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Original Article

# Understanding how infection prevention influences nurses' task sequencing using a mixed-methods, simulation-based approach

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A R T I C L E I N F O

*Keywords:*
Task sequencing
Patient care
Infection prevention
High-fidelity simulation
Nursing

A B S T R A C T

*Objective:* Better understand how and why nurses sequence their patient care tasks.
*Background:* Workflow mitigation strategies, such as working clean to dirty, could help reduce cross-contamination. However, the extent to which priorities, other than infection prevention concerns, influence the sequence of patient care tasks is poorly understood.
*Methods:* We had nurses perform high fidelity simulations of patient care tasks that incorporated common barriers to practicing infection prevention, such as time pressure, high workload, and interruptions. We assigned nurses patient care tasks that were either high or low in patient-infection risk and either high or low in dirtiness; a two-way repeated measures ANOVA was used to analyze the effect of these two factors on the order in which nurses completed the tasks. We used a cued-retrospective think-aloud to elicit why participants sequenced the tasks the way they did; open and closed card sorts were used to analyze this data.
*Results:* On average, participants completed low patient-infection risk, high dirtiness tasks first followed by low dirtiness tasks (regardless of patient-infection risk) and then finally high patient-infection risk, high dirtiness tasks. Analysis of the think-alouds suggest patient stability and patient comfort were, on average, higher priorities for task sequencing than infection prevention.
*Conclusion:* Healthcare workers have to balance competing priorities such as patient stability, patient comfort, and infection prevention concerns with the limited resources (e.g., staff, supplies, time) available to them. Future research examining how different task sequence approaches might affect these priorities would help inform how healthcare workers could sequence their tasks.

## 1. Introduction

Healthcare-associated infections are the most common adverse event (World Health Organization, 2011) and lead to the death of nearly 90, 000 patients annually (Stone, 2009), most of which are preventable (Umscheid et al., 2011). To prevent the spread of pathogens, healthcare workers (HCWs) perform specific infection prevention and control (IPC) practices during patient care, such as hand hygiene and using personal protective equipment (PPE). Although considerable attention has been devoted to understanding the factors that influence these practices (Erasmus et al., 2010; Jang et al., 2010), less attention has been given to the practice of sequencing one's workflow itself to reduce opportunities for transmission. For example, if an HCW toilets their patient in bed (i.e., a contaminating, or "dirty" task) before inserting a PIV in that patient (an invasive, or "clean" task), then pathogens from the patient's stool may be transmitted to the patient's IV site, assuming the HCW does not perform effective hand hygiene and use PPE appropriately between these tasks. If the HCW inserted a PIV before toileting a patient, however, then there is less opportunity to transmit pathogens from the patient's stool to their IV site (i.e., to work from "clean" to "dirty" tasks; Hor et al., 2017; Yoshikura, 2000). The current study focuses on better understanding how and why nurses sequence their patient care tasks, especially with regards to IPC.

Prior research of how HCWs sequence their tasks have raised

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concerns about cross-contamination. For example, Gregory et al. (2019) found that although nurses batch together tasks while caring for a patient on contact precautions, they tend to not perform hand hygiene between tasks or contact points in the environment. Chang et al. (2022) found that in contrast to the practice of working from "clean to dirty," HCWs tended to transition from dirtier tasks to cleaner tasks more often than from cleaner to dirtier tasks. Moreover, they found that hand hygiene adherence was lower when moving from dirtier to cleaner tasks—when it is crucially needed—compared to when they transitioned from cleaner to dirtier tasks. Thus, hand hygiene adherence is often low, and workflow mitigation strategies, such as working clean to dirty, could help reduce cross-contamination.

There is some prior research for why HCWs perform tasks in a particular sequence. Barg-Walkow et al. (2021) found that experienced HCWs sequenced their tasks based on task priority. Patterson et al. (2011) suggested a prioritization hierarchy in which imminent, life-threatening concerns and high-uncertainty activities (e.g., using a new device) are prioritized over "core" clinical tasks. Prior research outside of task sequencing found that HCWs must balance competing priorities during patient care, often prioritizing efficiency and organizational factors (e.g., having sufficient beds and staff available) at the expense of their personal needs, workload, and the quality and safety of patient care (Sanford et al., 2022). Research that examined task sequencing from an infection prevention perspective could only speculate that HCWs did not work from clean to dirty because they may be choosing to "batch" dirtier tasks together and cleaner tasks together for efficiency or performing the dirtier tasks first to "get them out of the way" (Chang et al., 2022, p. 222). Thus, although prior research has found HCWs sequence their tasks based on task priority, it is unclear how much infection prevention is considered for task sequencing, and there may be other priorities that affect task sequencing.

