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Mapping Information Flows That Support Adaptive Capacity in the Sterile Processing Department (SPD)

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MAPPING INFORMATION FLOWS THAT SUPPORT ADAPTIVE CAPACITY IN
THE STERILE PROCESSING DEPARTMENT (SPD)

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ABSTRACT

The Sterile Processing Department (SPD) is the part of the hospital that is responsible for decontaminating, assembling, and sterilizing surgical trays for use in the Operating Rooms (ORs). Errors in the SPD can lead to delayed surgeries or patient harm. The SPD is a complex system, with multiple interconnected subdepartments and roles. Complex systems require coordination between stakeholders. This study aims to discover how an organization can adapt to scale, and how information flows support these adaptations. In this study, observations, semi-structured interviews, and on-the-job interviews were conducted with members across the SPD and OR to elicit pressures, adaptations, and their corresponding information flows to understand the how coordination supports adaptive capacity in the SPD. A qualitative data analysis was conducted to find themes related to adaptations and coordination. Themes involving pressures include missing instruments and lack of proper staffing. Frequent adaptations include role evolution, prioritization, and anticipation. Coordination themes include unreliable artifacts and mistrust between the OR and the SPD. Maps of the adaptive workflows were created to visualize how pressures affect the textbook workflow, the responsive adaptations to overcome the pressures, and the information flow paths that support these adaptations. These findings can be used to provide insights to improve coordination and adaptive capacity of the SPD.

DEDICATION

This thesis is dedicated to my parents. Thank you for supporting me every step of the way.

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CHAPTER ONE

INTRODUCTION

The Sterile Processing Department

The Sterile Processing Department (SPD) in a hospital reprocesses surgical instruments for use in the Operating Rooms (ORs). Ensuring that instruments provided to the ORs are sterile is critical to patient safety. However, the SPD is a complex system that comprises multiple subdepartments, including decontamination, assembly, sterilization, and case carts (Segarra et al., 2022). This complexity can result in breakdowns such as contaminated instruments, delays in surgical cases, or lost instruments (Brooks et al., 2019). Additional breakdowns include delays in surgical cases, cancelled surgeries, or lost instruments. Therefore, it is a significant challenge to coordinate processes across the SPD-OR network to support a hospital's overarching goals of safe and efficient care for patients. Each of the subdepartments within the SPD has a specific function that requires coordination with other departments and entities.

Decontamination: Decontamination is the area where the used instruments are washed and freed from bioburden. Bioburden is body matter found on surgical instruments, such as bone, tissue, and blood (Alfred et al., 2020). Failure to properly decontaminate surgical instruments can lead to patients contracting healthcare-associated infections (HAIs). Workers in this subdepartment consist mainly of SPD technicians.

Assembly: The assembly section of the SPD is where decontaminated instruments are placed into trays according to the count sheet, which lists the instruments intended to

comprise the tray. The count sheet is viewed on a computer screen at the personal

workspace of the SPD technician using a surgical instrument tracking software. The goal

of the assembly subdepartment is to organize surgical instruments efficiently into trays

according to the count sheet, with the tray also containing the appropriate documentation,

chemical indicators, whilst being free of bioburden, such as tissue, blood, or hair (Alfred

et al., 2021). Most workers in the assembly subdepartment consist of SPD technicians,

along with SPD supervisors. The assembly subdepartment is where pressures such as

missing or broken instruments are often found.

Sterilization and Case Carts: In the sterilization section of the SPD, trays are sent

through sterilization machines, with the role of the technicians to select the appropriate

sterilization method (Alfred et al., 2020). The role of the technician in this area of the

SPD is to ensure that each tray is properly sterilized and placed on the cooling racks.

Technicians that oversee case carts are expected to assemble trays into carts according to

the needs list and send the completed carts to the OR at the proper time.

A Systems Approach to Sterile Processing

The interconnectedness of the SPD emphasizes the importance of analyzing the

system as a whole and across multiple levels. Levels in the SPD system includes frontline

work, supervisors and coordinators, managers, and hospital administration.

Communication and the exchanging of resources between the OR and the SPD is an

essential aspect of the well-being of the departments and the patients (Nyssen, 2017). It

has been argued that there are no two departments in a hospital that work more closely

than the OR and the SPD (Seavey, 2010). Across hospital systems, there is a negative view of the SPD by those in other areas of the hospital, particularly the OR (Brooks et al., 2019) and improving the trust between the two departments can lead to increased coordination. This viewpoint stems from an initial mistrust from the OR from errors made by the SPD. Continuing to foster the relationship between the departments can limit the potential errors that can arise from miscommunication.

The SPD as a Complex System

Complex systems consist of multiple interacting components, with the interactions occurring in numerous, often unexpected, ways (Dekker, 2011). When working with complex systems, it is important to understand the differences between the "work-as-done" (WAD) perspective, and the "work-as-imagined" (WAI) perspective. WAI is the description of work as it is supposed to be done, alternatively called the textbook workflow, while WAD is the method in which work is actually performed (Clay-Williams et al., 2015). The difference in WAI and WAD comes about due to frontline work in complex systems being adaptive and dynamic, thus WAD is every-changing. In complex systems, there can be a disconnect between the two perspectives by policymakers. Communicating the differences between WAD and WAI can allow for decision-makers to implement better policies that align closer to the WAD perspective. The SPD is a highly complex system that has a multitude of interacting stakeholders across levels of scale. Viewing the SPD as a system allows conclusions to be drawn about the effect of pressures across the entire SPD. Additionally, the SPD is a haven for variability, a defining quality of complex systems (Clancy et al., 2008), which results in

an environment that creates patterns of adaptations. An environment such as this can provide insight into how these patterns emerge.

Coordination in the SPD System

Identifying how communication travels, both in the textbook workflow and during adaptive events, across coordination loops is the initial step to finding gaps that occur that constrict the adaptive capacity of the SPD. Further research into coordination loops has been seen in the healthcare field. Differences in information allowances emphasize the need for vertical coordination. Without both bottom-up and top-down communication, it can be difficult to complete tasks. Lateral coordination is also seen in healthcare, which is the distribution of information across disciplines. In a complex system such as a hospital, interdisciplinary teams are frequently formed to adapt to pressures, emphasizing the need for this lateral communication. Further of importance in the medical field, longitudinal coordination is the communication of parties across time. When analyzing a system that operates continuously, finding the ability of the system to coordinate longitudinally in an efficient manner can assist in assessing the resulting adaptive capacity. Coordination across a complex system can also lead to shared awareness. Shared awareness, the part of the understanding of a situation that is shared across an organization, is an essential aspect of understanding complex systems that straddle multiple levels (Alberts, 2001; Canan & Sousa-Poza, 2019). In a resilient organization, shared awareness maintains the effectiveness of a system following the introduction of a pressure (Gichuhi, 2021). Among those who have studied shared

awareness, understanding the degree of shared awareness across an organization is essential to determining the efficiency of the system (Canan & Sousa-Poza, 2019). There have not been studies that focus on coordination of work in systems as complex as the SPD. This study intends to bridge that gap.

When evaluating methodologies that treat aspects of healthcare as a system, understanding coordination patterns across a large, complex, distributed system such as the SPD requires identifying how information flows within and outside the system. Mapping information flows will also assist in answering the questions posed by the social network theory: what information is exchanged and in what method is the exchange of information (Aalbers & Dolfsma, 2019)? Furthering this theory is the goal of this study, which will also account for "why" and "how" information is exchanged, particularly during adaptations. However, there are no concrete findings on how information flows support adaptive capacity within complex systems. It is essential to take a systems approach in this study in order to inform potential interventions based on an understanding of the interdependencies between various units and functions. This system deals with the safety of patients, and the ultimate goal is to help facilitate change in the system to better enable adaptations.

Competing, Conflicting, and Compounding Pressures

Within the SPD lies competing pressures that must be understood as they come about. As a complex system, the SPD has dynamic pressures that can conflict with one another and must be contained within an acceptable level to sustain adaptations already

present in the system. (Cook, 2005). Competing pressures also stem from the organizational level, for example an organization wanting to minimize costs of replacing tools or equipment. This is a pressure, as the organization will implement constraints and barriers for the frontline workers to replace equipment that can ease workflows within the system. There have been gaps in understanding the effect conflicting organizational pressures have on a complex system. Part of bridging this gap is understanding when and how these pressures emerge (Pache & Santos, 2010). An aim of this study is to understand these conflicting goals and tradeoffs and how they are managed. This includes understanding the frequency of emergence and discovering who makes decisions related to conflicting pressures. An additional aspect of pressures, compounding pressures are also seen in the SPD as disruptions that can surface alongside an additional pressure. These compounding pressures are coupled together and add increased variability to the already complex system. A goal of this study is to discover how increased coordination can mitigate these compounding pressures (Montpetit et al., 2010).

Resilience Engineering and Adaptive Capacity

The concept of resilience in a systems sense can be defined in multiple ways. Resilience can be considered the ability of a system to: rebound from disruptions events, manage complexity and other challenges, overcome brittleness, and sustain adaptations to adverse conditions (D. D. Woods, 2015). Resilient engineering (RE) studies how organizations utilize adaptations to recover from these disruptions (Branlat & Woods, 2010). A primary focus of RE is to learn from what goes right, as opposed to solely

learning from what goes wrong (e.g., adverse events), in a complex environment. Awareness of the resilience of an organization can allow decision-makers to focus on areas where brittleness is prevalent (D. Woods & Branlat, 2017). This awareness and action can further contribute to the resilient capabilities of the organization. When analyzing the resiliency of an organization, there are multiple levels of scale that must be considered. Just as systems can be resilient, people can be resilient (Bergström & Dekker, 2014). Individuals in a complex organization must be able to recognize the interconnectivity between themselves and others within the system. To fully understand the resilience of an organization, the perspectives of the "blunt" and "sharp" ends must be studied. The blunt end of an organization is management and decision-makers, while the sharp end consists of front-line workers who perform the tasks assigned to them by the blunt end. The sharp end provides perspectives of everyday challenges. The interdependencies between the two ends must be studied to have an elevated level of understanding of the system. A way to accomplish this level of understanding is to conduct interviews across the levels of scale (Bergström & Dekker, 2014). In these interviews, patterns of adaptations can be revealed, as well as constraints that limit adaptations.

