by a human factors and systems engineering model of work system, called the Systems Engineering Initiative for Patient Safety model (SEIPS 2.0).[4] In this

model, a work system is composed of persons (e.g., patient, caregivers, professionals), performing various tasks (e.g., reconciling medications), within a physical environment (e.g., home, hospital), using tools and technologies (e.g., pill boxes, medication list), within an organizational context (e.g., discharge policies, insurance coverage regulations). We recognize the multiple work systems involved during care transitions such as those in hospital, home, and pharmacy. In this study, we looked at hazards in the four domains in the SEIPS 2.0 model: professional hospital work system, patient home work system, collaborative professional-patient work, and external environment. We conceptualized that although post-discharge ADEs occur at home, hazards as conditions or circumstances may have been introduced or established in the hospital work system or in the interaction with the hospital work system, in addition to the hazards in the patient's home work system. These hazards have the potential to increase likelihood of harm from ADEs. This study was designed to build upon previous work primarily exploring risk factors associated with patient health conditions, prior history of ADEs, and use of certain medications such as anticoagulants, insulin, and opioids.[13]

Methods

We selected healthcare professionals as interview study participants as they may hold insights into hazards during care transitions. One example of such hazards is discrepancies between medications taken at home and medications listed on hospital discharge instructions, which existed in nearly half of the patients in one study.[14] Healthcare professionals in hospitals may encounter hazards such as this frequently while patients and family members may not be aware of them in isolated experiences.

Interview guide

A semi-structured interview guide was developed and pilot tested with several transitional care clinicians resulting in no changes. The interview guide was based on the SEIPS 2.0 model,[4] covering hospital and home work systems, collaborative work and external environment. The core questions included: (1) What do you see as top medication-related problems for elderly patients after discharge? (2) In your experience, what contributes to medication related problems when elderly patients are discharged from hospital? (3) What would you consider as essential to ensure medication safety after discharge? (4) What types of problems do you see in discharge medications? (5) What are the barriers in engaging patients and their caregivers in managing medications safely after discharge? Probes to core questions were organized to elicit details about barriers and strategies related to specific system elements, such as person, task, technology, physical environment, and organization.

Study participants

Interviews were conducted at four hospitals affiliated with two healthcare systems located in mid-Atlantic and South-Central regions of the United States. Both healthcare systems serve older adult populations, including those with low socioeconomic status. Each system had one large, urban academic medical center site and one medium sized suburban community hospital site. Human subjects study plans were reviewed and approved at all sites. We invited clinicians and staff including hospitalists and transitional care nurses with direct

working knowledge of care transitions to participate in interviews. We anticipated interviews to last approximately one hour, and study participants were offered $50 for their efforts. For physicians, we contacted hospital medicine physician groups to recommend study participants who frequently discharge older adult patients admitted for medical services. For bedside nurses, we contacted medical unit leaders to identify those with most experiences in discharging patients. For professionals who coordinate services after discharge, we contacted departments of care coordination and social works for study participants who were directly involved in discharge processes and in post-discharge patient contacts. Additionally, we contacted hospital pharmacy departments for pharmacists and pharmacy technicians who were involved in patient discharge education and in admission medication reconciliation. The number of study participants was based on our prior experience in conducting similar qualitative studies in this setting.[7]

Data abstraction

Interviews were recorded and transcribed, with identifying information removed. As an initial step to identify hazards, transcripts were screened by a primary reviewer for sentences expressing concerns for potential harms associated with medication use, where concerns may be in the forms of potential medication related problems, potential harms, issues, errors and therapeutic gaps. To avoid general, vague expressions of concerns, only those with specific examples of medications by either generic names, brand names, or drug classes were included. The primary reviewer highlighted such sentences in transcript files. A human factors specialist reviewed a sample of transcript files and discussed with the primary reviewer on screening decisions on whether a concern was expressed and whether a medication was referenced. For example, one interviewee mentioned "[the patient] could have been sent home, for instance, they were at home taking Lasix 20 mg and now they have a prescription coming home that they filled for furosemide 40 mg." In this example, the concern was for the potential harm from duplicating therapies without realizing the new prescription was to replace, not to be added to, home medications. For each medication-related concern identified, a record was created in a data table of medication cited, summary of the concern and context along with reference information to locate in the transcription file. Medications were normalized by their generic names, brand names if mentioned, and drug class using a tertiary drug information database (Lexicomp®, Hudson, Ohio). Two pharmacists reviewed medication class coding independently and corrected any errors identified.

