MedStar Health
National Center for
Human Factors in Healthcare

A Memory-Based Approach to Reducing Medication Errors

Project Final Report

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Principal Investigator:
Sadaf Kazi, PhD

Team Members:
Raj Ratwani, PhD
Ella Franklin, MSN, RN
Deanna-Nicole Busog

Organization:
MedStar Health National Center for Human Factors in Healthcare, MedStar Health Research Institute

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Structured Abstract

Purpose: To investigate the contribution of prospective memory (PM) demands on medication administration errors (MAEs) in inpatient medical/surgical units

Scope: Aim 1: Identify nurse PM demands during medication administration. Aim 2: Identify medication errors by analyzing technology usage data in the inpatient medication cycle (i.e., prescription, dispensing, administration, and documentation).

Methods: We conducted interviews with 14 medical/surgical unit nurses recruited from three hospitals in the mid-Atlantic region to investigate PM demands in the inpatient medication administration cycle. We also identified electronic health record (EHR) signals of PM failures for anticoagulant therapy (warfarin) that may manifest as international normalized ratio (INR) levels greater than 3.5 and result in complications.

Results: *Interviews:* Most PM demands occurred during planning and monitoring. PM tasks can be anticipated during medication planning, but PM tasks can arise dynamically based on the patient's condition or changing nurse or unit workflow priorities. PM tasks during planning can be encoded as reminders on the EHR and nursing paper tools, but it is important to develop tools to support dynamic PM tasks. *EHR data:* Two percent of total warfarin orders placed had nonoptimal INR values, with a gap of more than 24 hours from previous INR measure, indicating potential error.

Key Words: prospective memory; medication administration; medication errors; warfarin

Purpose and Study Objectives

Our overarching research objective was to apply theories from cognitive psychology to investigate the contribution of prospective memory demands on medication administration errors (MAEs) in inpatient medical/surgical units. Specifically, we identified prospective memory demands embedded in the inpatient medication administration workflow and strategies for managing these demands, and we ideated technology design solutions to support prospective memory processes. In addition, we investigated the link between prospective memory demands during the medication administration cycle and MAEs. This work was conducted through two specific aims:

Aim 1: Identify and quantify nurse prospective memory demands during medication administration through interviews

Aim 2: Identify and quantify medication errors by analyzing technology usage data in the inpatient medication cycle (i.e., prescription, dispensing, administration, and documentation), and align medication errors with PM demands

Scope

Background, Context, and Prevalence of Medication Errors

Despite being widely studied, medication administration errors (MAEs) remain a persistent problem in healthcare, with errors ranging from 10 to 50% in inpatient units.[1–5] MAEs refer to deviations during administration from the prescribed medication order, preparation and dispensing instructions, or regulatory guidelines.[2] Current approaches that apply general error taxonomies to classify types of MAEs find that lapses – memory-related failures due to issues with encoding, retaining, and recalling information[6] – account for a substantial proportion of MAEs.[7,8] Prospective memory (PM), which is remembering information that must be acted on in the future, is a frequent memory process used by nurses during medication administration and is a potentially significant source of the memory lapse errors.[9] The goal of our project was to uncover the medication administration workflow, including tasks during planning, dispensing, administration, documentation, and monitoring.

Application to Medication Errors in Anticoagulation Therapy

Safe management of warfarin in inpatient settings involves remembering to order warfarin, order labs to monitor and maintain therapeutic international normalized ratio (INR) levels, and check INR value before administration. Forgetting these tasks may manifest as INR levels greater than 3.5 and result in complications from nonoptimal warfarin levels, including supratherapeutic levels, severe bleeding, and death. Our pilot study explored preliminary electronic health record (EHR) signals of potential memory errors through these questions: (1) How many warfarin INR labs are greater than 3.5? (2) How many consecutive INR orders have a gap of more than 24 hours between orders?

Methods

Interview Study

Participants

We conducted semi-structured interviews with 14 nurses working on medical/surgical units (see Table 1 for demographics). Nurses were drawn from three hospitals in a large healthcare system in the mid-Atlantic. Nurses were recruited through nurse leaders and word of mouth.

Procedure and Data Analysis

Interviews were conducted remotely through a secure web-based application and lasted for about an hour. Nurses received compensation for participation, and the study was approved by the IRB. The interview guide was structured to elicit general PM demands embedded in each stage of the medication administration workflow and specific types of PM demands based on the literature in cognitive psychology (see Appendix 1 for interview guide). Interviews were audio recorded and transcribed. Grounded theory was used to code interview themes.