HCWs' perceptions about the tasks themselves are also important for task sequencing because HCWs will use them when deciding how to sequence their tasks; for example, to work from clean to dirty, a HCW must perceive tasks as varying along a clean to dirty dimension. Mumma et al. (2021) found that HCWs do perceive their tasks varying in terms of dirtiness and the risk of bodily fluid exposure (i.e., HCW contamination). Moreover, they found that HCWs also perceive the same tasks varying in terms of the degree of infection risk to their patient ("patient-infection risk"). That is, HCWs believe that certain tasks are (a) high in both dirtiness and patient-infection risk, (b) high in dirtiness but low in patient-infection risk, (c) low in dirtiness but high in patient-infection risk, or (d) low in both dirtiness and patient-infection risk. No prior research has examined whether one or both dimensions are important for HCWs' task sequencing.

The current research aims to address a gap in the literature: understanding how a concern for infection prevention drives task sequencing relative to other priorities. Prior research suggests if nurses sequenced their tasks from clean to dirty, it could help reduce cross-contamination (Hor et al., 2017; Yoshikura, 2000). However, before developing intervention strategies, it is first necessary to understand why nurses structure their workflow the way they do because there may be other priorities that compete with infection prevention; in the terms of Safety II (Ham, 2021), we must understand the work as performed rather than the work as imagined. Accordingly, the current work was open-ended with regards to understanding why nurses sequence clinical tasks the way they do. Furthermore, in addition to nurses perceiving tasks varying along a dimension of dirtiness, they also perceive them varying along a dimension of infection risk to the patient (Mumma et al., 2021). We build upon this in the current study to examine how and why HCWs sequence tasks that vary in the perceived dirtiness and patient-infection risk. We hypothesized that a task's perceived dirtiness or patient-infection risk would influence the task's ordinal position in a sequence of tasks, but it was unknown whether these characteristics had main or interactive effects.

## 2. Methods

We performed high-fidelity simulations of patient care tasks that incorporated common barriers to practicing IPC that may influence task sequencing, such as time pressure (participants were told they had one hour to complete and document eight tasks), interruptions (participants were interrupted twice in each patient room at specific moments, such as during Foley catheter insertion), and shortage of staff (participants did not receive assistance from others). The simulation involved caring for two male adult inpatients (high-fidelity manikins), in separate rooms, who required only standard precautions (see Supplementary Materials for details about each patient). We chose to perform high-fidelity simulations to control the tasks assigned and measure how different task types affect task sequencing; accordingly, the two independent variables were the two dimensions that describe how HCWs perceive tasks from an infection prevention perspective: dirtiness and patient-infection risk (Mumma et al., 2021). Each of these dimensions have tasks that fall on the high and low extremes, which yielded a 2 (dirtiness: high, low) x 2 (patient-infection risk: high, low) within-subjects experimental design with four total conditions. For each patient, we selected one task to represent each of the four conditions (Table 1; Wells & Windschitl, 1999; see Supplementary Materials for more information). Participants were instructed to perform these eight tasks for the simulation in any order that they wished. To understand why participants sequenced the tasks the way they did and how priorities such as infection prevention affected task sequencing, we used a cued-retrospective think-aloud (Alhadreti et al., 2017; Van Den Haak et al., 2003), wherein HCWs described their thought-processes while watching a playback of their simulation.

### 2.1. Participants

Forty-five nurses from a tertiary/quaternary academic medical center (Median = 4.5 years since first licensure, IQR = 2.3 – 16.4) participated in the current study. The sample of nurses came from intensive care units (ICU; $n$ = 15), emergency departments (ED; $n$ = 12), and medical/surgical units (MS; $n$ = 18). One participant's think aloud transcript could not be coded because their think aloud was not captured due to equipment issues; consequently, they were excluded from the task sequence reasoning analysis. For two and a half hours of their time, nurses were compensated with $125, a parking voucher, small amount (< $10) of credit to an Emory store, and an elective credit towards Emory's professional development framework. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Board at Emory University. Informed consent was obtained from each participant.

### 2.2. Procedure

Each simulation began with the participant receiving a scripted walkthrough of the simulation space (see Supplementary Materials), wherein the experimenter familiarized the participant with the supplies,

**Table 1**
Patient-infection risk and dirtiness of patient care tasks.

| Patient Room | Independent Variables | | Task |
|---|---|---|---|
| | Patient-Infection Risk | Dirtiness | |
| 1 | High | High | Foley Catheter Insertion |
| 1 | High | Low | IV Medication Administration |
| 1 | Low | High | Stool Specimen Collection |
| 1 | Low | Low | Auscultation |
| 2 | High | High | Wound Care |
| 2 | High | Low | PIV Insertion |
| 2 | Low | High | Toileting |
| 2 | Low | Low | NG Tube Insertion |

equipment, tasks to be completed for each patient, and time limit for completing the tasks (one hour). After the walkthrough, an experimenter placed a mobile camera (GoPro® HERO8) on the participant's forehead to record the simulation, both visually and audibly, from their point of view. Then the participant and a nurse from the research team playing the role of the off-going nurse performed a scripted handover for each patient (see Supplementary Material), which involved reviewing the patients' conditions (e.g., atrial fibrillation tachycardia, ileus). In both the walkthrough and patient handover, the experimenter emphasized that the sequence in which the participant visits their patients and the sequence in which tasks are performed is completely up to the participant. Beyond this, the participant was not informed that we were interested in their task order. The participant then performed the eight patient care tasks. Immediately following the simulation, participants performed a retrospective think aloud while watching the mobile camera's playback of their simulation in a nearby meeting room. The think aloud audio and video playback were recorded synchronously.