Adaptive capacity is the ability of a given system to overcome and reduce vulnerabilities (Luers, 2005). Adaptability must complement control due to the increasing trend of complexity in modern day organizations (Provan et al., 2020). This increasing complexity also increases interdependencies across levels of scale. However, while an organization may become more adaptive overall, it becomes more at risk for other

situations for which it did not previously prepare (D. Woods & Branlat, 2017).

Identifying the underlying vulnerabilities can help policymakers in the blunt end of the

spectrum focus resources with the goal of creating further resilience in the system.

Gaining the perspectives of both the sharp and blunt ends of a complex system can allow

for a deeper understanding of cross-scale interactions and how the interactions affect

adaptive capacity.

Coordination and Adaptive Capacity

In an organization there are boundaries to coordination that limit the facilitation of

adaptations. (Bishop & Waring, 2019). Complex systems require prominent levels of

coordination to function. In a system with conflicting pressures, coordination across

levels is used to facilitate adaptations (Branlat & Woods, 2010). Conflicting pressures

mean that trade-offs in the system can occur. Recognizing how these trade-offs are

managed across levels of scale is essential to understanding the adaptive capacity of an

organization. As mentioned previously, coordination is a key driver of adaptive capacity.

A lack of coordination in systems where there are people at risk can increase brittleness,

and the likelihood of harmful incidents.

Information Flows – the Currency of Coordination

Information flow is the communication between members of an organization. It is

argued that information flows are vital to the well-being of an organization and can even

be considered indicative of how well an organization functions in terms of coordination

across levels, employee satisfaction, and safety culture (Westrum, 2014). Identifying

coordination across levels can see how interactions between levels of scale support each

other during off nominal events. These information flows can be seen in different

coordination loops: vertical, horizontal, and projective (Voshell et al., 2007). The

coordination loops are types of information flows that are formed in response to an event,

such as a pressure. Vertical loops represent coordination across hierarchies, or levels of

scale (Hegde et al., 2020; Voshell et al., 2007). These loops are designed to be two-way

flows of information, with "higher" levels—such as managers and decision-makers—

communicating plans with those on "lower" levels, typically front-line workers, and the

lower levels of scale responding and communicating back to the upper levels. Horizontal

coordination loops are formed across groups with similar scopes, and projective loops

represent coordination in a specific area of interest before an event occurs. Horizontal

loops can be seen in a variety of industries that are not necessarily interconnected but

share a common goal. To further expand this concept, horizontal loops can be applied to

groups with a common goal when adapting to an emergency who act according to their

respective best interest despite the presence of communication between the groups.

Identifying coordination loops can help distinguish pathways taken for coordination

during adaptive events. Understanding the current state of coordination across a system

can help identify weaknesses in coordination and pressures that may suppress these flow

paths. These loops can highlight interdependencies across and within levels of scale.

These interdependencies play a large part in facilitating adaptations in a system.

Mapping Information Flows Across a System

Multiple methods have been used to analyze and map information flows throughout the healthcare industry. For example, one related study conducted a link analysis for emergency departments (Fairbanks et al., 2007). A link analysis is a visual aid to identify level and presence of communication between roles. Consisting of interconnected hubs and links, aspects of link analyses include having link thickness proportional to the level of communication between the roles represented by the nodes and the ability to identify baseline relationships. In the study focused on emergency departments, the link analysis allowed the researchers to identify communication hubs and bottlenecks in the system. Similarly, a case study of an emergency department mapped information as a unit while recording the associated artifacts used to facilitate this flow of information (Pennathur et al., 2014). Analysis of the results of this study found that the vast amounts of information communicated is maintained by reducing the amount of uncertainty in the system. Another mapping technique used in healthcare is the use of sociogram. Sociograms can be used in healthcare to inquire into team behaviors, patterns in communication, and artifacts used in information flow (Bonaconsa et al., 2021). A case study focused on communication in the surgical ward utilized sociograms along with traditional qualitative analysis techniques to track the quantity and theme of communication between the patient and caretaker. Methods of analyzing effects of information flow can be seen in other industries. One such study zero-inflated negative binomial modeling to identify performance decreases following a mass layover event (Aalbers & Dolfsma, 2019). The specific model used minimized the risk of bias, as this

quantitative approach was able to draw conclusions based on information flows that existed prior to the mass layoff event. Using mapping techniques can reveal coincidental boundaries in coordination (Bishop & Waring, 2019). Integrating pressures and adaptations into an information flow map can show what are the causes of the boundaries and how the current workflow works around them.

Research Objectives

While studies have been conducted with a focus on resilience engineering, information flows in the workplace, and SPD improvement, there has been little-to-no synthesis between the topics. Additionally, there have been no studies that have systematically mapped information flows that support adaptations, specifically from a WAD perspective. There are several questions that this study intends to explore. The first is to find how to find how information flows support adaptive capacity of a system, with the SPD as the system of focus. With this inquiry, how can mapping information flows advance the ability of an organization to adapt to scale? Furthermore, is a systematic way needed to: characterize how information flows evolve to support adaptations and coordination (1), understand how existing information flows vary with differing pressures (2), or find what constrains and enables information flows (3)?

The overall focus of the interviews was to discover how information flows support coordination and the effect it has on the adaptive capacity within the SPD system. We designed a semi-structured interview technique to identify how hospital workers manage multiple—often conflicting—pressures and how information flows support the

resulting adaptations. To assess the adaptive capacity of the system, we identified gaps in information flows during adaptations and constraints on the system due to pressures. Following the interviews, a qualitative data analysis was conducted to extract themes from participant responses. Finally, information flow maps were created with multiple layers to illustrate: the textbook workflow, the effects of a pressure on the workflow, and adaptations and the resulting adaptive workflows with their corresponding information flow paths. The resulting findings can lead to insights to improve coordination, and thereby, adaptive capacity of the SPD.

CHAPTER TWO

METHODS

Setting

The setting for this study was a large university hospital system in the Southeastern United States. The hospital system has several SPDs, with some that cover multiple individual hospitals. This includes SPDs that provide reprocessing for the hospitals they are attached to or nearby. As a university hospital, this hospital system has unique challenges—and advantages—in the sense that there are multiple hospitals in the system in proximity, albeit with differing specialties, which rely on each other for the system to function. At the hospital setting, there are SPDs attached to multiple hospitals, with some SPDs routinely servicing additional hospitals than the ones to which they are attached. Having multiple SPDs in proximity to each other facilitates coordination and cooperation between SPDs such as sharing resources. This includes instruments and staff. Across the hospitals within the systems, there are approximately one hundred workers employed by the SPD. According to interviews with SPD management, the SPD department is currently slotted for 150 employees. Additionally, there is an off-site center used solely for reprocessing instruments. This new center is approximately 30 minutes from the other locations and poses additional needs for coordination between the center and the hospitals it serves. These added dimensions showed the benefit of conducting the study at this location. Conducting the study at a hospital system opposed to a standalone hospital provided additional insight into the importance of information flows, as well as

being able to elicit differences in adaptations in response to the same pressure at each SPD location.

Observations

To gather a better understanding of the SPD system, multiple SPDs were observed within the hospital system. These observations were conducted by several human factors researchers, including researchers embedded in the hospital system. This understanding would allow for a visualization of the textbook workflows associated with instrument reprocessing. Additionally, noted by the researchers during observations were adaptations, pressures, and communication that occurred in the SPD. During the observations, interviews were conducted with SPD workers during 'downtime' in their shifts. Downtime included breaks and periods where the participant was walking between areas. The on-the-job interviews were intended to put visual context to responses in the interviews.

Interview Question Formulation

The interviews conducted were designed to elicit adaptations used by those in the OR/SPD to overcome obstacles or off-nominal events. The goal of the interviews was to be semi-structured, intended to give the impression of a discussion or conversation rather than a question-and-response interview. The questions were designed to utilize knowledge elicitation techniques to probe the participant for responses where they may have had to utilize adaptations. Following the response to these questions, the

information flows used to carry out the adaptations were found. The interview protocol was a unique blend of approaches that combined the multiple goals of this study. The utilization of multiple approaches requires trade-offs on each of the methodologies used but allowed for the results of the interview to align more closely with intentions of the study.

The Systemic Contributors and Adaptations Diagramming (SCAD) model (Jefferies et al., 2022) was used to inform the design of questions. The SCAD method focuses on eliciting responses based on pressures and corresponding adaptations rather than specific, "one-off," instances of conflict. This method was used to create questions designed to elicit pressures and conflicts within the SPD and how they conflict with everyday work. The purpose of the SCAD method was to establish the textbook workflow of a scenario, pressures during this workflow, and scenarios where the participant did not follow the textbook workflow.

To elicit descriptions of an adaptation, an altered version of the Critical Decision Method (CDM) (Hegde et al., 2020) was used. This method differs from the traditional CDM in that it does not focus on scenarios where there was a critical breakdown, but rather on adaptations that are routinely carried out to maintain the current workflow. Cognitive probes were used to lead the participant to recant scenarios of adaptation. For example, questions such as *"Can you tell us an example of a workaround that you use to account for a lack of staffing?"* were asked.

Questions concerning information flows were also incorporated into this interview protocol. These questions probed the participant about who they communicate

with as part of adaptive workflows, as well as eliciting scenarios where communication broke down because of pressures in the system: "*Can you tell me about a time when communication broke down within the SPD?*" This question aligns with the SCAD approach, as it is discussing a scenario that did not follow the textbook workflow but with a focus on information flows. These questions intertwined with both SCAD- and CDM-based questions as a framework for participants to further elaborate on how information flows contribute to adaptations, as well as facilitate pressures.