Table 1. Demographic Information About Participants

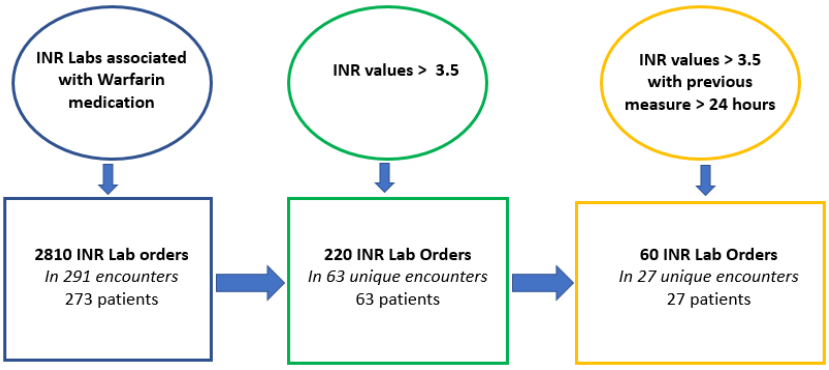
Demographic	**Sample Size/Number**
Gender	
Female	13
Male	1
Practice Site	
Site 1 (Washington, DC)	5
Site 2 (Baltimore, MD)	4
Site 3 (Baltimore, MD)	5
Experience	
Range	10 months – 28 years
Average	6 years, 10 months

PM-based Medication Errors in Anticoagulation Therapy through EHR data

Methods and Analysis

EHR data were extracted for November 2020 admissions for all inpatient units at a nine-hospital healthcare system in the mid-Atlantic region. We extracted patient- and encounter-level information (e.g., inpatient registration date, account number, encounter facility) and INR information (e.g., time of placing lab order, drawing labs, lab result) for warfarin orders (see Figure 1). The R Core Team 2019 statistical computing package was used to identify INR orders >3.5, because patients may have goal INR values between 2 and 3.5 based on medical indication for anticoagulants. From this subset, we built an algorithm to identify consecutive INR orders that had a >24-hour difference between them to identify errors due to potential memory failure.

Figure 1: Informatics Data Extraction Process



Results

Interview Study

We investigated PM demands in the inpatient medication cycle, including planning, dispensing, administration and documentation, and monitoring. Most PM demands were concentrated in the stages of planning and monitoring.

Prospective memory demands in medication administration stages.

During the planning stage, nurses must encode scheduled PM tasks by reviewing the handoff report and the electronic medication administration record (eMAR). Nurses use tools such as paper 'brains' to encode the medication name, administration time, and special medications (e.g., PRNs). PM tasks that are unscheduled and not encoded at the planning stage may be challenging to spontaneously encode and recall at a later point in time.

During the administration and documentation stages, nurses are in the salient window of opportunity for scheduled medications. Technology such as eMAR and EHR task managers provide salient alerts to support PM at this stage. However, nurses also face challenges at this stage, including remember to check medication therapeutic levels before administration and remembering to return controlled substances refused by the patient during administration (e.g., pain medication).

During the monitoring stage, nurses must encode scheduled PM tasks, including remember to follow up to monitor the effects of medications. This can include checking the patient's blood pressure or pain levels.

Varieties of PM tasks imposed on nurses during medication administration.

Time-based PM tasks: Tasks that must be remembered to be performed at a specific time of the day (e.g., remember to give medications at 9 am), at regular intervals of time (e.g., monitoring a patient's fluid intake and output every 4 or 8 hours to check patient's response to some medications), or after a specific amount of time has passed (e.g., evaluating the effectiveness of pain medication 1 hour after administration). Challenges with time-based tasks include as-needed (PRN) medications not being associated with an EHR alert.

Event-based PM tasks: Tasks that must be remembered to be performed after the occurrence of a specific event (e.g., remember to add a medication to the list after multidisciplinary rounds), before performing a task (e.g., checking pre-meal blood sugars), after performing a task (e.g., administering sliding scale insulin), and after waiting for a delay (e.g., administering an antibiotic when a patient returns from dialysis). Challenges with event-based tasks include the inability to reschedule medication time to later if patient is unavailable on the unit, remembering to re-start medications that are being temporarily suspended, and keeping track of new PM tasks that get added during the day (e.g., reminding pharmacy to fill a medication order).

Strategies and tools that nurses use to remember PM tasks impacting medication administration.