### 2.3. Assumption check

A key assumption was that participants were able to freely choose the sequence in which they performed tasks in each room. Because the only basis for allocating tasks together was that each task represent a different type of task, it is possible that we inadvertently placed tasks together in a way that constrains the sequence in which participants could perform those tasks (e.g., Task A must be done before Task B). We reasoned that if participants could freely choose the sequence of tasks for each patient, then it should be possible for every task to follow every other task. We verified that, within each patient room, every task immediately followed every other task at least once across all participants.

### 2.4. Dependent variable

The dependent variable was the ordinal position in which each participant performed the four tasks for each patient (i.e., first, second, third, or fourth); we reviewed the video footage from the simulation to determine the ordinal position of tasks. The ordinal positions of the two tasks representing each experimental condition for each room were averaged. Given that participants sometimes intersperse tasks or did not complete tasks, we used "critical actions" that we defined as shown in Table 2 to determine rank sequence.

### 2.5. Data and analysis

#### 2.5.1. Task sequence

We applied the nonparametric Aligned Rank Transform (Wobbrock et al., 2011) before analyzing our data with a 2 (patient-infection risk: high, low) x 2 (dirtiness: high, low) repeated measures ANOVA. We used this nonparametric procedure because our dependent variable was ordinal. The significance level was set to 0.05 for all analyses, and follow-up pairwise comparisons were protected from Type I error using a Holm correction (Aickin & Gensler, 1996; Holm, 1979; Levin, 1996).

**Table 2**
Critical action for each patient care task.

| Task | Critical Action |
|---|---|
| Foley Catheter Insertion | Inserting the Foley Catheter |
| Medication Administration | Inserting medicine into IV line. |
| Stool Specimen Collection | Placing stool specimen in cup |
| Auscultation | Placing stethoscope on patient |
| NG Tube Insertion | Inserting NG Tube |
| PIV Insertion | Inserting needle |
| Toileting | Removing bedpan from bed |
| Wound Care | Any action for flushing or wiping wound out |

*Note.* IV = intravenous; NG = nasogastric; PIV = peripheral intravenous.

Effect size estimates are given using generalized eta squared ($\eta_G^2$; Bakeman, 2005; Olejnik & Algina, 2003).

#### 2.5.2. Task sequence reasoning

We were interested in the reasons participants provided in their retrospective think alouds about their task sequencing during the simulation and whether those reasons related to IPC. To this end, we started by having two coders review the transcripts and identify every verbalization in which they believed the participant was clearly providing a reason for how they sequenced tasks during the simulation. The two coders had near perfect agreement (Gwet's AC1 = 0.985, 95% CI = [0.977,0.994]; Landis & Koch, 1977) for the five transcripts they both coded, which made up 10.0% of all verbalizations coded. We divided the remaining transcripts between the two coders.

Subsequently, we identified the task(s) being discussed in these verbalizations and had two coders determine whether the task(s) being discussed were being prioritized, delayed, or neither. The two coders had substantial agreement (Gwet's AC1 = 0.756, 95% CI = [0.568,0.944]) for the 36 verbalizations they both coded, which comprised 20% of all verbalizations coded.

We organized the verbalizations into eight card sorts such that each of the four experimental conditions (e.g., high patient-infection risk and high dirtiness) had two card sorts each — one for tasks being prioritized and one for tasks being delayed. A card sort is a method to uncover how people organize objects or items known as "cards" (Robertson et al., 2020). In this case, each card was a verbalization with a task sequence reason. For the eight card sorts, we asked two nurses and three public health graduate students to group together cards that described similar reasons for why tasks were prioritized or delayed. These card sorts had no pre-existing groups of reasons, meaning sorters created and named as many groups as they wanted (i.e., an open card sort). We met with the card sorters after they finished sorting the cards to discuss task sequence reason groups and what to name them. Using the task sequence reason groups from the open card sorts, we asked a different set of judges (two nurses and two public health graduate students) to complete a "closed" card sort; that is, we asked them to group together cards with similar reasons for why tasks were prioritized or delayed and provided them with pre-existing groups—the groups from the open card sorts. Sorters had substantial to near perfect agreement (Gwet's AC1 = 0.703 – 0.977), depending on the task sequence reason group. An open card sort followed by a closed card sort is an accepted way to confirm the grouping of cards is appropriate (Robertson et al., 2020). In both the open and closed card sorts, we allowed the sorters to duplicate cards if they believed the card described multiple task sequence reasons.