In addition to utilizing the combined approach to formulating the interview script, this approach is distinct from prior research as the specific questions were tailored to the specific roles of the participant. Tailoring questions to roles allowed for the responses to be organized, yet unique to the perspectives of the participant. The versatility of the interview script was essential and eased the ensuing qualitative data analysis. Responses that were structured allowed for comparisons between found themes. It was found that questions should be created to elicit coordination across time, space, goals, and workflow.

Questions were designed to initially discuss specific scenarios of adaptation and further investigate factors such as frequency, priority, and timing in those scenarios via follow-up questions. The interview script was initially divided into eleven sections, each of which corresponded with an action conducted within the SPD, such as quality inspections, checking for missing instruments, and the nominal assembling of the trays. The purpose of dividing the questions in this sense was to ensure that the flow of information throughout the entire SPD was learned from these interviews and that each

participant had questions tailored to their roles. Throughout the initial question formulation, elements of CDM and questions regarding information flows were initiated into the question sets, creating an innovative method for discovering how information flows support adaptive capacity. The interview questions would often begin with a question regarding a breakdown of communication in the system: *"Can you tell me about a time when communication broke down between the OR and the SPD? (OFF-NOMINAL),"* which represents a pressure stemming from a lack of coordination. This allowed for the interview to inquire into adaptations that helped resolve the breakdown. Questions are also intended to elicit trade-offs when addressing competing or conflicting pressures. These questions were intended for the participants to reveal how they prioritize pressures, as well as if this prioritization is an adaptation created by the participant or part of the textbook workflow. An example of a question intended to reveal a situation with trade-offs is: *"When addressing situations with multiple disruptions, how do you decide on which disruption to handle first? (TRADE-OFFS)."* Additionally, questions focused on adaptations, such as workarounds were asked to elicit the adaptive workflow of workers in the SPD: *"Can you tell me about a time when you had to do something a little bit differently, or something a bit different happened, related to the priority of trays coming through assembly?"* To find the extent at which information flows support these adaptations, questions such as *"How did you receive the information that signaled to you that there was a problem at hand?"* were asked. These questions were focused on the artifact that facilitated the coordination between staff members as well as the roles involved in the adaptive workflows.

Each question had a bolded word or phrase to indicate to the interviewer the intended focus of the question and the cognitive probe associated. For example, in the question *"Is this how information is **typically** communicated during this step?,"* the word *typically* is bolded to show the interviewer that this question is intended to elicit the textbook flow of information during this action. Similarly, the question *"Can you tell me about a time where there was a **breakdown** of communication involving bioburden inspection?"*, the bolding of the word *breakdown* indicates that the question is designed to have the participant discuss a scenario where there was a lack of proper information flow regarding a specific action in the SPD, in this case a bioburden inspection. Additionally, questions that were specifically designed to prompt discussions regarding information flow were highlighted in a distinct color than other questions on the script. Furthermore, questions that were intended to find pressures in the system, such as time, lack of inventory, and increased workloads were also highlighted. These two types of questions were essential prompts that were used to identify pressures, (and their corresponding adaptations), and the means of communication that eventually were used to map. Following each question, capitalized "tags" indicating the overarching theme of the question were placed. These methods were designed to help guide the interviewer.

Multiple iterations of the questions were created. To prepare for interviews with participants, a mock interview was conducted with a fellow researcher with an understanding of the interview process. During this mock interview, an initial protocol was developed based by blending questions related to the SCAD method, CDM, and

information flows. Based on the mock interview, questions were refined for better comprehensibility, conversational flow, and conciseness.

Interview Process

For this study, interviews were conducted on-site and online. Each interview had at least two researchers who conducted the interviews, one from the hospital in which this study is set and the primary researcher. Each participant was briefly introduced to the project and asked for permission to record. Lasting approximately an hour, each interview script was to the participant's sub-departments and roles in the SPD. For example, SPD traveling technicians are limited to working in the Assembly and Decontamination areas of the SPD, so the participant in this role was asked solely to recant scenarios that occurred in those two subdepartments.

An essential note of this interview-based study was the importance of building a relationship between the interviewers and the participants. Responses did not always align with the textbook workflow desired by the hospital administration, and these scenarios were essential to accurately portray information flows and identify adaptations in the system.

Participants

To identify perspectives from diverse roles at multiple organizational levels that face conflicting pressures, a wide range of participants were recruited. This range included workers from multiple SPD and OR roles at various levels of scale. This led to

conducting observations in the SPD during high-volume hours. Observations in the SPD and initial interviews identified several key roles across the SPD that participated in frequent communication with roles across the system. This identification process was done by focusing on roles that engaged in the most frequent communication, either face-to-face with other workers in the SPD, or via phone, indicating communication with the OR. Interviews with OR personnel were also conducted. This was because of the importance placed on the communication and coordination between the OR and the SPD by those interviewed during observations. For the OR participants, questions were tailored to elicit adaptations in the OR and scenarios where the OR participant had to coordinate with workers in the SPD. Questions for the actions that occur during the transportation of case carts to the OR from the SPD and returning the trays to the SPD after surgery were of focus as well. These actions were frequently discussed as areas with prominent levels of communication breakdowns and resulting adaptations. An added dimension to the variety is that the hospital system studied has multiple SPDs and ORs, with each department having slightly different textbook procedures or learned adaptations for responding to off-nominal events. Differences between how each role manages similar critical events were noted during the analysis.

Qualitative Data Analysis

Following each of the interviews, the recordings were transcribed for analysis, and a qualitative data analysis was performed. The data analysis was conducted in the software Atlas.ti. Codes were formed during the qualitative data analysis process, with

each code representing a frequently found response in the transcribed interviews. This process is known as thematic analysis, which uses open-ended data to identify patterns in responses across participants, which are the resulting themes (Hegde et al., 2020; Karavadra et al., 2020). The finalized set of codes were referred to as themes. A single researcher coded the interviews over multiple iterations. An additional researcher was consulted to provide feedback and consensus on the contextualization of the themes. Using the software, the fully developed codebook classified codes applied into overarching themes, which the specific themes were sorted into accordingly.

Nominal workflows were defined to be events that **do** follow the textbook workflow. The Challenges/Pressures code group consisted of events or instances that constrained the workflow within the SPD. There were a multitude of challenges and pressures found across the SPD and OR system, focused both on the system itself and relationships within the system. Frequently occurring systematic challenges included staffing issues and a lack of inventory. These challenges were determined to have a significant impact on the workflow within the system. Adaptations are responses to the challenges and pressures in the system, including workarounds. Adaptation codes consisted of themes that evoked resilience within the SPD and OR system. These codes include changing of roles and tray substitution response. Both codes were commonly found themes regarding adaptations in the analyzed interviews. Communication events were documented to classify the type and frequency of information flows in the SPD/OR system. The types of events include the level of communication: cross-level or within-level, as well as distinguishing information flows between the SPD and OR and events

where mass communication occurred, such as on Microsoft Teams. The frequency of this interdepartmental interaction, the distinct roles that interact, and the methodologies used to communicate are essential aspects that were focused on to provide a basis on which to create a map of information flows within the system.

Information Flow Mapping

The intent of the information flow mapping is to represent how pressures and challenges are handled in the OR/SPD system, whether it be the textbook workflow or adaptive workflows. In the mapping, there are three layers that are represented: textbook workflow, constrained workflow due to pressures, and adaptive workflows with information flows, similar to the coding groups created during the qualitative data analysis. The textbook workflow in this mapping is the textbook order on how off-nominal events should be resolved within the OR/SPD system. This layer is represented in a similar fashion to a process diagram, as each figure represents a process that is accounted for within the workflow. Each figure in this layer is represented by the same color—purple—to illustrate textbook workflow.

The second layer contained both pressures and adaptations. The pressures were indicated with a red irregular shape and arrows protruding from the representative shape indicated the section of the nominal workflow that was constrained by the specific pressure. The responsive adaptation was noted with a green irregular shape and called attention to the steps taken to work around the pressure. The purpose of the irregular

shapes for the pressures and adaptations was to highlight the difference between the textbook workflows and the variability of the adaptations that resulted from pressures.

The third layer of the mapping was the information flows that coincide with the adaptations described in the previous level. These flows were indicated with orange ovals. Furthermore, the arrows originating from the information flow nodes are unlike the arrows from the nominal workflows, which were right-angled, akin to a process diagram. The arrows associated with information flows were curvilinear to represent the flowing nature of communication during adaptations. When possible, the method of communication was noted, whether it be verbal, phone call, e-mail, or other artifacts, as well as the roles who were originating the communication and the roles of the workers receiving the communication, were represented on the left and right sides of the information flow shapes, respectively. The representations of the roles consisted of silhouettes, with the corresponding role labeled underneath. Also included in this layer are the processes that result from the adaptations and their information flows. These processes, colored in blue, return to the form taken by the first layer, as they are akin to true process flow diagram shapes.

Figure 1. Key to identify the types of roles participating in the information flows in the maps. Specific roles are labeled in the maps accordingly.

Restrictions and constraints on the system because of pressures were considered as well during the mapping process. This was represented using a "graying" of the workflow. This graying was applied to nominal processes that would be unable to be performed due to the pressure applied in each scenario. The goal of this mapping is to be able to give a visual representation of how workers in the OR/SPD system handle pressures, as well as identify constraints on the system that can limit these adaptations. This can be presented to hospital administration to demonstrate the effects of these pressures.