Hazard coding

From the abstracted data, a human factors specialist (YX) iteratively developed a list of hazards by coding conditions or circumstances underlying the concerns. For example, one concern was for duplicated therapies due to the confusion over a new prescription as a replacement of versus an addition to a home medication. The underlying condition causing the confusion was coded as a hazard. Original transcripts were reviewed as necessary. We used a combination of deductive (i.e., using the four domains of the SEIPS 2.0 model and well-known work system elements in the coding structure) and inductive approach in our coding. A second human factors specialist and co-developer of the SEIPS 2.0 model (APG[11]) coded 20% of the records independently as a way to identify codes emergent

(i.e., inductive) from the data. The two specialists discussed any differences in their coding categories in depth over multiple meetings and reached consensus with respect to hazards and whether an existing domain could be used as a primary code (e.g., hospital work system, external environment), or a new code needed to be added to better capture the richness and details in the data (e.g., patient and caregiver factors, home resources). The list and groupings of hazards with coding examples were reviewed by a clinical pharmacist (AMW) who has a background in medication safety in ambulatory settings. Theoretical saturation was monitored during coding.[15] About halfway through transcripts, hazard coding structure was stabilized in terms of occurrences of new hazards. After the list and groupings of hazards were finalized, the abstracted data were coded a second time with the finalized coding and grouping. Illustrative quotes were selected for each group of hazards.

Results

Thirty-eight professionals participated in the interviews (numbers inside brackets were from each of the two healthcare systems): five hospitalists (4/1), 24 nurses (working at the bedside or as case managers, 16/8), four clinical pharmacists (1/3), three pharmacy technicians (1/2), and two social workers (0/2). Interviews ranged between 30 and 60 minutes each, resulting in 594 pages of transcript (285 pages from one system and 309 from the other), and 183 records of concerns were abstracted. Clinicians cited medications from 48 drug classes to describe their concerns for medication safety during care transitions due to ADEs (e.g., bleeding, falls). The concerns most frequently expressed for medication-related harm were unintentional duplications, stopping or continuing pre-hospitalization chronic medications contrary to discharge care plans, administration errors, gaps in lifesaving therapies, and oversedation. The hazards (i.e., conditions or circumstances underlying the concerns) were categorized along the four domains of home work system, hospital work system, collaborative work, and external environment. The hazards in the home work system domain were further categorized by medication tasks, patients and caregivers, and resources, due the large number of hazard types in this domain. Example hazards for each group are in Table 1, with example quotes in Table 2.

Home work system - medication tasks.

Hazards in this group reflected interviewees' concerns about the task demands placed on patients and home caregivers, as intrinsic to characteristics of the medications used. The characteristics mentioned included difficult to understand and/or to follow regimens, requiring more efforts to reduce risks, requiring new skills and introducing additional tasks for medication use, and imposing lifestyle burdens which made it difficult for patients to adhere at home. These characteristics increased difficulties for patients and home caregivers to safely manage medications, potentially resulting in ADEs from errors in administration, monitoring, and communicating with others.

Home work system – patients and caregivers.

Hazards in this group reflected interviewee's concerns over knowledge, skills, attitude and practice issues of the patient and caregiver, potentially resulting in non-adherence,

medication errors, and unintentional polypharmacy. These issues, such as confusions and at-risk medication management practices, may be developed and accumulated over time.

Home work system – resources.

Interviewees reflected on the increased need for home support during care transitions and gave examples of insufficient support at home as the patient was ill enough to be hospitalized in the first place. Interviewees were concerned about cost barriers to medications resulting in gaps in life-saving therapies, or cost-induced workarounds leading to non-adherence, or errors. For example, interviewees were concerned some of the critical discharge medications had non-sustainable cost, or that the discharge medication was a replacement of a home medication, but was much more expensive.