Quotes from participants during the retrospective think aloud are provided to help illustrate participant's rationale for sequencing tasks and their planning process. The selected quotes are the clearest and most representative for the given category. Additional data will be provided upon reasonable request.

## 3. Results and discussion

We first present the results for how both a task's perceived patient-infection risk and dirtiness affected the sequence in which participants ordered their tasks. Then, we present the results from the think aloud that describe participants' reasoning for sequencing their tasks the way they did.

### 3.1. Task sequence

Fig. 1 shows that on average, participants completed low patient-infection risk, high dirtiness tasks first (lowest mean ordinal rank) followed by low dirtiness tasks (regardless of patient-infection risk) and then finally high patient-infection risk, high dirtiness tasks. This was supported by a repeated measures ANOVA that had a significant

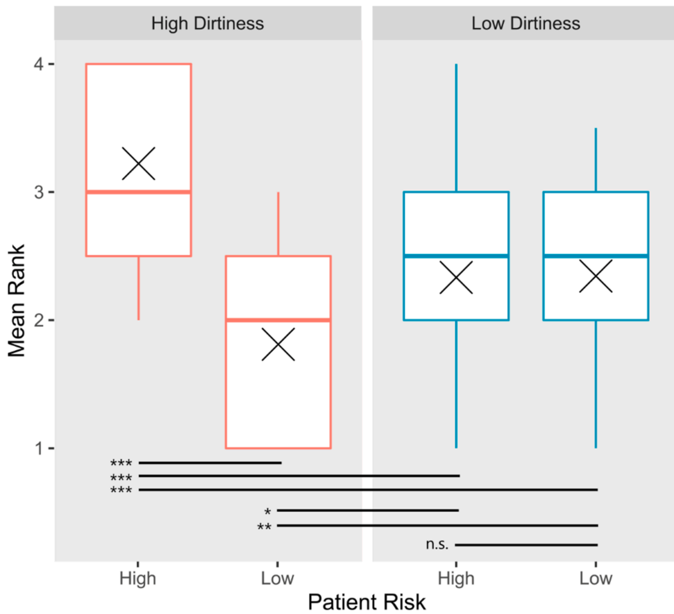


**Fig. 1.** Boxplots of mean rank sequencing of patient care tasks broken down by patient-infection risk and dirtiness.
*Note*. The X's represent the mean. The black horizontal lines below the box plots represent the pairwise comparisons between conditions with the asterisks reflecting statistical significance. n.s. = not significant ($p > .05$). * $p < .05$. ** $p < .01$. *** $p < .001$.

interaction between patient-infection risk and dirtiness, $F(1, 44) = 42.38$, $p < .001$, $\eta^2_G = 0.221$, and the follow-up Holm-corrected pairwise comparisons that showed all pairwise comparisons were significantly different except for the pairwise comparison between the two low dirtiness conditions as shown by the black horizontal lines with asterisks reflecting statistical significance at the bottom of Fig. 1 (see Supplementary Materials for additional statistics).

### 3.2. *Task sequence reasoning*

The overall results of the closed card sorts are shown in Fig. 2. The most common reason for sequencing tasks was to maintain or bring the patient to a stable condition (34%), which was given more than twice as frequently as any other single reason. Two reasons were related to IPC (17% combined): (1) decrease risk of contamination: perform clean tasks then dirty tasks and (2) decrease risk of contamination: removing/ cleaning soiled areas before performing other tasks. Prior research (Chang et al., 2022; Hor et al., 2017) has only focused on the former and not the latter IPC-related task sequence reason and attributed working from dirty to clean as always increasing the risk of contamination. However, the current results have uncovered an infection prevention reason to perform a dirty task before a clean task: cleaning soiled areas first. For example, if a patient is sitting in stool and needs a Foley catheter inserted, a nurse should clean up the stool before inserting the Foley catheter to prevent contamination during catheter insertion.

The results broken down by experimental condition and task priority are shown in Fig. 3. It is important to note that if a verbalization is coded as prioritizing a task (or delaying a task), it does not necessarily mean that task was performed first (or last); instead, it means that task was prioritized ahead of at least one other task (or after at least one other task). For example, a participant could be explaining why they prioritized a task they performed first, or they could be explaining why they prioritized the task they completed third ahead of the task they completed fourth. Hence, the number of prioritization verbalizations and delaying verbalizations or the ratio between them do not reflect the ordinal position a task type was completed at.