CHAPTER THREE

RESULTS

Observational Findings

Over the course of this study, four SPDs and an OR were observed. During these observations, the textbook workflow was observed in order to be compared with off-nominal events elicited during the interviews. Additionally, during observations, interview questions were asked to six participants. Asking questions during observations allowed participants to provide real-time context to the questions they were asked. The observations revealed adaptations that were frequently used by the entire SPD, such as excessive tray storage or racks containing extra instruments in the event that trays or instruments were needed. One interview occurred while following the participant across the OR and the SPD as they conducted their typical workflow while answering questions. This was to provide real-time scenarios to answer questions asked. Also observed was a quality assurance (QA) team member participating in a daily huddle focused on escalated situations while assembling a tray. Further coordination observed was the real-time communication between ORLs and case cart personnel in the SPD.

Furthermore, the observations revealed that display boards are used in the SPD to display important messages to the entire SPD staff. These messages included daily turnover trays (trays that will be used and need to be reprocessed within that day), schedules, and educational emphasizes spotlights. More informal display boards were also observed in the OR. The boards observed in the OR provided quick access to the locations of frequently used trays. These observations further supported the questions

designed to elicit the importance and usefulness of display boards from the perspectives of multiple levels of scale, as well as provide context to the role of display boards as state by participants.

Participants Interviewed

Nineteen total interviews were conducted in this study. Twelve employees from three SPD and OR locations participated in this semi-structured interview part of the study, with thirteen interviews conducted (one participant had two interviews). Six workers were interviewed during observations across four SPDs and an OR. The roles interviewed included an overall SPD manager, four SPD managers or assistant managers, three SPD supervisors, an SPD asset coordinator, four SPD technicians, (with three having an additional role), an SPD educator, two OR liaisons, an OR coordinator, and an OR nurse and educator (twice). Experience levels for SPD managers ranged from being in the role for less than half a year to having over 20 years of experience in the SPD. Technicians interviewed had experience ranging from within a year of hiring to being employed for over six years by the hospital system. Experience levels of SPD supervisors ranged from five to seven years employed by the hospital but in their current position, experience levels ranged from less than a month to several years. The OR employees interviewed were in their positions between two months and several years.

Role	Role-Specific Focus(es)
Quality Assurance Team Member	Interactions with management Added requirements due to QA role
SPD Traveling Technician	Restrictions on role How travelers are viewed in the workplace
Educator	Interactions with new hires Effect of constant staff turnover
SPD Supervisor	Interactions with management v. with front-line workers How to handle trade-offs
Asset Coordinator	Interactions with third-party suppliers Role in solving off-nominal events
OR Liaison	Extent of coordination between the OR and SPD How the ORL role is utilized to assuage pressures
OR Nurse	Extent of interaction with SPD
OR Coordinator	Extent of coordination with ORL Extent of coordination with OR leadership

Table 1. The focus of interviews based on the role of the participant.

SPD Roles

SPD technicians are front-line workers who frequently communicate within the department and with front-line workers in the OR. It was essential to obtain perspectives from technicians, as they are the baseline of communication and coordination within the SPD/OR system. Off-nominal events such as missing instruments and found bioburden begin at the front-line level in the SPD. Pressures such as immediate tray turnarounds are placed on SPD technicians, with the handling of these situations considered adaptations. These pressures can also conflict with each other. For example, time pressure to turnover a tray and the pressure to ensure the tray is properly decontaminated and sterilized to prevent threats to patient safety. Differing levels of experience, location, and position led to multiple rates of understanding of the textbook solutions for off-nominal events. In

addition to having auxiliary roles, the technicians interviewed were stationed at various locations, with two on-site SPDs represented as well as the off-site sterilization center.

In addition to standard SPD technicians, a technician who had recently been promoted to be on the quality assurance team was interviewed. This position allowed the technician to access the Microsoft Teams escalation chat and attend managerial huddles. This added the perspective of a worker who still encounters off-nominal events and witnesses how they are rectified in real time. Workers at this "gateway" position are not yet supervisory or management. Additionally, working on the quality assurance team requires the technician to have a higher level of understanding of the SPD process and requires interdisciplinary coordination to maintain quality assurance. Furthermore, a traveling SPD technician, a "*traveler*," was interviewed. The traveler role was interviewed to gather comparisons between the standard SPD technician role and travelers. It was stated during interviews that approximately one third of SPD technicians employed by the hospital system studied are travelers. To this, questions regarding differences between how off-nominal events are handled between the setting and locations the participant had previously worked at were added to the typical script. As previously stated, travelers are restricted to working in certain areas of the SPD, so questions asked were restricted to these areas. The communication between travelers and standard technicians was added to the script, as well as the perspective the hospital or SPD leadership has on travelers was focused on.

Educators were also interviewed for this study. This includes an educator that also worked at the offsite SPD. The purpose of interviewing educators was to fully

understand how present adaptations are different from the textbook workflow, and what workarounds are potentially used to respond to the constant influx of new workers. Additional coordination with couriers and restrictions on communication between off-site and on-site workers locations were discussed in the interview.

Among participants were *SPD supervisors* who manage their respective SPDs during their shifts. During observations, supervisors had to communicate constantly with SPD technicians, ORLs, OR coordinators, and managers. Finding the capacity at which SPD supervisors communicated with each of these roles was a major emphasis of these interviews. To map the information flows in the SPD, it was essential to understand the perspectives of SPD supervisors. While SPD workers represented the front-line level of scale, SPD supervisors were the following level. This mid-level position is critical, as they face pressures from the organization and management, but still have to facilitate adaptations on the floor of the SPD.

The *Operating Room Liaison (ORL)* role is a communicator role that communicates frequently with workers in both the OR and the SPD. Workers in this role play a large part in the communication and coordination between the two departments. The ORL role fit multiple needs that qualified them to be considered a high-priority role. Employees of the SPD, the role of the ORL is to help communicate needs of the OR to the SPD they represent. They interact across levels and between both departments. This role also facilitates much of the coordination between the OR and the SPD. The perspective is essential to mapping the full extent of adaptive capacity, as those in this role represent "personified adaptation." The ORL role is not a universal role and has been

added to assist several SPDs in the hospital system setting. This role was added to help improve the communication and the relationship between the OR and the SPD. This allowed for questions to find information flows during adaptations both before and after the introduction of the ORL into each SPD. Many participants discussed an interaction with the ORL during adaptations.

In addition to the front-line and managerial roles, an *asset coordinator* was interviewed. Often serving as a communicator between SPD leaders and third-party suppliers, an interview with someone in this role would help achieve our goals due to their perspective regarding pressures related to inventory management and pressures due to broken equipment and a lack of instruments. Questions involving their role in frequent pressures were asked.

The next level of scale in the SPD is the managerial level. Typically, a hands-off role, *managers* within the SPD deal with pressures across the hospital system, with higher-level managers occasionally being included in the flow of communication during off-nominal events. Again, it was essential to gain the perspectives of SPD managers in order to find their roles in adaptations, how they respond to organizational pressures, and when and why they are included in information flows during off-nominal events. Managers in the SPD are included in mass communication when off-nominal events need to be escalated to the entire SPD system. In response to this need, a high-ranking overall SPD manager was interviewed. This manager was able to provide high-level insight into the SPD system and the changes they have helped implement to overcome the pressures observed and elicited from the participants.

OR Roles

Also interviewed was an *OR nurse* that is also an educator, and an *OR coordinator*, both employees of the OR. These interviews were conducted to understand the coordination that takes place from the OR to the SPD from the perspective of the OR. Both roles interviewed interact with surgeons, scrub technicians, and ORLs, as well as other staff in their respective roles. The workers in the OR are able to see the effects of pressures in the SPD by way of missing instruments or trays, or contaminated instruments, which can compromise the well-being of a patient.

Pressures in the OR/SPD System

Pressures in the OR/SPD system were commonly found to define the day-to-day work in the SPD. Participants showed signs of anticipating these pressures—an adaptation—due to the frequency of these pressures. Pressures often were conflicting in nature and required trade-offs. Trade-offs occurred in situations where there was a time pressure to provide the trays to the OR in the desired time frame while ensuring that the appropriate reprocessing and sterilization methods were completed., Pressures that will be discussed were found to occur frequently within the SPD. Pressures such as missing instruments occur multiple times per day, while some specific instances discussed occur irregularly. Despite occurring irregularly, these pressures still affect the workflow and how the managing of pressures is approached.

Missing Instruments

A major pressure found during the qualitative data analysis was missing instruments. Workers in the SPD at the study location define missing instruments as instruments that are lost, broken, extra, or incorrectly in a tray as defined by the count sheet. Critical events can occur from having missing instruments. A desired tray with missing instruments is a scenario where essential coordination was required between the OR and the SPD.

> *Now, it's one thing if somebody comes in and they need… an open belly case, that which is what I would coordinate for. It's another thing when they don't have a sterile tray and they can't physically open a chest... That has been detrimental. I don't know if a patient has been harmed from it, but that's hugely stressful. We get heart transplants. And then an emergency comes, and then we're supposed to have two patients on the table, but we don't have an emergency cardiac tray available.*
>
> *– OR Coordinator*

When instruments in a tray are missing or ineffective, this can alter the course of the surgery, either delay the surgery, present a risk of patient harm, or result in a cancellation of a surgery. Missing instruments are a significant pressure, as in certain cases, there are no workarounds that can be done to rectify the instrument to maintain patient safety. This shows the limitations of adaptive capacity when working in a system where there are lives at stake. Often these pressures have responsive workarounds, but

each of these workarounds come with conflicting pressures, such as the effects of delayed workflows.

"But then sometimes it's just besides that being an issue, it's the fact that when you have a tray that's down and it was worked on or it was audited, someone went into the system, they pulled the tray, they were working on the tray, and they had something missing and they said okay, a forceps is missing. Now this is why I can't put this tray up. But the tray is left, and we have a missing cart area, so the tray doesn't go up or get sterilized because it's missing that instrument. So that kind of hinders the process on that end."