Hospital work system.

The interviewees highlighted their concerns about aspects of hospital information systems and patient engagement practices that increase risk for ADEs. The most frequently cited hazards were errors in the discharge medication information, such as duplications.

Collaborative work between hospital and home work systems.

The interviewees mentioned a number of concerns associated with collaborative work handing off the responsibility of medication management to the patient and caregiver at home. Their concerns underscored gaps in preparing and supporting patients and caregivers in understanding and managing medication changes made during hospitalization. The most frequent hazard was lack of awareness of the importance of newly prescribed medications.

External environment.

The interviewees expressed a number of concerns related to hazards in the healthcare system in a broader sense, which include all types of providers, safety-net organizations, and pharmacies. These hazards were associated with disruptions and disconnections, which may result in gaps in therapies and other risks for ADEs.

Although we did not directly ask study participants to identify specific medications, the medications mentioned as examples in concerns raised by the interviewees provide further insight into how specific types of medications were associated with different types of hazards. Medications most frequently cited were anticoagulants, insulins, diuretics, opioids, and antiplatelets (Table 3). Antibiotics, anticoagulants, diuretics and insulins were cited in five of the six groups of hazards. The most frequent hazard categories by medication were resource-related factors at home for anticoagulants and task-related factors at home for insulin therapies.

Discussion

Our analysis based on a human factors and systems engineering model (SEIPS 2.0) adds to the existing literature by providing an in-depth, rich, detailed understanding of the underlying mechanisms contributing to ADEs among older adults. We identified often under-appreciated hazards due to medication task factors at home when transitioning to

self-management. With aging and increased use of medications,[2] old adults are more likely than other population groups to have diminishing abilities to manage medication tasks. One previous study reported a high number of changes in medications at discharge.[16] We identified these changes as hazards, as frontline clinicians appreciate these changes requiring additional tasks on the patient part, failure of which increases the risks for ADEs, such as taking duplicate medications or starting a stopped medication unknowingly.[17] A seemingly clinically insignificant change in medications within the same class represents a hazard in duplicated therapies. Hazards due to patient and caregiver related factors included knowledge gaps, echoing previous research on unmet information needs of patients who were recently discharge from hospitals.[18] We also identified hazards due to tasks imposed by the hospital work system, often without explicit recognition, such as to address errors and confusions in discharge medications, which are more likely with frequent hospitalizations and associated regimen changes among older adults. There were hazards due to collaborative work factors between the patient and the hospital professionals to implement medication regimen changes at home. Older adults often rely on caregivers to accomplish this, and thus caregiver involvement is essential in the collaborative work during transition. The work system approach provided potential new avenues in designing interventions or redesigning previously failed or costly interventions to improve medication safety among older adults, such as pharmacist home visit post discharge,[19] remote patient monitoring,[20] or home visits by advanced practice nurses.[21] In terms of future improvement efforts, the types of hazards directed attention to challenges in home work system, defects in professional work systems, collaborative work and broader health care environment.

Anticoagulant, insulin, and antiplatelet were top medication classes cited by the frontline clinicians; this finding is consistent with what is previously reported in the literature.[22] Insulin was mentioned most frequently as an example medication class and was associated with many of the hazards, such as home resource-related factors in terms of cost, and task factors in terms of increased requirements for tasks and skills, and interference with daily activities. Such a concern on insulin was supported by previous research on self-management of anti-glycemics.[23] One surprise may be diuretics, which challenged the patients to use safely because of frequent titrations, a number of different choices of diuretics, required adjuvant therapies, and lifestyle burdens associated with their usage.