Nurses use two main strategies to remember PM tasks. First, nurses write down PM tasks. Tasks may be written on a paper tool that enables strategies such as annotating and highlighting tasks on the tool to track the task's nature and completion status, writing tasks on their hand or scrubs, and writing tasks on whiteboards in patient rooms. Second, nurses use electronic tools to keep track of PM tasks. This includes using tasks lists in the EHR to remember tasks and using alarms on cell phones to monitor time-based tasks.

Conclusions and Implications:

- The medication administration workflow in inpatient settings is complex and encompasses a variety of PM tasks. PM failure is likely to have adverse patient safety implications because of heightened risk of medication administration errors.
- PM tasks can be anticipated during medication planning; however, several PM tasks also arise dynamically depending on changes to the patient's condition or because of changing nurse or unit workflow priorities.
- Although PM tasks that arise during planning are amenable to being encoded as reminders on the EHR and nursing paper tools ("nurse brains"), there is a need to develop tools to improve support for PM tasks that arise dynamically.

PM-based Medication Errors in Anticoagulation Therapy through EHR data

Descriptive statistics were used to summarize the data (see Table 2).

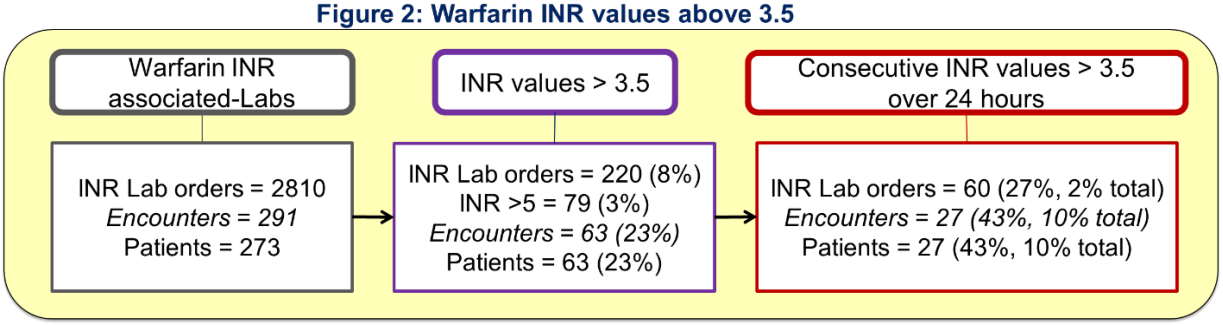
Table 2: Descriptive Statistics of INR values >3.5

Metric Name	Range	Mean	Median	Standard Deviation
INR >3.5*	3.6 - 12.6	5.0	4.4	1.7
INR >3.5 & previous measure >24 hours*	24.1 - 400.6	50.0	25.6	65.0

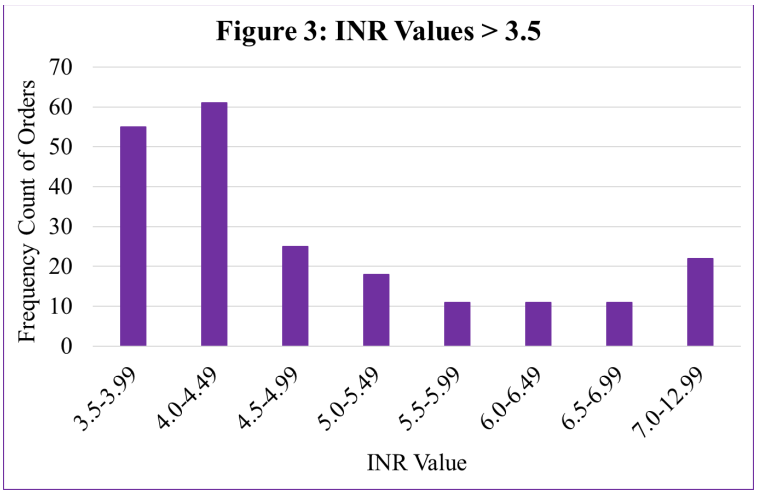
* Exact values greater than 12.6 were unavailable and therefore excluded from the descriptive statistics calculations.

Overall, 2810 warfarin-associated INR lab orders were placed across 273 patients in all nine facilities (see Figure 2 and Table 2).