– SPD Asset Coordinator

Missing instruments can also be caused by adaptations to other pressures, including other instances of missing instruments. Participants discussed scenarios where trays that were in storage were found to have missing instruments because instruments were pulled from the stored tray to fulfil the count sheet for a tray that was actively being assembled. The removed instruments were not notated on the trays after altering their composition. Pulling instruments from completed trays is an adaptation, but the lack of coordination between the SPD staff became a pressure for when the stored tray was intended to be pulled. The lack of preemptive planning is evident of a gap within longitudinal coordination.

Time Pressure

A significant pressure discussed by the participants was the constant time pressure. Time pressures were seen to be constraining of the flow of information and required those involved to take flow paths not typically used during the textbook or adaptive workflows. As the SPD is a constantly running system and dependent on the OR for determining workload, time can be seen as a conflicting pressure when compared to other pressures in the system, most of which desire to avoid patient harm. Much of the time pressure stems from add-on cases. These add-on cases require trays that need to be reprocessed and sterilized that were not originally planned for. The number of add-on cases in a given day is always variable, and while expected, the variable number of cases expected for a given SPD adds to the uncertainty of the system. These may be instances where surgeons request additional trays, or when trays that contain bioburden need to be reprocessed immediately. The latter case, known as a quick turnover, is stated to add considerable time pressures if substitution trays are unavailable. These quick turnovers are a type of rework—already a pressure in that it adds to the workload of the SPD—that has an added time pressure. Quick turnovers occur when the tray that is requested or needs to be reworked is a one-of-a-kind tray, a commonly mentioned pressure by participants.

> *"It's a four-to-six-hour process from start to finish and we like to really*
>
> *say a six-hour [process] because you have to allow room for error."*
>
> *– SPD Supervisor*

Time pressures often force workers in the SPD and the OR to consider tradeoffs. In situations where instruments or trays are needed urgently, but are not yet decontaminated or sterile, trays will be sent once they are decontaminated and assembled straight to the OR, where they will then be steam-sterilized, a less effective—but quicker—alternative than the traditional sterilization process (Alfred et al., 2021; Hutzler et al., 2013). The use of steam sterilization is an adaptation that involves a trade-off, as it decreases turnaround time, which alleviates the time pressure, but increases the risk of patient harm.

Staffing

Levels of staffing were noted to have a significant impact on the OR/SPD system. The turnover rate of staff in the SPD was noted by participants on all three levels of scale (front-line workers, supervisors, managers). The turnover is not specific to front-line workers, as multiple changes in leadership have occurred during the tenure of the participants.

"There's been such a changeover in employees, staff, all the way from

techs to management to directors. So, there's been a big change.

There's been a lot of changes, a lot of techs again, coming and going.

I've myself been through probably five managers in the time I've been

here, as well as probably the same amount in directors."

– SPD Supervisor

The constant turnover in leadership can lead to alterations in the textbook workflow. Changes to textbook procedure on how to handle pressures in the SPD were noted to lead to confusion among staff members. Several participants have noted that they are indifferent to procedure changes as long as the given procedure is permanent. Confusion, or lack of understanding, has an impact on the newer SPD workers. Confusion can also affect the flow of information, as participants noted that there were instances where they did not know who to escalate problems or questions to. An example of this lack of understanding is a lack of communication when phone calls are exchanged between the OR and the SPD. Experienced participants described scenarios where new hires would answer the phone and gather the information from the OR but not relay the message to those who are more apt to handle the situation. This was attributed to a lack of training of newer hires.

Staffing can furthermore affect communication by creating constrictions on the availability of higher-ranking staff. SPD supervisors interviewed recanted scenarios where they had to work on the front lines assembling trays due to staffing issues (or heavy influxes of add-on cases). From the interviews, two scenarios have resulted in supervisors working in the assembly subdepartment: staff exoduses and lack of available slack. It has been noted that entire shifts of SPD workers have walked out in the past. Additionally, in instances where technicians have been unavailable to work, supervisors have had to replace them while maintaining their supervisory duties.

In one such instance, an SPD supervisor had to fill in for a technician that could not come into work. This led to the supervisor missing communications from their

partner OR that was searching for a tray. This again emphasizes the lack of slack in the SPD, as a single technician not coming into work can be the difference in a patient's safety. The lack of staffing also restricts information flows, as multiple attempts were made to contact this supervisor to no avail. Furthermore, the staffing pressure leads way to additional pressures, such as a loss of quality inspections, a nominal workflow for an SPD supervisor. A loss of quality inspections can lead to incomplete or contaminated trays being sent to the OR.

A theme related to staffing is that SPD staff are not being placed in optimal locations throughout the SPD. SPD technicians had noted that even when staffing levels were adequate, areas of the SPD that needed higher levels of attention had an inadequate number of technicians.

"I would say for the decontamination area, the flow of it in my opinion,

can go much better if you place the people where you actually need

them. It's all about communication. So, if we're not communicating and

talking with each other, it's hard for us to get the job done efficiently.

So, I say that to say that. We need to put people in the place where they

need to be."

– SPD Technician

This issue is compounded by the constraint of travelers restricted to working only in the assembly and decontamination subdepartments. These concerns had been relayed to management, but had not been rectified, according to the participants who have noted

this occurrence. Additionally, the impact that staffing has on education is a commonly occurring theme. Participants who were educators also have traditional roles in the OR and the SPD, and constant influx of new workers takes away from the participants' true roles. Staffing issues are not a pressure specific to the SPD. An experienced SPD supervisor noted that new hires in the OR no longer work in the SPD during the training period, as they are needed in the OR immediately. This was stated to lead to mistrust of the SPD by those in the OR who did not experience extensive training due to staffing issues in the OR.

Adaptations in the OR/SPD System

Role Evolution

In this study, role evolution is defined as a hospital staff member changing or altering their daily role to adapt to pressures to ensure an efficient workflow. This includes the introduction of new roles, current staff members changing roles to compensate for staffing pressures, or a role changing in response to time pressures in the system. This was seen in real time during observations. During an observation, an SPD manager was witnessed assembling a tray, which is outside the intended workflow of that role. This specific change in workflow was in response to staffing pressures, as there were not enough technicians on the floor to complete the required trays.

A frequently referenced role evolution was the introduction of the ORL role. The ORL is not a universally used role across hospital systems and was seen as an adaptation to increasing pressures in the OR/SPD system. Pressures created by tray and instrument

substitutions, as well as single-day turnovers, were intended to be assuaged with the introduction of ORLs.

"We could have used an ORL for a long time… Once the instrument

issues started getting worse, I guess even pre-COVID it was not great

with contaminations, and they'd be running behind… I'd say we needed

one for the past, like at least four years, three years. Like need, need."

– OR Nurse

Stated frequently throughout the interviews, ORLs coordinated frequently with both the OR and the SPD. Participants employed by the OR have discussed scenarios where they have sent the ORL to the SPD to retrieve a case or communicate an add-on if the communication between the two departments is lacking. This allows the OR personnel to remain within their department, alleviating time pressures and staffing concerns. Situations where ORLs are unavailable have led to other SPD positions substituting in that role. Both technicians and supervisors have substituted as ORLs to fill gaps where true ORLs are unavailable. In addition to the introduction of ORLs into the OR/SPD system, other roles have been created to fill needs. With prominent levels of leadership turnover, new mid-level managerial roles were created to provide consistency within the SPD.

While many of the scenarios where role evolution was involved were initiated by front-line workers, changes in workflow for staff members can be conducted at the managerial level. One such instance that occurs is the utilization of disaster teams to

work over the weekend for when there is a buildup of unprocessed trays that are needed for the next week. Weekend staff in the SPD is limited, which means that there are fewer trays reprocessed than during a typical weekday. During these "disaster" events, SPD leadership can decide to keep the off-site reprocessing site open through the weekend. This is a scenario exemplifies an adaptation that does not frequently occur but is available in the event of a considerable time pressure.

Prioritization and Anticipation

Prioritization of pressures is a widespread adaptation across multiple levels of change. Workers in both front-line and supervisory roles credited their respective experience in the OR or SPD for the ability to prioritize needs and pressures. A scenario where prioritization is an essential aspect is when multiple ORs in the hospital system need the same one-of-a-kind tray within a certain time. To facilitate this prioritization, SPD management and OR coordinators huddle daily to coordinate at which time each OR will receive the tray in question.

> *"In my position, I've learned that everybody feels that their situation is*
>
> *urgent, so what I need is what I need right now, and for me, in the*
>
> *position that I can't always just work off that. So, I have to work on off*
>
> *of how urgent it is really?"*
>
> *– SPD Supervisor*

Prioritization can be seen in a more established capacity in tray turnovers. Trays are assigned "Levels" that establish the time until they are needed, hence their priority.

By assigning trays formal designations for their urgency, this allows for all the workers involved in preparing the tray to be aware of the time in which the tray needs to be completely reprocessed and sent to the OR.

"Even if you do your best to prevent a situation, it's going to happen

anyway."

– OR Liaison

Further adaptations can be seen in the assembly of trays that have missing instruments. Missing instruments are a frequent pressure that can cause a variety of problems in the OR/SPD system. An adaptation that can circumnavigate pressures created by missing instruments is the combination of peel-packed instruments with trays containing missing instruments. This adaptation requires coordination between experienced technicians or supervisors in the SPD and ORLs or OR coordinators. This coordination allows for the SPD staff to send incomplete trays to the OR to be supplemented by peel-packed instruments kept in the OR.