Multiple hazards can further increase the risks for ADEs, such as patients not correctly understanding medication administration instructions combined with complicated medication regimens. By identifying and understanding hazards, we may target improvement strategies and eliminate hazards identified as presenting the highest potential for harm. For example, the underlying reason for a patient taking multiple anticoagulants by mistake may be labeled as a health literacy issue when he or she may not have recognized these medications as anticoagulants. As another example, the so-called "patient errors"[24] are used to explain the reason for patients not following medication changes after discharge, which is found among nearly half of the patients 30 days after discharge[25]; while the underlying hazard may be a lack of effective mechanisms to inform patients about changes in medications. In other words, from a systems perspective, hazards underlying patient errors may be a reflection of defects in the professional work system (e.g., processes of patient education and engagement, hospital medication reconciliation, and discharge). For

any successful improvement effort, it is essential to focus on the underlying hazard, rather than on more easily identifiable or visible 'symptoms of the problem.'

Our analysis of hazards attributed their sources to multiple systems (the hospital work system and the patient home work system) and to the interactions between components across different systems (healthcare providers with the patient and caregiver, such as in inadequate handoffs of medication management tasks from inpatient settings to home). Studies on contributors to ADEs have been on a single work system, such as patient age, income, clinical conditions, and individual prescriber actions or inactions including prescribing[26] and monitoring.[27,28] In contrast, our analysis contributes to the understanding of risks to medication safety during care transitions in a "system of systems" that is highly dynamic and has additional complexity due to not only interactions within system components, but also interactions between various components of different systems.[29] We identified hazards reflective of the complexity and highly dynamic nature of how actions in one system impacting on subsequent actions in another system. As reflected by the hospital based professionals in our study, hazards in the hospital work system in the form of errors in medication documentation and discharge summaries are common,[30,31] and their trickledown efforts on patient abilities to manage medications safely at home are not always recognized.

We believe our study findings have direct implications for improvement of medication safety during care transitions among older adults in the domains of home work system, hospital work system, collaborative work, and external environment. Improvement in the hospital work system can have a direct impact on the home work system, especially on those older adults with limited capacities to understand their medications and to overcome errors. One recent analysis highlighted barriers perceived by clinicians to help patients.[32] Conversely, better assessment of the home work system of older adults can inform the professional work system to tailor harm reduction strategies, in collaboration with the patient and family, to address hazards related to medication task related hazards at home and home resource-related hazards. For example, automated means to flag patients with high task complexity[33] may encourage professionals to assess if the home work system of older adults is able to handle medication task related hazards, and if actions are needed to remove such hazards. As another example, tools to provide easy access to information on cost to patients may help professionals to overcome time burden[34] and may encourage professionals in their interactions with patients in shared decision making related to cost. As a third example, discussions on medication risks should balance benefits of medications with risks from medication task related hazards unique to a patient's home environment. As a final example, hazards in external environment, such as medications unavailable after discharge, may be anticipated and alternative plans can be developed with patients and families.

Although there may be tendencies to focus on health literacy to improve adherence,[35] our analysis results help to focus on strategies beyond discharge education during the usually hectic and unpredictable process of discharging. For example, during hospitalization, healthcare professionals can potentially collaborate with patients and family in identifying these hazards in the home work system, and be sensitive to requirements of tasks and skills for specific medications imposed on the home work system, especially among older adults with physical and cognitive limitations. As another example, hospital professionals

can develop tools for the home work system to reliably incorporate and implement regimen changes, such as medication schedules and specific instructions on starting or stopping medications. Improvement of the hospital work system to reduce confusions and errors in discharge medications can simplify the task of settling into new medication routines by the home work system.[11]

Our study was limited to hospital-based clinicians, although they worked directly during care transitions, including transitional care nurses those whose primary job was to support care transitions. Just as patients and families may be unaware of all the hazards in the home work system, professionals may also be limited in their awareness of all the hazards in the hospital work system. The views of hospital-based clinicians may be different from those expressed by outpatient or skilled home care professionals.[36] Future studies to integrate perspectives from all stakeholders, including older adults and their caregivers, are needed to improve our understanding of hazards in different work systems and in collaborative work. The sampling of interviews was based on convenience, although we made sure to sample from all major hospital-based roles involved in care transitions. Future studies may also ask professionals directly on concerns associated with specific medications, to understand how therapy classes are connected with hazards and how prescribing frequencies influenced prioritization in addressing hazards.