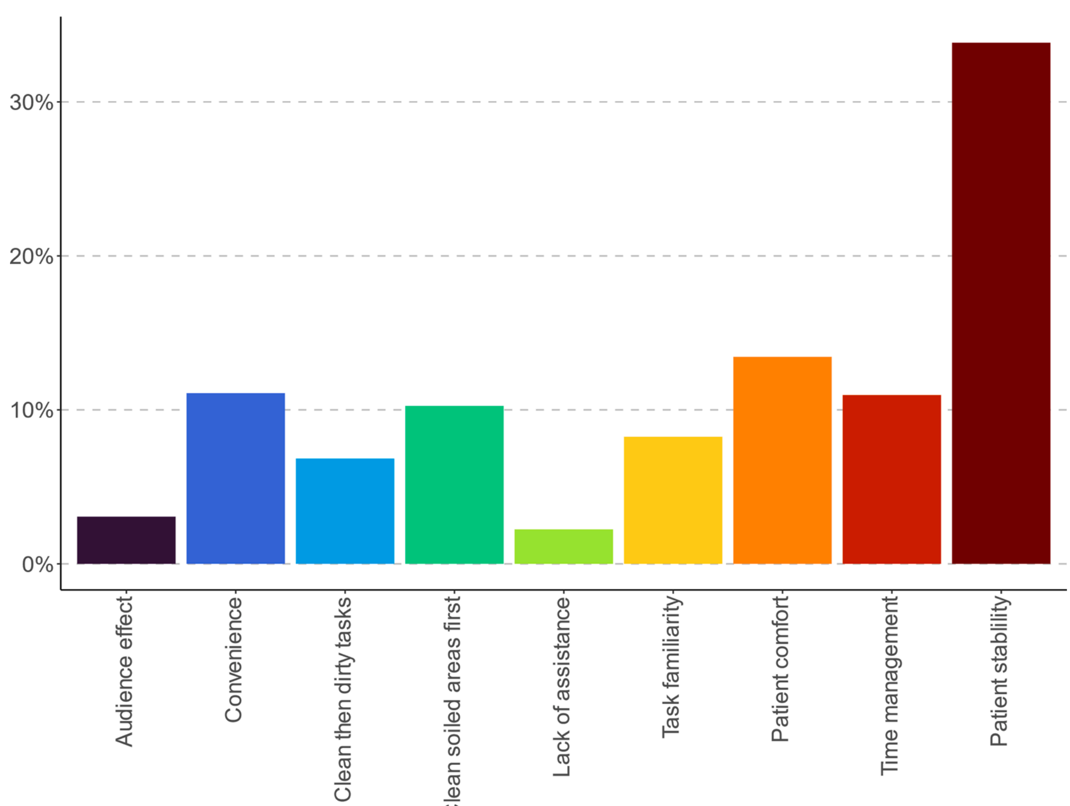


**Fig. 2.** Bar chart of task sequence reasons.
*Note*. The task sequence reasons along the x axis have been shortened for presentation.