Anticipation was found to be a large part of the role of the ORL. Participants described that part of the daily workflow of an ORL is to analyze the case schedule to identify potential pressures. This allows the ORL to prepare for these situations and have a plan in the event of a pressure. This can be seen in days where there are a multitude of similar cases that use similar instruments. The ORLs will collect extra instruments of that type to be stored close to the OR to prevent time delays. However, this requires coordination between the ORL and the SPD, as the ORL must inform the SPD of their

adaptation. Anticipation is not limited to those directly in the OR and the SPD. A detrimental pressure that was discussed was third-party vendors delivering single trays late or contaminated. This especially disrupts the workflow as there are no substitute trays for these situations. However, experienced vendors have begun to bring multiple trays of the same kind to avoid this situation. Experienced staff in the SPD can anticipate potential pressures and preemptively adapt to avoid them. In a related scenario, participants discussed double peel packing instruments that are unique or essential to the case. This is to prevent a single error—such as dropping the instrument onto the floor while opening the peel pack—from delaying an entire case. This adaptation is supported by the communication between the OR and the SPD, as the OR informing the SPD of essential instruments can allow those in the SPD to take precautionary measures with such instruments, such as double peel-packing them.

Information Flows

A frequent theme found in the interviews was the importance of communication. Communication and coordination were stated to being essential to having the SPD function smoothly. Communication between a multitude of distinct roles was observed and discussed during interviews. Huddles are events that are hubs for communication that occur in both the front-line levels of the SPD and in management. Huddles are used to communicate essential information within-level and across-level. It was found that daily huddles between SPD management and OR coordinators take place to discuss outstanding problems and potential pressures. These problems include instances of

mistrust and pressures include having multiple service locations desiring specific types of trays at a rate faster than the SPD can provide them. This is where prioritization stems from an increase of communication, as those that have partaken in these huddles have noted that OR coordinators will communicate with their counterparts across location or specialty to discuss how urgently or early in the workday their surgeon need a specific tray.

Communication Within the OR

Within the OR, communication between nurses, scrub technicians, and surgeons is frequent and time sensitive. In interviews with OR personnel, it has been stated that a lack of communication between nurses and surgeons regarding tray usage can lead to delays due to a lack of slack in the system. Scheduling changes or changes to trays are communicated from OR personnel to surgeons, often coming from the charge nurse. Communication from the surgeon often comes in the form of written notes. Also playing a role in communication within the OR, display boards were observed to be present in areas of the OR that involve pulling trays and case carts. The message boards provided a way to communicate frequently asked questions to the entire OR, including scrub technicians, nurses, and ORLs. This use of mass communication is an established adaptation to alleviate time pressures or the risk of lost communication.

Communication can be impeded in the OR due to time pressures. When incidents—such as trays containing bioburden are sent to the OR—the textbook workflow after the surgery is for nurses or scrub technicians to fill out an incident form describing the incident on the computer within the OR. This is for hospital administration

to quantify and understand the effects of incidents occurring during cases. These reports are also analyzed by SPD management to allow them to be aware of incidents that may have originated in the SPD. These managers can propose interventions to correct frequently occurring issues after reviewing these reports. However, these reports are not completed appropriately, attributed to the turnover time between cases. The workers who are asked to fill out these forms may elect to not submit the form to prevent case delays. This is a further example of a trade-off in the OR/SPD system. The result of not filling out the incident reports is that this communication is lost in two loops: the vertical loop between front-line workers in the OR and hospital administration, and the horizontal loop between the OR and the SPD.

Communication breakdowns are not exclusive to the SPD. A breakdown in the OR often leads to events that can potentially harm the patient. A scenario that requires coordination across the entire OR/SPD system was when the anesthesia department brought an unconscious patient into an emergency OR that had not been prepared by the other members of the OR. This pressure was extremely time sensitive, as the patient had already been put under anesthesia. This was a clear communication breakdown, as it was assumed that the OR would be ready for operation. This is a situation where the available information flow channels are available but not used, thus resulting in a critical event.

Communication Within the SPD

Communication within the SPD between supervisors and technicians were found to be associated with multiple adaptations. Similar to huddles between SPD and OR management, huddles within the SPD are sources of disseminating information, whether

it be shift-to-shift (within-level) or from supervisor to front-line worker (cross-level). For the shift-to-shift huddles, these are described as events where events from the previous shift are communicated, such as add-on cases and needed rework. In these huddles, SPD managers, supervisors, and technicians are involved from the outgoing and incoming shifts. These meetings are also seen as a warning for the incoming shift, keeping them informed of trends that have gone on throughout the day. While important, there are challenges to the usefulness of huddles. Multiple SPD supervisors and technicians discussed the difficulty of divulging information within the SPD—where the huddles take place—due to the mechanical noise of the machinery.

"And I think that information, not just that information, but any information in the huddle is kind of obscured to the point where I think people are just watching you talk, but they're not hearing all the information because again, the person that is delivering the information is being thwarted by all the mechanical noise."

– SPD Supervisor

A theme that frequently occurred during this study was lost communication. Participants discussed the challenges that lost communication presents on the workflow. Communication that is lost, either to pressures such as mechanical noise, or a constraint in the information flow. A scenario that invokes the latter involves a lack of communication *during* a workaround. A frequently occurring scenario eliciting from participants is when SPD technicians will remove instruments from decontaminated trays

to attempt to meet the needs of the tray on which they are currently working without communicating that the altered tray is now missing an instrument. This adaptation (instrument substitution) without proper documentation, leads to additional pressures that must be solved by other technicians, coordinators, and supervisors. Documentation within the SPD has been mentioned as a key cornerstone to the well-being of the department. Essential to coordination, documentation across the system must be maintained to track instruments and avoid further pressures.

> *"Communication breaks down daily. However, what we try to do is, as failures happen, we try to pick up the pieces on the back end."*
>
> *– SPD Manager*

Coordination and a lack thereof have a significant impact on the ability of the SPD to adapt to pressures. In the hospital system, as there are multiple SPDs servicing different hospitals, coordination between the departments regarding one-of-a-kind trays is required. A scenario where this coordination put the adaptive capacity of the SPD at risk is when an off-site SPD took a tray from an on-site SPD without consulting leadership of the needs of the tray. This would have negatively affected the workflow, as the tray was needed for a first case in the original SPD. This action displayed a variety of pressures, including a lack of prioritization, information flow constraints across levels (not consulting with leadership), and information flow constraints within levels (a lack of coordination between SPDs). The lack of coordination created pressures that would not have occurred if the off-site SPD had communicated their need for the unique tray. This

required adaptive coordination by leadership outside of their working hours to facilitate retrieving the case to ensure no cases were delayed. This required cross-level and within-level coordination, as technicians had to communicate with managers in the most advantageous way to proceed. The sole artifacts used in this scenario are phones, due to the physical disconnect of the on- and off-site locations, and the off-the-clock leadership.

> *"So again, allowing that first incident to have been closed would have*
>
> *taught the entire team the better way to prevent it from happening*
>
> *again... It's very easy to task and delegate, but where we fall short and*
>
> *I think communication definitely is a part of it, but it's the follow up." –*
>
> *SPD Educator*

A lack of coordination within the SPD has led to cancelled cases. Vendors from external tray providers are required to deliver trays 48 hours (about 2 days) before the case begins to ensure that there is enough time for the trays to be properly sterilized. Due to uncontrollable pressure—inclement weather—there was a delay in the vendor delivering trays to the off-site sterilization center needed for a case several days in advance. However, the on-site SPD had the ability to turn over the tray but failed to communicate this with the off-site location. This resulted in the vendor being turned away and the case had to be cancelled.

Communication Between the OR and SPD

The frequency of communication and the coordination between the OR and the SPD was found to have a strong impact on handling pressures in the system. An area of communication that was deemed essential to communication and coordination between

the two departments was the use of phones. Landlines are present in both the OR and the SPD and were stated to be the most frequent artifacts in the system. Scenarios that result in pressures include instances where phone calls originating from the OR never reach the correct person. Attributed to this is the lack of understanding of newer employees, who may be unsure of who to escalate calls to. Not only can this happen with newer staff members, but the interviews revealed instances where experienced SPD workers of multiple levels—technicians and supervisors—have been unable to fulfil phone-based requests of the OR due to distractions or other pressing needs.

> *"I feel like I'm like the fourth or third person to get it. And sometimes*
>
> *there's travelers upstairs and they're not used to the system, and*
>
> *someone answers the phone, information is not relayed to someone*
>
> *who can actually see if they can handle the situation and it's lost. And*
>
> *then someone from the OR actually comes down and they're like: 'hey,*
>
> *did you know, hear what we were saying?'"*

> *– SPD Technician*

Additionally, the landlines in the SPD have had periods where they do not work. This example of lost communication can cause delays, threats to patient safety, and mistrust. Participants from both the OR and the SPD discussed phone lines not working as being precursors to delays in cases, as workers in the OR would call the landlines in the SPD to no answer. This lack of communication would then result in delayed workflows, as often OR staff would have to physically walk to the SPD to communicate

their needs. This pressure also could lead to patient harm, as the preferred method of communication when a tray is urgently needed is via the landline. These calls not being picked up limit the ability of the SPD to mitigate the threats to patient safety. Mistrust also stems from these instances, as situations where OR workers travel to the SPD to deliver information appear to be angered by the fact that the phone calls stemming from the OR have not been picked up.

A related pressure that results in lost communication between the two departments is nonoperational "Wi-Fi" phones. These phones, used by the ORLs, are cell phones designed for work use. Noted during interviews was the frequency of these phones not being functional. Calls have been dropped in the middle of discussions between the ORL who is using the phone and the staff member on the other line. Frequently, these phones are used to coordinate adaptations with the OR coordinator. Calls dropping can present a significant level of frustration for the user and the people they are communicating with. This pressure has been noted to occur on a daily basis by participants.

A frequently discussed aspect of communication and coordination was the use of Microsoft Teams between higher-level workers in the OR and SPD. Titled the "Escalations Chat," it was a clear display of resilient behavior. Previously unused under previous managerial regimes, a greater need for coordination among the different SPDs, ORs, and the new off-site reprocessing center brought about the use of the Teams chat. The use of the chat itself can be seen as an adaptation to increased workloads.