In summary, our study systematically examined hazards increasing risks for medication-related harms following hospital discharge by harnessing the insights from frontline care professionals and by using a systems approach. We uncovered multi-factorial aspects of hazards, including those introduced by the hospital work system in the form of errors in discharge medications, poor hand-offs to the home work system and those unrecognized and unaddressed defects in the home work system. Use of the safety science concept 'hazard' could potentially provide more meaningful and effective intervention strategies to make systematic improvements. Our analysis suggests the need for tools and processes for systematic changes in identifying hazards in the patient home and hospital work systems, and in their interactions. Such tools and processes can support individualized or tailored proactive strategies to reduce risks for preventable medication related harms for different home work systems during care transitions.[5]

Acknowledgements

References

1. Forster AJ, Murff HJ, Peterson JF, Gandhi TK, Bates DW. Adverse drug events occurring following hospital discharge. Journal of general internal medicine. 2005;20(4):317–323. [PubMed: 15857487]

2. Kanaan AO, Donovan JL, Duchin NP, et al. Adverse drug events after hospital discharge in older adults: types, severity, and involvement of Beers Criteria Medications. Journal of the American Geriatrics Society. 2013;61(11):1894–1899. [PubMed: 24116689]

3. Sarkar U, Lopez A, Maselli JH, Gonzales R. Adverse drug events in U.S. adult ambulatory medical care. Health services research. 2011;46(5):1517–1533. [PubMed: 21554271]

4. 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(11):1669–1686. [PubMed: 24088063]

5. Holden RJ, Schubert CC, Mickelson RS. The patient work system: an analysis of self-care performance barriers among elderly heart failure patients and their informal caregivers. Applied ergonomics. 2015;47:133–150. [PubMed: 25479983]

6. Werner NE, Malkana S, Gurses AP, Leff B, Arbaje AI. Toward a process-level view of distributed healthcare tasks: Medication management as a case study. Applied ergonomics. 2017;65:255–268. [PubMed: 28802446]

7. Arbaje AI, Hughes A, Werner N, et al. Information management goals and process failures during home visits for middle-aged and older adults receiving skilled home healthcare services after hospital discharge: a multisite, qualitative study. BMJ quality & safety. 2019;28(2):111–120.

8. Carayon P, Wooldridge A, Hoonakker P, Hundt AS, Kelly MM. SEIPS 3.0: Human-centered design of the patient journey for patient safety. Applied ergonomics. 2020;84:103033. [PubMed: 31987516]

9. Lee JL, Dy SM, Gurses AP, et al. Towards a More Patient-Centered Approach to Medication Safety. J Patient Exp. 2018;5(2):83–87. [PubMed: 29978022]

10. Xiao Y, Abebe E, Gurses AP. Engineering a Foundation for Partnership to Improve Medication Safety during Care Transitions. J Patient Saf Risk Manag. 2019;24(1):30–36. [PubMed: 30842993]

11. Werner NE, Tong M, Borkenhagen A, Holden RJ. Performance-Shaping Factors Affecting Older Adults' Hospital-to-Home Transition Success: A Systems Approach. Gerontologist. 2019;59(2):303–314. [PubMed: 29304235]

12. Battles JB, Lilford RJ. Organizing patient safety research to identify risks and hazards. Quality & safety in health care. 2003;12 Suppl 2:ii2–7. [PubMed: 14645888]

13. Stampfli D, Boeni F, Gerber A, et al. Assessing the ability of the Drug-Associated Risk Tool (DART) questionnaire to stratify hospitalised older patients according to their risk of drug-related problems: a cross-sectional validation study. BMJ Open. 2018;8(6):e021284.

14. Mixon AS, Myers AP, Leak CL, et al. Characteristics associated with postdischarge medication errors. Mayo Clinic proceedings. 2014;89(8):1042–1051. [PubMed: 24998906]

15. Glaser BG, Strauss AL. The discovery of grounded theory; strategies for qualitative research. Chicago,: Aldine Pub. Co.; 1967.