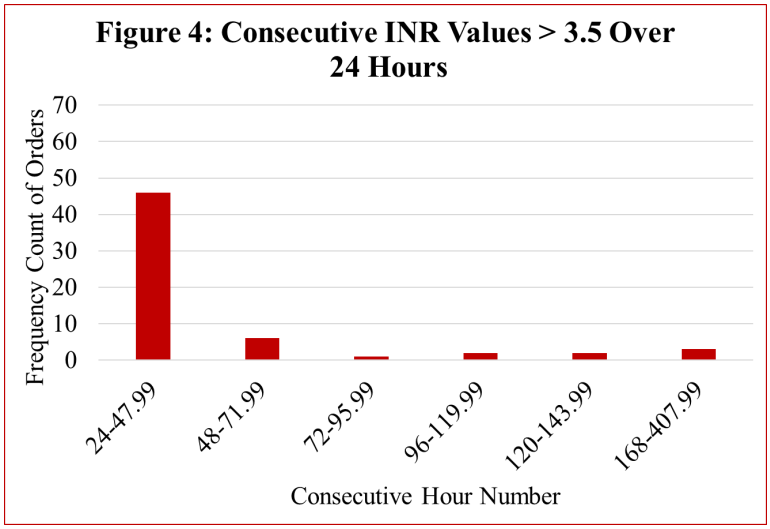
Figure 2: Warfarin INR values above 3.5



Eight percent of all INR levels were above 3.5 (see Figure 3), and 3% of all INR levels were above 5.



In the subset of INR levels over 3.5, 27% were consecutive INR levels above 3.5 over a 24-hour period (see Figure 4). This represented 2% of total INR values across the entire dataset and 10% of patients sampled.



Two percent of total warfarin orders placed had nonoptimal INR values, with a gap of more than 24 hours from previous INR measure, indicating potential error. These potential errors were located on different units and facilities, demonstrating the need for systematic solutions and spreading best practices across the healthcare organization. We are conducting chart reviews to investigate the context of these potential errors and conducting failure modes and effects analyses to identify brittle points in the warfarin workflow that could contribute to errors.

Limitations

- Data represent only 1 month of orders. It is important to expand the timeline of these data to examine potential monthly trends.
- Data are not clinically validated to verify that they represent errors instead of intended actions.

Conclusions and Implications:

- Eight percent of total warfarin orders had INR values greater than 3.5.
- Two percent of total warfarin orders with INR >3.5 had a gap of more than 24 hours from previous INR measure, indicating potential memory error.
- Potential errors were located on different units and facilities, demonstrating the need for systematic solutions and spreading best practices across the healthcare organization.

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List of Publications and Products (Bibliography of Outputs) from the study.

Kazi, S., Weir, C., Franklin, E., & Steege, L. (2022). *Human Factors in Nursing and Future Directions.* Invited panel presentation at the 2022 International Symposium on Human Factors and Ergonomics in Healthcare, New Orleans, LA.

Kazi, S., Busog, D.-N., La, L., Bennett, S., Ratwani, R., & Franklin, E. (2021). *Nurse Prospective Memory Demands in Inpatient Medication Administration: Gaps and Design Opportunities.* Lecture presentation at the 2021 International Virtual Symposium on Human Factors and Ergonomics in Healthcare.

Bennett, S.S., Franklin, E.S., Long, L., Busog, D.-N., Blumenthal, J., Hettinger, A.Z., & Kazi, S. (2021). *Detecting Memory-Based Medication Errors in Anticoagulation Therapy through EHR Data.* Poster presentation at the 2021 MedStar Health-Georgetown University Research & Education Symposium.

Appendix 1. Interview Guide: Memory Demands During Inpatient Medication Administration

Interview Objectives

- To elicit prospective memory (PM) demands during distinct stages of medication administration (i.e., planning, preparing, administration, monitoring)
- To understand the nature of PM challenges during each medication administration stage, including the structure of PM tasks, source of PM task (self created, other created, workflow related), cues to PM, strategies to remember PM tasks, and which tasks are considered especially challenging and why
- To elicit PM tasks that are high value and at high risk of being forgotten
- To elicit design suggestions for tools that can aid in completing PM tasks

Introduction script

"Thank you for participating in our study. Have you had a chance to review the consent form? There are two parts of the consent document that I'd like to discuss before we begin. First, we will be audio recording this interview. The recordings will only be accessible by study personnel, uploaded to a secure server until the completion of the study, after which they will be destroyed. Second, you may withdraw from participating in the study at any time and for any reason without penalty or consequence.

Switch on audio

This study requires verbal consent. Do you consent to participate in our study?