Coordination between SPD workers and the surgeon is used to adapt to pressures. Communication between surgeons and SPD workers is limited and not a part of the textbook workflow for most scenarios. An instance where a surgeon coordinated directly with the SPD is when a surgeon was concerned about the turnover of several specific trays over the weekend, so they communicated directly with SPD mid-level management throughout the weekend to ensure that the trays were reprocessed without error. This coordination occurred via e-mail between a surgeon and a manager within an SPD. Coordination in the event of missing instruments can prevent instances that exceed the adaptive capacity of the SPD. One such instance that can cause delays in cases is when a tray needed for a case is not at the appropriate temperature to be used. This cannot be rushed by the SPD, as the trays must cool down without use of aid, and the use of a tray that has not cooled properly can lead to patient harm. Despite this, surgeons may waive this risk and allow trays to be opened before the proper time. This requires coordination between the surgeon, OR coordinator, and SPD leadership, particularly a manager or supervisor. All of whom must witness the opening of the "hot" tray. This is another example of a trade-off, as there are conflicting pressures at hand. In this scenario, the decision ultimately is up to the surgeon, who must decide whether the time pressure of the case supersedes the patient safety pressure. The decision of the surgeon is relayed to the OR coordinator, who then contacts the SPD via phone call.

Mistrust

Mistrust of the SPD as a department was a commonly discussed theme in the interviews. Participants who work in the SPD noted that workers in the OR had a strong

lack of understanding of what goes into reprocessing instruments and assembling trays. This mistrust in the quality of trays sent to the OR has resulted in OR personnel requesting an excessive number of trays for a given case to increase the likelihood of having enough usable instruments to conduct the surgery:

So, the mistrust, we'll have coordinators requested in excess. We had one place, it was offsite, that actually wouldn't pull from their [emergency] trays. They make us send right from down here to them so that they would have their own backup if you will. So, that is still in-progress as far as building the trust. I did have a case where over the weekend. I got a nice nasty email, but she was frustrated, she wanted a one-of-a-kind tray and couldn't get it.

– SPD Manager

Ordering trays in excess was found to create an unnecessary burden on the SPD and further constraints the already brittle system. SPD technicians stated that add-on cases were detrimental to the workflow within the SPD. The action of ordering in excess and subsequently hiding trays is detrimental to the OR as well, as it prevents SPM from noticing a high rate of turnover, which then results in no suggestions for management to order more of these trays. This instance of mistrust resulted in a pressure that negated a potential adaptation in ordering additional trays. Also in this response is the emphasis on the work-in-progress relationship between the OR and the SPD. Several participants noted that each person in the SPD and OR are "teammates" who strive towards a

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common goal: patient safety. While this mistrust is not always malicious, it results in OR workers being weary of the ability of the SPD.

> *"But it's typically me going to her saying: 'Hey, where do we stand*
>
> *with this? And if this isn't sterile in time, then get this tray.' I feel like*
>
> *SPD is so underwater with trying to keep up with the trays and*
>
> *everything that I don't think they have time to come to us with issues.*
>
> *It's our responsibility to look at what the issues are and come to them*
>
> *and have alternatives to fix the problem."*
>
> *– OR Coordinator*

The understanding OR workers have of the current state of the SPD results in added workloads for OR and SPD staff. The OR (as a unit) anticipates conflicts stemming from the SPD and preemptively adapts to these pressures. Informing the ORL of the procedure if an off-nominal event occurs without prompt displays the systemic lack of faith in the SPD by workers in the OR. This can lead to added pressures and over reliance on specific pieces of the system. This idea of self-reliance is not exclusive to the OR because of mistrust of the SPD. Throughout observations and interviews, tasks were not properly delegated due to a lack of expectation that they would be done correctly and efficiently. This scenario occurs in the coordination between OR coordinators and ORLs. As opposed to relying on the SPD to turnover a tray in a timely manner, ORLs have assembled trays and peel packed instruments at the request of coordinators. This

constrains the system, as the ORL that is turning over this tray is unable to conduct their typical functions, further reducing the adaptive capacity of the system.

Mistrust was not exclusively found between the OR and the SPD. Mistrust between front-line workers and upper-level hospital management was found as well. Participants discussed instances about suggestions and concerns that were ignored by hospital administration.

"So, anyway, for what I can just speak from a management side, you are in an uphill battle, the reality is they want to do what's easy, not what's right. And so, they don't want to listen to your solutions about what's right. They want to listen to what's easy."

– OR Nurse

Participants have warned of the usefulness of communicating to management. The lack of response by management to voiced concerns is considerable in the perspective of participants from both the OR and the SPD. Participants stated their desire to help improve the OR/SPD system but were met with resistance from hospital management. Innovations have been implemented to improve the system by staff without the consultation of upper-level management, out a fear that the innovations would not be implemented otherwise. Furthermore, participants questioned the ability of employees not on the floor (of the OR or the SPD) to implement changes into the workflow that truly help the front-line workers.

Information Flow Maps

Following the qualitative data analysis, information flows were mapped with respect to pressures and adaptations. Each scenario mapped corresponded to a pressure found frequently in the interviews and had multiple layers to show the effect of the pressure and the corresponding adaptation(s). The first layer mapped is the textbook method to handle certain off-nominal events. Finding the textbook method is a step in the SCAD method during interviews (Jefferies et al., 2022). The textbook workflow was mapped to be the baseline for adaptations, as well as to show the effect of pressures in the system when applied.

Missing Instruments

Layer 1: Textbook Workflow
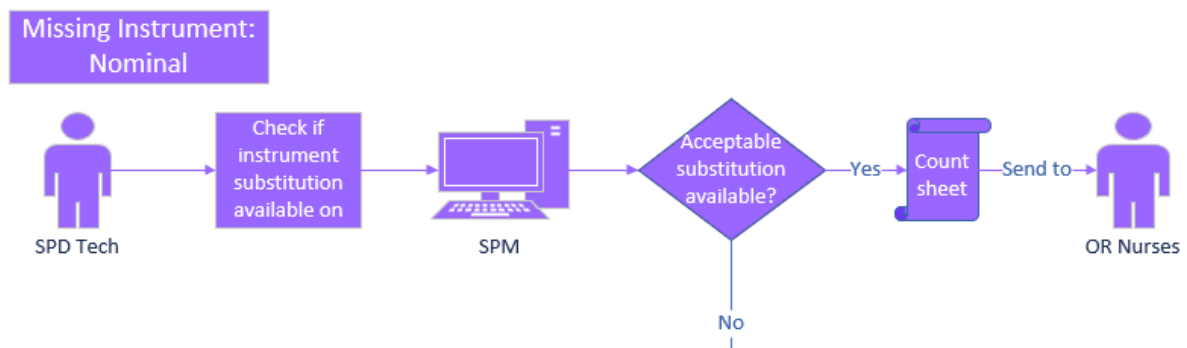
Figure 2. The textbook workflow on how to handle a case with a missing instrument.

The textbook workflow of how to handle missing instruments is an individual effort utilizing SPM. The expected workflow is for the SPD technician to notice the instrument is missing (which is not guaranteed), for them to check the SPM software for acceptable substitutions, acquire the substitution, and finish the tray while noting the change on the count sheet included in the tray or on SPM. Any further actions are

examples of time pressures that are not accounted for by the slack in the system. It was

noted by SPD technicians that when assembling trays, there are often events that deviate

from this workflow that can be considered time pressures, such as phone calls, questions

about instruments, and questions from other technicians or management, which can

further delay this workflow.
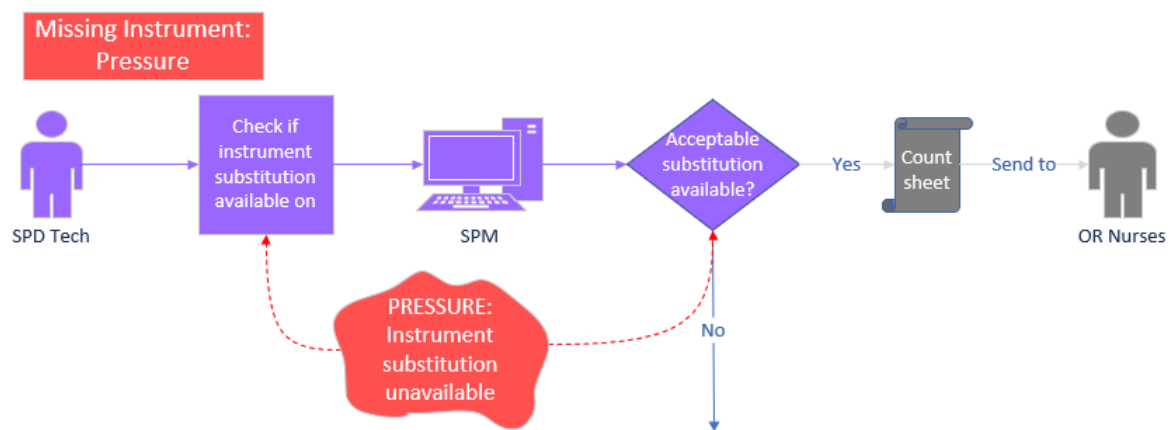
Layer 2: Introduction of a Pressure

Figure 3. The textbook workflow on how to handle a case with a missing instrument with the introduction of a pressure: unavailable instrument substitutions.

The second layer in the mapping process was the introduction and consequences

of pressures. In the situation above, the pressure at hand is that there are not any

instrument substitutions available for the tray of question. This may be that the SPM

system does not list appropriate substitutions or the substitutions that are listed are

unavailable. The former reason is found in cases that have specialty instruments that are

found in limited numbers across the hospital system. SPD technicians interviewed noted

that in these scenarios, often they recognized the pressure preemptively—this is an

adaptation in itself—and immediately shift to adapting when complex or unique cases are

at hand. In the latter scenario, if given substitutions are unavailable, similar constraints are placed on this workflow.