16. Harris CM, Sridharan A, Landis R, Howell E, Wright S. What happens to the medication regimens of older adults during and after an acute hospitalization? Journal of patient safety. 2013;9(3):150–153. [PubMed: 23965837]

17. Scales DC, Fischer HD, Li P, et al. Unintentional Continuation of Medications Intended for Acute Illness After Hospital Discharge: A Population-Based Cohort Study. Journal of general internal medicine. 2016;31(2):196–202. [PubMed: 26369941]

18. Romagnoli KM, Handler SM, Ligons FM, Hochheiser H. Home-care nurses' perceptions of unmet information needs and communication difficulties of older patients in the immediate post-hospital discharge period. BMJ quality & safety. 2013;22(4):324–332.

19. Gurwitz JH, Kapoor A, Garber L, et al. Effect of a Multifaceted Clinical Pharmacist Intervention on Medication Safety After Hospitalization in Persons Prescribed High-risk Medications: A Randomized Clinical Trial. JAMA internal medicine. 2021.

20. Ong MK, Romano PS, Edgington S, et al. Effectiveness of Remote Patient Monitoring After Discharge of Hospitalized Patients With Heart Failure: The Better Effectiveness After Transition -- Heart Failure (BEAT-HF) Randomized Clinical Trial. JAMA internal medicine. 2016;176(3):310–318. [PubMed: 26857383]

21. Stauffer BD, Fullerton C, Fleming N, et al. Effectiveness and cost of a transitional care program for heart failure: a prospective study with concurrent controls. Arch Intern Med. 2011;171(14):1238–1243. [PubMed: 21788541]

22. Shehab N, Lovegrove MC, Geller AI, Rose KO, Weidle NJ, Budnitz DS. US Emergency Department Visits for Outpatient Adverse Drug Events, 2013–2014. JAMA. 2016;316(20):2115–2125. [PubMed: 27893129]

23. Geller AI, Shehab N, Lovegrove MC, et al. National estimates of insulin-related hypoglycemia and errors leading to emergency department visits and hospitalizations. JAMA Intern Med. 2014;174(5):678–686. [PubMed: 24615164]

24. Buetow S, Kiata L, Liew T, Kenealy T, Dovey S, Elwyn G. Patient error: a preliminary taxonomy. Annals of family medicine. 2009;7(3):223–231. [PubMed: 19433839]

25. Weir DL, Motulsky A, Abrahamowicz M, et al. Failure to follow medication changes made at hospital discharge is associated with adverse events in 30 days. Health services research. 2020;55(4):512–523. [PubMed: 32434274]

26. Tamblyn R, Huang A, Taylor L, et al. A randomized trial of the effectiveness of on-demand versus computer-triggered drug decision support in primary care. Journal of the American Medical Informatics Association : JAMIA. 2008;15(4):430–438. [PubMed: 18436904]

27. Bundy DG, Marsteller JA, Wu AW, et al. Electronic health record-based monitoring of primary care patients at risk of medication-related toxicity. Joint Commission journal on quality and patient safety / Joint Commission Resources. 2012;38(5):216–223.

28. Gurwitz JH, Field TS, Harrold LR, et al. Incidence and preventability of adverse drug events among older persons in the ambulatory setting. Jama. 2003;289(9):1107–1116. [PubMed: 12622580]

29. Harvey C, Stanton NA. Safety in System-of-Systems: Ten key challenges. Safety Science. 2014;70:358–366.

30. Caleres G, Modig S, Midlov P, Chalmers J, Bondesson A. Medication Discrepancies in Discharge Summaries and Associated Risk Factors for Elderly Patients with Many Drugs. Drugs Real World Outcomes. 2020;7(1):53–62. [PubMed: 31834621]

31. Callen J, McIntosh J, Li J. Accuracy of medication documentation in hospital discharge summaries: A retrospective analysis of medication transcription errors in manual and electronic discharge summaries. International journal of medical informatics. 2010;79(1):58–64. [PubMed: 19800840]

32. Hannum SM, Abebe E, Xiao Y, Brown R, Pena IM, Gurses AP. Engineering care transitions: Clinician perceptions of barriers to safe medication management during transitions of patient care. Applied ergonomics. 2020;91:103299. [PubMed: 33161183]