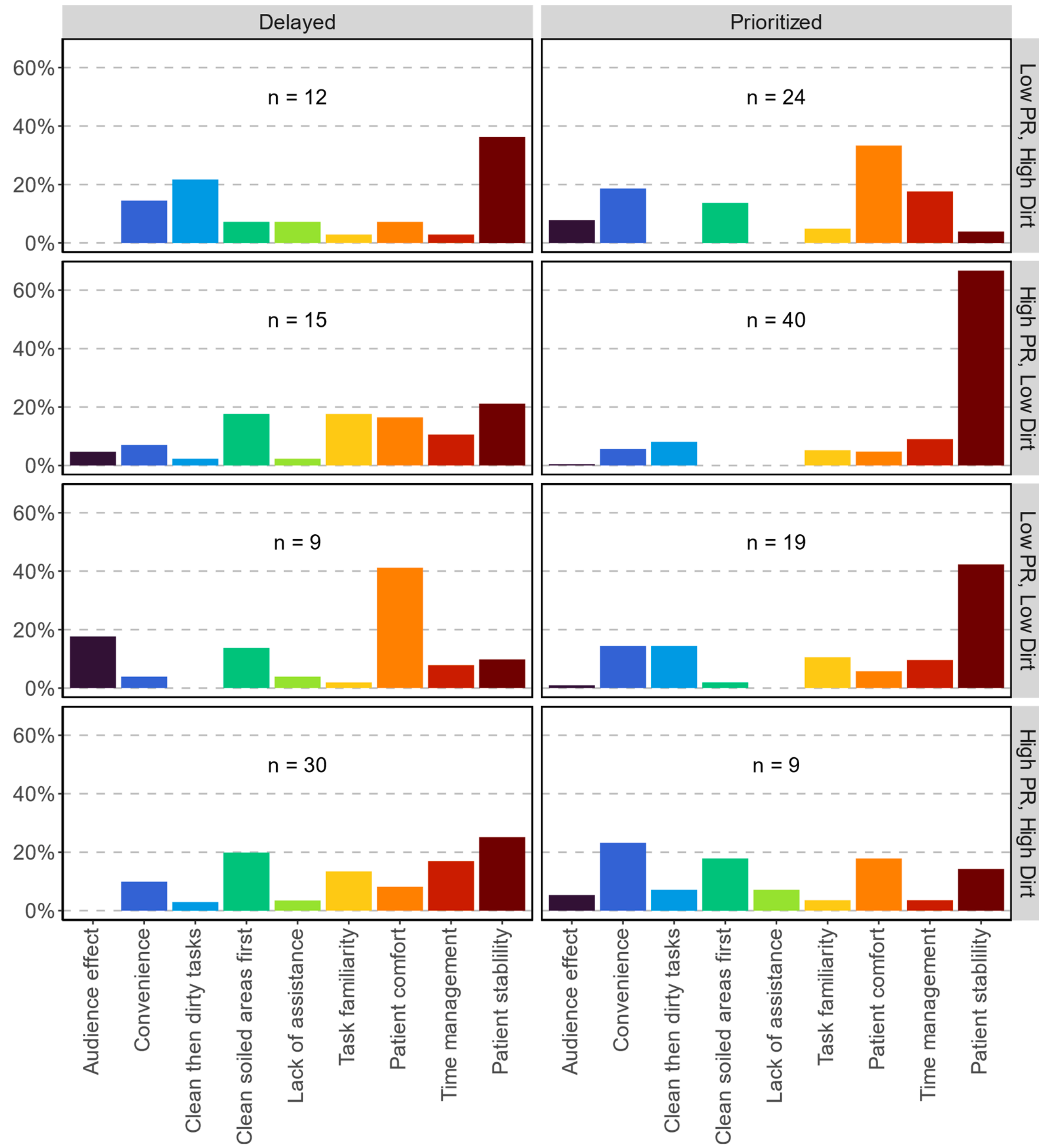


**Fig. 3.** Bar charts of task sequence reasons broken down by experimental condition and task priority.
*Note.* The task sequence reasons along the x-axis have been shortened for presentation. The bars represent the proportion of cards sorted into that task sequence reason across all card sorters. Dirt = Dirtiness. $n$ = number of verbalizations in that card sort (for each card sorter before duplicating cards). PR = Patient-Infection Risk.

#### *3.2.1. Reasoning for low patient-infection risk, high dirtiness tasks*

As discussed previously, participants tended to complete low patient-infection risk, high dirtiness tasks first (stool specimen collection and toileting a patient on a bedpan). Participants described prioritizing these tasks ($n = 24$) more frequently than delaying them ($n = 12$; Fig. 3). The most common reason given for prioritizing these tasks was out of concern for the patient's comfort (33%; e.g., MS34: "*I wanted to get him off the bedpan for pain relief first*"; ICU3: "*The metop [metoprolol] was late, but you had already told me that the other guy was on the bedpan. So, I like wanted to get him off of it first.*"). The finding that patient comfort was the top priority was unexpected to us given participants were informed during the handoff at the beginning of the experiment that the patient had an elevated heart rate (120s – 130s) and was late for a medicine to address it (metoprolol). Other common reasons for prioritizing these tasks included convenience (19%; e.g., MS20: "*If I'm [going to] clean him up, I should get the stool sample too*") and time management (18%; MS8: "*I decide to get the [stool] sample first because I didn't want to waste time looking for the Foley. I was like I can figure that out later.*"). The latter quote illustrates how the availability of supplies can affect task sequence and change the participant's original plans to perform the clean task first.

If these tasks were delayed, participants most often said it was to maintain or bring the patient to a stable condition first (36%; e.g., ICU29: "*He needed to get his Lopressor first. Everything else could wait. I don't care if he was sitting in a pile of stool. His-heart rate is too fast.*"; ICU12: "*I was going to do the stool sample—clean up the guy first—and I thought well … maybe the metoprolol is due? Or was it j- was it supposed to be past due? … Around here I decided to change my, my [plan to giving metoprolol first].*"). The participants with this rationale for delaying these tasks directly contrast with the participants that decided to prioritize such tasks. The two sides likely weighted the importance of administering the heart medicine differently, and the participants that prioritized medication administration were in the minority given toileting and stool sample collection were performed first on average. The second most common reason these tasks were delayed was to perform clean tasks before dirty tasks (22%; ICU11: "*I kinda [sic] thought about getting him off the bedpan first… I wanted to do everything that was kind of clean before I did all the things that were dirty. So, I figured if he was comfortable enough on the bedpan, then he would be okay until I got all of my 'clean' stuff done.*"). Even for this participant that had IPC in mind and wanted to work from clean to dirty, the patient's comfort was still a consideration.