We are interested in understanding information and tasks that nurses must remember during medication administration. Think of these tasks as medication-related to-dos. Your to-dos may be involve remembering to perform something at a specific time (e.g., remembering to administer medication at 9 am) or before or after performing a task (e.g., remember to check IV patency). We define the medication workflow as comprising planning medication administration, preparing and retrieving medication, administering medications, and monitoring the effects of administration. I will now ask you questions about tasks that are generated as to-dos related to these different parts of the medication administration workflow. Do you have any questions before we begin?

We will begin with planning medication administration at the beginning of the shift."

Interview guide

Demographics

a) Special training/certifications
b) Total experience as a nurse (excluding preceptor)
    i) Total experience at MedStar
        (1) Clinical ladder
    ii) Total experience outside MedStar
c) Total experience in medical/surgical units

i) Unit name

d) Which units outside of medical/surgical do you have experience in?
e) Which EHRs do you have experience in?

Planning medication administration (medication-related considerations, e.g., allergies, special supplies like IV tubing, including (1) receiving handoff report; and (2) planning medications that you are responsible for during the shift)

1. Can you describe your workflow during the planning stage, focusing on information you need, when receiving handoff report:
    a. from the previous nurse on an existing patient in the unit? *(e.g., when patient last received pain med, when to evaluate med effectiveness/side effects or need for additional med, allergies?)*
    b. on a new admission or transfer from another unit? *(e.g., if the patient takes a home med, if home med is stored at bedside or in Pyxis?)*
2. What medication-related tasks or to-dos do you generally receive from the previous nurse during handoff/a new admission/transfer? *(e.g., remember to crush med if patient has difficulty swallowing)*
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
3. What medication-related tasks or to-dos do you generally create for yourself when you are receiving handoff/a new admission/transfer?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
4. What tasks get added during the shift? (*e.g., new orders, new patients, covering for colleagues*)
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
5. Can you describe a medication-related situation for which you have to wait for additional information from the previous nurse or from another source at the beginning of your shift?
    a. When do you receive information to be able to complete making your to-do or complete your task?
6. Reflecting on your workflow at the planning stage:
    a. What are medication-related tasks that you are unable to perform immediately but must remember to do at a later point?
    b. What are medication-related tasks that you must remember to perform at a specific time of the day (*e.g., 9 am and 9 pm for medications that are given twice a day)?*
    c. What are medication-related tasks that you must remember to perform at regular intervals (*e.g., monitoring a patient's fluid intake and output every 4 or 8 hours to check patient's response to some medications*)?
    d. What are medication-related tasks that you must remember to perform after a specific amount of time has passed (*e.g. evaluating the effectiveness of pain medication 1 hour after administration*)?
    e. What are medication-related tasks that you must remember to perform after receiving some information (*e.g. after the attending physician makes rounds*)?
    f. What are medication-related tasks that you must remember to perform before performing a task (*e.g., checking pre-meal blood sugars*)?
    g. What are medication-related tasks that you must remember to perform after performing a task (*e.g., administering sliding scale insulin*)?

h. What are medication-related tasks that you must remember to perform after waiting for a delay (*e.g., administering an antibiotic when a patient returns from dialysis, administering timed medications that a patient had missed when they return from physical therapy, adjusting a heparin drip after PTT result returns*)?

7. Do you record the information/tasks you receive during patient handoff?
    a. Where?
    b. What information do you record about these tasks?
8. What tasks have you found most challenging to remember when you are planning medication administration? What tasks are frequently forgotten by novices?
9. What strategies do you use to remember tasks you receive or create during handoff?
    a. Are there strategies you use when your workload is high?

Preparing medications (lower priority)

1. Can you describe your workflow focusing on information you need, when you are gathering supplies and preparing medications from the Pyxis and other storage areas in the unit?
    a. What is your workflow when gathering medications from the Pyxis vs. medications directly from the pharmacy?
    b. How many different places on your unit might you have to go to find a medication for a patient *(e.g., 1) Pyxis, 2) fridge, 3) designated place (counter) where pharmacy drops off stat med, 4) go to pharmacy personally, 5) send someone else to pharmacy, 6) patient bedside, 7) others)*?
2. What information do you generally need when preparing medication?
    a. Where is this information located? Do you have to remember it?
    b. Is there information that you often find missing or incorrect?
3. Are there any tasks for your to-do list that are created when you are preparing medications?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
4. Do you use any tools during medication preparation *(e.g., e-documentation tools, paper tools, tablet, barcode reader)*?
    a. What do you record on these during dispensing?
    b. After finishing dispensing?
5. What tasks have you found most challenging to remember when you are preparing medications? What tasks are frequently forgotten by novices?
6. What strategies do you use to remember tasks during medication preparation?
    a. Are there strategies you use when your workload is high?