33. McDonald MV, Peng TR, Sridharan S, et al. Automating the medication regimen complexity index. Journal of the American Medical Informatics Association : JAMIA. 2013;20(3):499–505. [PubMed: 23268486]

34. Alexander GC, Casalino LP, Meltzer DO. Physician strategies to reduce patients' out-of-pocket prescription costs. Archives of internal medicine. 2005;165(6):633–636. [PubMed: 15795338]

35. Cohen MJ, Shaykevich S, Cawthon C, Kripalani S, Paasche-Orlow MK, Schnipper JL. Predictors of medication adherence postdischarge: the impact of patient age, insurance status, and prior adherence. Journal of hospital medicine. 2012;7(6):470–475. [PubMed: 22473754]

36. Nicosia FM, Spar MJ, Stebbins M, et al. What Is a Medication-Related Problem? A Qualitative Study of Older Adults and Primary Care Clinicians. Journal of general internal medicine. 2020;35(3):724–731. [PubMed: 31677102]

Table 1.

Hazards for adverse drug events following hospital discharge, in six groups in the domains of home work system, hospital work system, collaborative work, and external environment.

Hazards	Examples
Home work system - medication task related	
Complex dosing	• Titrating, tapering, loading and maintenance doses • Different doses of the same medication on different days • Strict timing or conditions (e.g., every 6 hours, empty stomach) • With instructions difficult to follow (e.g., "continue home regimen of insulin, 20 units of Lantus twice a day and your NovoLog insulin as needed three times a day")
High risk medications	• Narrow therapeutic index • High potentials for drug-drug or drug-food interactions • Potential for misuse or addiction
High burdens associated with medication use	• Frequent follow-up care (e.g., clinic visits for monitoring and lab testing) • Self-monitoring (e.g., blood glucose or monitoring for bruises) • Difficult administration methods (e.g., injection or via special devices)
Lifestyle burdens associated with medication use	• Side effects making compliance difficult • Restrictions on diet or daily activities • Interfering with daily, sleeping or social activities (e.g., void more frequently or to be taken at set time of the day)
Home work system – patient and caregiver related	
Unsafe practices at home	• Unwilling to accept increased lifestyle burden to take the medication • Self-medicating for symptoms relief outside medical advice (e.g., taking multiple inhaler doses for COPD treatment) • Work-arounds to reduce medication burdens (e.g., combining multiple doses in a day into a single dose) • Under or improper use of safety tools (e.g., using pill boxes only as storage) • Risky medication handling practices (e.g., multiple bottles of same medications in different doses, different medications in a single bottle)
Knowledge gaps	• Not aware of taking duplicate or multiple similar action medications • Confusion of brand versus generic names • Not aware of importance of adherence or not fully understanding the risks of stopping a prescribed medication, often due to cost to medication side effects or improved symptoms • Unaware of taking medications incorrectly • Misbeliefs about medications • Not aware of major risks or not aware of ways to reduce major risks • Unable to provide accurate information on medications taken at home
At-risk behaviors in coping with cost	• Holding on to expired or not current medications • Reliance on coupons and free samples resulting gaps in therapies • Stretching doses • Patient's reluctance to communicate about affordability