### 3.2.2. Reasoning for low dirtiness tasks

Next, participants tended to perform low dirtiness tasks, regardless of the perceived infection risk to patient (medication administration, PIV insertion, auscultation, and NG tube insertion). Participants more often verbalized prioritizing these tasks ($n = 59$) compared to delaying them ($n = 24$). Although there were more prioritizing verbalizations, it is important to remember verbalizations were coded as prioritizing a task if it was prioritized ahead of at least one other task—not necessarily because it was prioritized to be completed first. The reason given for prioritizing these tasks in the majority of cases was to maintain or bring the patient to a stable condition (59%; e.g., MS22: "*I like to do assessment first and then give the medication to make sure he's stable before we do the Foley.*"; MS34: "*You know the NG tube was important because of the ileus… while the risk of aspiration is high, I feel like the delay in cardiac medicine was higher… of importance. The Foley and the wound care… the wound care was on the backburner,*"). The next most common reason—though much less common—for prioritizing these tasks was to perform clean tasks first and then dirty tasks (10%; e.g., ED8: "*I wanted to assess before I did anything. And… metoprolol would be an important med to give, especially since it's overdue with the Afib and the high rate. I also wanted to move from clean to dirty. So, assessing and medicating can come before toileting even though it might be uncomfortable for the patient,*"). This particular verbalization combines the rationales of working clean to dirty and addressing the patient's stability to set the task sequence. In line with the verbalization for delaying low patient-infection risk, high dirtiness tasks, the participant explicitly alludes to the patient's comfort as an important consideration but a necessary tradeoff.

When these tasks were delayed, participants most often said it was for the patient's comfort (26%; e.g., ICU42: "We're gonna get him off the bedpan… because that was uncomfortable, and then I'll do the, um, NG tube later… 'cause sometimes NG tubes are unpleasant. People are like 'I'm done. We're not doing nothing else,'"; ICU3: "The metrop [metoprolol] was late, but you had already told me that the other guy was on the bedpan. So, I like wanted to get him off of it first,"). The next most common reason to delay these tasks were to clean soiled areas first (16%; e.g., ED22: "I figured that I would… get the stool sample while he was still dirty. Then clean him and get him on the clean chux pad and then do medication and the Foley once he's clean."). Aligning with the task sequence results, one participant articulated how low dirtiness tasks that differed in patient-infection risk did not differ much in priority of which came first, and patient comfort was used to determine task order: "I didn't think it was a priority whether we got the NG tube in first or the IV. So, I kinda did what would be the least painful for him first, in case we needed the extra IV for access, but he already had a working IV so" [ED1].

### 3.2.3. Reasoning for high patient-infection risk, high dirtiness tasks

Participants tended to complete the high patient-infection risk, high dirtiness tasks (Foley catheter insertion and wound care) last. Participants more often verbalized delaying these tasks ($n = 30$) compared to prioritizing them ($n = 9$). The most common reason given for delaying these tasks were to maintain or bring the patient to a stable condition first (25%; e.g., ED13: "*In this situation, giving the medicine was a priority over stool and Foley I think,*"; MS22: "*I like to do assessment first and then give the medication to make sure he's stable before we do the Foley,*"). The next most common reason for delaying these tasks were to clean soiled areas first (20%; e.g., ICU12: "*So I thought, you know, before you insert the Foley you should make sure they're not soiled.*"; "*I got a big mess to clean up before I [take care of the wound]*"). The most common reason given for prioritizing these tasks was convenience (23%; e.g., ED13: "*So, I'm thinking what can I, how many things can I do in as little movement as possible? So, as I'm taking the bedpan out from underneath him, I might as well go and change the wound too,*").

## 3.3. Findings in context

Our results revealed many competing priorities participants needed to balance during patient care similar to Sanford et al. (2022). In the participants' verbalizations, they were clearly trying to negotiate patient comfort, minimizing contamination spread, and maintaining or bringing the patient to a stable condition, which could be sub-categories of Sanford et al.'s (2022) "Quality and Safety" pressure. Choosing to prioritize one task over another task was often good for some priorities but not others. For example, taking a patient off a bed pan before inserting a PIV makes the patient more comfortable and compliant but increases the risk of spreading contamination by not working clean to dirty assuming the HCW does not perform effective hand hygiene and use PPE appropriately between these tasks. As such, task sequencing alone is likely insufficient to balance all of the competing priorities.

Many of the verbalizations showed maintaining or bringing a patient to a stable condition was an important priority to participants; it was the most common reason participants prioritized low dirtiness tasks. This aligns well with Patterson et al.'s (2011) prioritization hierarchy that puts life-threatening activities as the most important. Patient comfort was also an important priority to the participant for task sequencing; it was the most common reason for why the task performed first was prioritized. Minimizing the spread of contamination to prevent infections was not as important for task sequencing; the two IPC-related task sequence reasons were fifth and seventh most commonly cited among nine total task sequence reasons, and neither were the most commonly cited reason for any of the experimental conditions. Hence, our results suggest patient stability and patient comfort were, on average, higher priorities for task sequencing than IPC. This may help explain why Chang et al. (2022) found nurses had twice as many dirty to clean transitions than clean to dirty transitions.

Nurses ostensibly prioritize patient stability because of the importance of the patient potentially deteriorating. That is, nurses perform tasks to address a patient's condition (e.g., atrial fibrillation tachycardia, ileus). Additionally, alarms sound when a patient's vital signs are abnormal (e.g., hypotension). This provides immediate, salient feedback to the nurse about the patient's stability, which may also prompt the nurse to respond to the patient's condition.