Administering medications

1. Can you describe your workflow focusing on information you need when you are administering medications (*e.g., batching tasks in patient room like checking vitals, dressing, assisting patient in ambulation*)?
    a. Where is this information located? Do you have to remember it?
    b. Is there information that you often find missing or incorrect?
2. Reflecting on your workflow at the administration stage:
    a. What are medication-related tasks that you are unable to perform immediately but must remember to do at a later point?

b. What are medication-related tasks that you must remember to perform at a specific time of the day (*e.g., 9 am and 9 pm for medications that are given twice a day)*?
c. What are medication-related tasks that you must remember to perform at regular intervals (*e.g., monitoring a patient's fluid intake and output every 4 or 8 hours to check patient's response to some medications*)?
d. What are medication-related tasks that you must remember to perform after a specific amount of time has passed (*e.g., evaluating the effectiveness of pain medication 1 hour after administration*)?
e. What are medication-related tasks that you must remember to perform after receiving some information (*e.g., after the attending physician makes rounds)*?
f. What are medication-related tasks that you must remember to perform before performing a task (*e.g., checking pre-meal blood sugars*)?
g. What are medication-related tasks that you must remember to perform after performing a task (*e.g., administering sliding scale insulin*)?
h. What are medication-related tasks that you must remember to perform after waiting for a delay (*e.g., administering an antibiotic when a patient returns from dialysis, administering timed medications that a patient had missed when they return from physical therapy, adjusting a heparin drip after PTT result returns*)?
i. Are there certain medications that have a lot of tasks associated with them?
j. Are there certain medications that tend to be given one time?
k. Are there tasks that need to be performed infrequently?

3. Where do you record these tasks?
    a. What information do you record about these tasks?
4. Are there any tasks for your to-do list that are created during medication administration?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
5. Are there any tasks for your to-do list that are created after completing medication administration?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
6. What tasks have you found most challenging to remember when you are administering medications? What tasks are frequently forgotten by novices?
7. What strategies do you use to remember tasks during medication administration?
    a. Are there strategies you use when your workload is high?
8. In an ideal world what would a tool look like that could help you remember these tasks?

Monitoring the effect of medications (lower priority)

9. Can you describe your workflow focusing on information you need when you are monitoring the effect of medications (*e.g., batching tasks in patient room like checking vitals, dressing, assisting patient in ambulation*)?
    a. Where is this information located? Do you have to remember it?
    b. Is there information that you often find missing or incorrect?
10. Reflecting on your workflow at the monitoring stage:
    a. What are medication-related tasks that you are unable to perform immediately but must remember to do at a later point?
    b. What are medication-related tasks that you must remember to perform at a specific time of the day (*e.g., 9 am and 9 pm for medications that are given twice a day)*?

c. What are medication-related tasks that you must remember to perform at regular intervals (*e.g., monitoring a patient's fluid intake and output every 4 or 8 hours to check patient's response to some medications*)?
d. What are medication-related tasks that you must remember to perform after a specific amount of time has passed (*e.g., evaluating the effectiveness of pain medication one hour after administration*)?
e. What are medication-related tasks that you must remember to perform after receiving some information (*e.g., after the attending physician makes rounds)?*
f. What are medication-related tasks that you must remember to perform before performing a task (*e.g., checking pre-meal blood sugars*)?
g. What are medication-related tasks that you must remember to perform after performing a task (*e.g., administering sliding scale insulin*)?
h. What are medication-related tasks that you must remember to perform after waiting for a delay (*e.g., administering an antibiotic when a patient returns from dialysis, administering timed medications that a patient had missed when they return from physical therapy, adjusting a heparin drip after PTT result returns*)?

11. Where do you record these tasks?
    a. What information do you record about these tasks?
12. Are there any tasks for your to-do list that are created during monitoring?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
13. Are there any tasks for your to-do list that are created after completing monitoring?
    a. Do you record these tasks? Where?
    b. What information do you record about these tasks?
14. What tasks have you found most challenging to remember when you are monitoring the effect of medications? What tasks are frequently forgotten by novices?
15. What strategies do you use to remember tasks during monitoring?
    a. Are there strategies you use when your workload is high?