Hazards	Examples
	• Perception of unjustifiable high cost and/or low no benefits (e.g., not filling antibiotics when symptoms had resolved)
Gaps in knowledge and skills in managing regimen changes	• Not understanding discharge medications as short-term bridging medications before seeing primary care physicians
	• Not aware of temporary nature of regimen changes that require followup with primary care physicians who knew the patient
Home work system – resource related	
Unaffordable cost	• Medications with non-sustainable long-term cost
	• No or inadequate insurance, or coverage gap
	• Medications with high copay
	• Medications requiring prior authorization
Deficiency in home support	• Inadequate or no help needed at home (e.g., to administer discharge medications)
	• Transportation barriers for followup visits or picking up medications
	• Loss of prescriptions
	• No system to ensure refill
Hospital work system	
Errors in discharge medications	• Unintentional duplications (same or medications with similar actions)
	• Omissions or dose errors recorded in home medications
	• Discontinued home medications listed as active
	• Not resuming home medications upon discharge medications
	• Inaccurate or missing allergy information in inpatient charts
	• Unnecessary prescription of opioids or not using less risky alternatives
Communication barriers	• Variations in discharge and communication processes over shifts or weekends resulting in gaps and confusions
	• Difficulty adding instructions in EHR on discharge medications
	• Inability to alert patients to dose changes
	• Time pressure preventing thorough review and communication with patients on discharge medications
	• No reliable process to review potential side effects and ways to manage side effects
Technology and policy barriers in helping patients manage cost	• Difficulties in determining out-of-pocket cost to patients
	• No process for engaging patients and families on cost and access issues
	• Burdens in working on insurance coverage
	• Cost issues induced from inpatient and outpatient formulary differences
	• Hospital staff not having time or not aware of the need to address cost
Collaborative work between hospital and home work systems	
Inadequate hand-offs for patients and caregivers to manage changes	• Patients not aware, not educated on, or not prepared to manage new medications
	• Mistaking dose changes as new medications or failure to adjust
	• Lack of clear instructions and ability to resume or stop home medication
Inadequate understanding about changes	• Switching from branded medication names to generic

Hazards	Examples
	• Switching within the same medication class due to formulary differences • Changing chronic home medications
External environment	
Medications unavailable after discharge	• Pharmacies unable to dispense same medications with only dose changes due to insurance coverage restrictions • Discharge medications not available at local pharmacies or requiring special orders
Gaps in access to care or in sharing medication information	• Barriers to follow up visits with primary care provider (e.g., scheduling and insurance issues) • Confusion over whom to reach out about refilling discharged medications • Conflicting information to patients from different providers • Medication information not shared across settings
Difficulties in obtaining medications after discharge	• High burdens in meeting regulatory requirement to obtain medications • Medications difficult to obtain outside hospital

Table 2.

Example quotes from the interview transcripts illustrating hazards for adverse drug events following hospital discharge

Home work system - medication task related	"Amiodarone and other medications that have loading doses. Not understanding the loading dose when it's finished and when to switch to the maintenance dose." [Transitional care nurse practitioner. Hazard coded: Complex dosing]
Home work system - patient and caregiver related	"I had one just yesterday who decided she was going to stop taking her Janumet twice a day, and only take it once a day. The nurse practitioner had already urged her to take it as directed, but "No, I need to cut back on my medicines." [Case manager. Hazard coded: Unsafe practices at home]
Home work system – resource related	"Even though you don't need blood work with it and it is supposed to be much better, they can't afford it." [Pharmacy technician. Hazard coded: Unaffordable cost]
Hospital work system	"Sometimes, we see that the discharge summary is wrong and the patient says 'Well, they gave me a prescription for this,' but it's not listed on the sheet that the patient takes home, which is really concerning." [Case manager. Hazard coded: Errors in discharge medications]
Collaborative work	"[T]hey could have been sent home, for instance, they were at home taking Lasix 20 mg and now they have a prescription coming home that they filled for furosemide 40 mg. They don't see that it is the same med, right?" [Care coordination nurse. Hazard coded: Inadequate handoffs for patients and caregivers to manage changes]
External environment	"They said Toprol for 30 days, am I supposed to stop it? … You are going to be like "Here is 30 days. You need to see somebody because you need to make sure blood pressure is tolerating it." [Hospitalist. Hazard coded: Gaps in access to care or in sharing medication information]

Table 3.

Top medication classes and number of times referenced by the study participants in describing medication related concerns

Medication classes	Home work system			Hospital work system	Collaborative work	External environment
	Medication tasks	Patients & caregivers	Resources			
Antibiotic	2	5	2	1	1	
Anticoagulant	9	8	11	2	2	
Antiplatelet	2	3	2	6		
Beta blocker		2		4	2	1
Diuretic	4	3		4	4	4
Insulin	13	4	4	2		2
Opioid	7			3		3