Nurses may prioritize patient comfort because patients often repeatedly request the nurse clean them up. If the nurse does not keep the patient comfortable, the patient may begin to complain. This would provide immediate feedback clearly understood by the nurse. In the current work, one participant verbalized how the patient's complaint affected their task sequencing: "*I wanted to go ahead and take a blood pressure at that point, and then immediately give him metoprolol, and then the heart rate. But since he's complaining that he's dirty, I was… and then go ahead and make sure he's cleaned up*" [MS23]. In contrast, the feedback for the spread of contamination is not as salient or immediate. Although nurses likely recognize sources of contamination, they cannot see the pathogens. Therefore, they may spread contamination without knowing if they do not adequately perform IPC practices (e.g., hand hygiene, PPE use, working clean to dirty). This spread of contamination may cause a later infection, which may not have a clear causal contamination event. Prior research has shown that immediate feedback is more conducive for learning than delayed feedback (Anderson et al., 1995; Corbett & Anderson, 2001). Hence, the inherent delayed and unclear feedback for contamination spread may mean nurses are not very good at assessing whether they have spread contamination, and the more direct feedback loop for patient comfort may help explain why patient comfort was prioritized over IPC on average.

Future research examining how different task sequence approaches affect spread of contamination, patient comfort, and patient stability would help inform how nurses should sequence their tasks. Future research should also examine whether HCWs accurately assess how much contamination they spread and examine whether training involving specific feedback about when a contamination event occurred during a simulation changes how nurses prioritize their tasks. Such trainings may help HCWs to adapt to the complex, dynamic situations that they work in as opposed to prescribing a particular task sequence (e.g., work clean to dirty) that may not be suitable for the varying circumstances that arise (Dekker, 2003).

Limited or unavailable resources such as limited time, supplies, or help from staff may have affected the participants' task sequencing. In one verbalization discussed previously, the participant stated they did not want to waste time looking for a Foley catheter and chose to collect the stool sample. Other verbalizations mention how they would complete the tasks differently if they had help (e.g., ED8: "*Not having any techs or additional staff support makes my prioritization different*"). Hence, sufficient resources and staffing are important because they affect how nurses sequence their tasks, and if there were two staff members to complete tasks, they would ostensibly be able to satisfy multiple priorities simultaneously.

### *3.4. Limitations*

The current study has a few of limitations worth noting. First, we did not confirm how the participants in the study perceived the tasks in terms of patient-infection risk and dirtiness. However, we chose the tasks based on prior research (Mumma et al., 2021), which found that how nurses organize these tasks is highly consistent and falls along two dimensions: infection risk to patient and dirtiness. Second, we only focused on task sequencing and did not examine other behaviors relevant to IPC, such as hand hygiene or PPE use that affect contamination spread. Third, we used a simulation to examine task sequencing, and for any simulation, it is not a perfect emulation of the real-world. However, we designed the simulation to be realistic with aspects such as time pressure and interruptions; seven participants indicated in the post-study questionnaire that the simulation was realistic after the study even though we did not specifically query them on the realism of the simulation. Performing simulations allowed us to carefully control what tasks participants had to complete and what occurred while the participants completed the tasks to keep as much as possible constant across simulations. In the real world, this would not be possible.

## 4. Conclusion

We set out to better understand how a concern for infection prevention drives task sequencing relative to other priorities. We found nurses have to balance competing priorities such as patient stability, patient comfort, and IPC-concerns with the limited resources (e.g., staff, supplies, time) available to them. For sequencing tasks, participants prioritized the stability or comfort of their patients over infection prevention concerns. This may help explain why prior research (Chang et al., 2022) found nurses had twice as many dirty to clean transitions than clean to dirty transitions. However, we also uncovered an infection prevention reason to complete dirty tasks before clean tasks that could also help explain these findings: nurses choose to clean soiled areas before completing other tasks in that area. This prioritization resulted in nurses completing low patient-infection risk, high dirtiness tasks (e.g., toileting) first followed by low dirtiness tasks (e.g., medication administration) and then high patient-infection risk, high dirtiness tasks (e.g., Foley catheter insertion).

The current work is important because we must understand why nurses sequence the tasks the way they do to inform any intervention that aims to improve their task sequencing; that is, we must understand the work as performed rather than the work as imagined (Ham, 2021). Ideally, the HCW would have ample resources in terms of time and help from staff, but this is unlikely to always be the case. Training HCWs about how to better sequence their tasks for infection prevention or more effectively performing other IPC practices, such as hand hygiene, between tasks are alternative approaches; immediate feedback of when HCWs spread contamination would likely be a critical component of such trainings.

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## Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Joel Mumma reports financial support was provided by Centers for Disease Control and Prevention.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hfh.2023.100046.

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