Also seen in this layer is the graying of the latter part of the textbook workflow. The graying shows the result of the pressure without adaptations. The lack of adaptations in this layer constrains the system and does not allow the trays to progress to the OR.
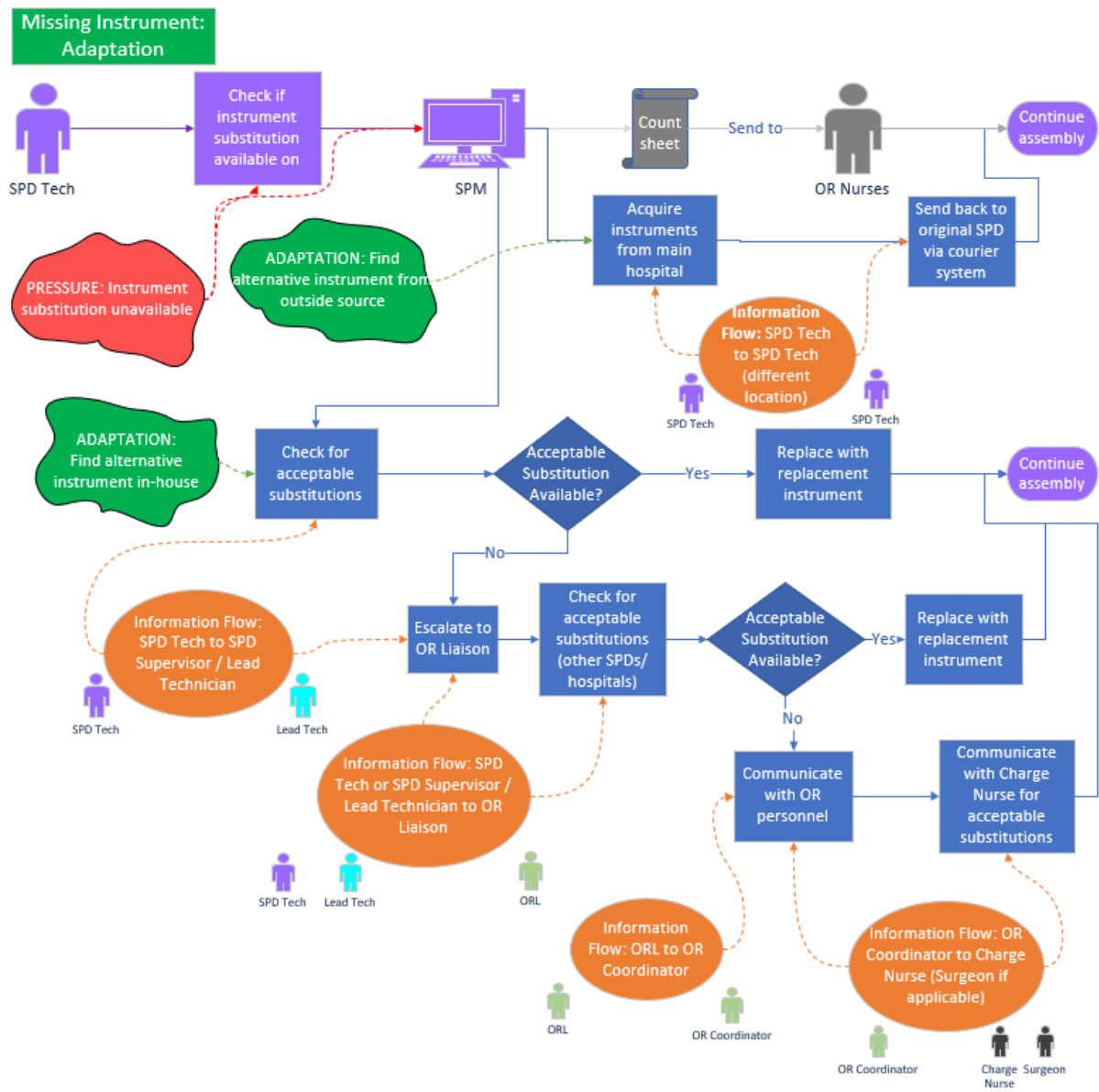
Layer 3: Adaptations

Figure 4. Map of the textbook workflow for handling missing instruments, constrained by the introduction of a pressure, and two responsive adaptations and their complimentary information flows.

In the third layer of mapping, the initial two layers are once again shown with the introduction of two common adaptations and their associated information flows. Two adaptations are present in this diagram, with the first involving within-level communication across different hospitals, and the second involving cross-level communication to employ higher-level employees to assist in a search for appropriate instruments. Similar to the shape that represents the pressure at hand, both adaptations are amorphous shapes to represent the versatile and undefined nature of these adaptations.

The first adaptation was an inter-SPD, within-level approach. This involved the SPD technician faced with the pressure contacting SPD technicians at other SPDs on campus. Technicians who utilized this adaptation stated that the main SPD is the first option for this communication, as this location has the largest inventory, as well as being solely responsible for storing robotic instruments. The communication is done via phone call when done from technician to technician, as this was said to be the most efficient option. Following confirmation that the instrument is at the desired location, the instrument in question would be couriered over to the SPD of the original technician.

The second adaptation was an in-house, cross-level approach. This approach begins with the SPD technician with the missing instrument escalating the pressure to the lead technician on the shift or the shift supervisor. This communication is done verbally, as all staff involved are actively within the SPD. If those in these roles are unable to produce a viable solution, this situation is further escalated to those in communicator roles, (ORLs, OR coordinators). These communicators can potentially ask OR personnel within the OR, including nurses, and in extreme cases, the surgeon for the impending

case. Communication with surgeons is extremely limited, as the only participant interviewed that noted that they communicate with surgeons was the OR coordinator. These repeated escalations are each individual adaptations, as each succeeding escalation is a result of a proper substitute instrument being unavailable, a pressure. Also, the delayed workflow associated with the escalations is a compounding pressure in this scenario. A conflicting pressure noted is the pressure of time, as it is expected that trays are turned over in a given amount of time, and these delays can result in delayed surgeries or patient harm.

Contaminated Tray

Layer 1: Textbook Workflow
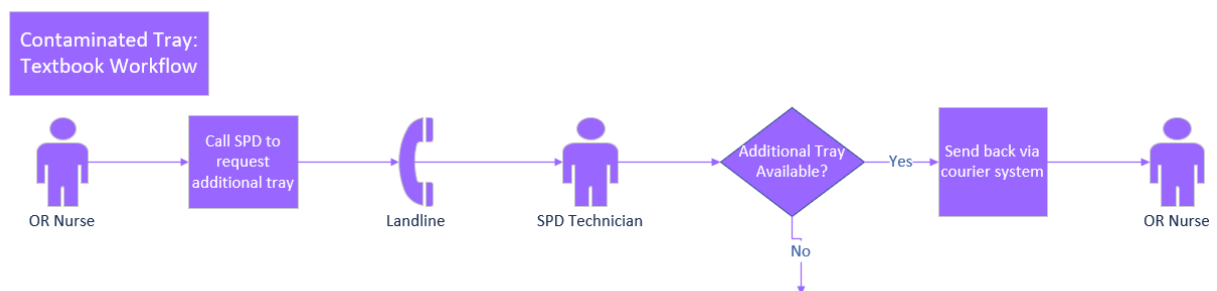
Figure 5. The textbook workflow on how to replace a contaminated tray in the OR.

The above scenario shows a visual representation of the workflow described by both OR and SPD personnel on how situations where a tray contains bioburden should be resolved. This involves the appropriate OR personnel, typically a nurse, calling the SPD and informing them that they need a replacement tray. The SPD would then send an identical tray back to the OR via the courier network, similar to the standard procedure of

the SPD. This is typically done via the landline system and directly from the OR to the

SPD, due to the urgent nature of the situation.

Layer 2: Introduction of a Pressure
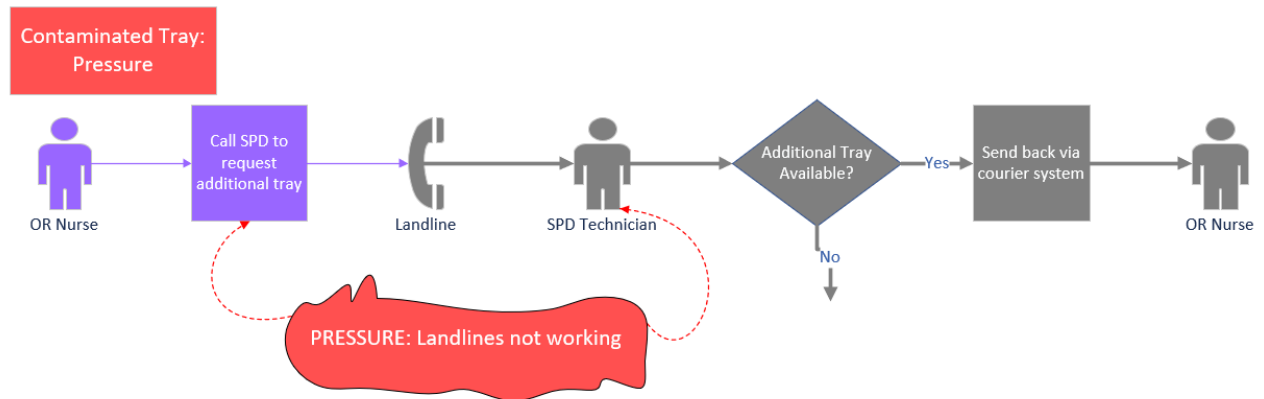
Figure 6. The introduction and effects of a pressure (landlines not working) in replacing a
contaminated tray.

This shows the introduction of a pressure in the system noted by both OR and

SPD workers. Landline phones are the most frequently used artifact among front-line

workers. When the landlines are not working, the communication between the two

departments is stagnant and needs from the OR cannot be relayed to the workers in the

SPD. This constrains the system and does not allow for the replacement of the

contaminated trays. This pressure can lead to delays in cases, or potentially patient harm

if the bioburden is found during a case.
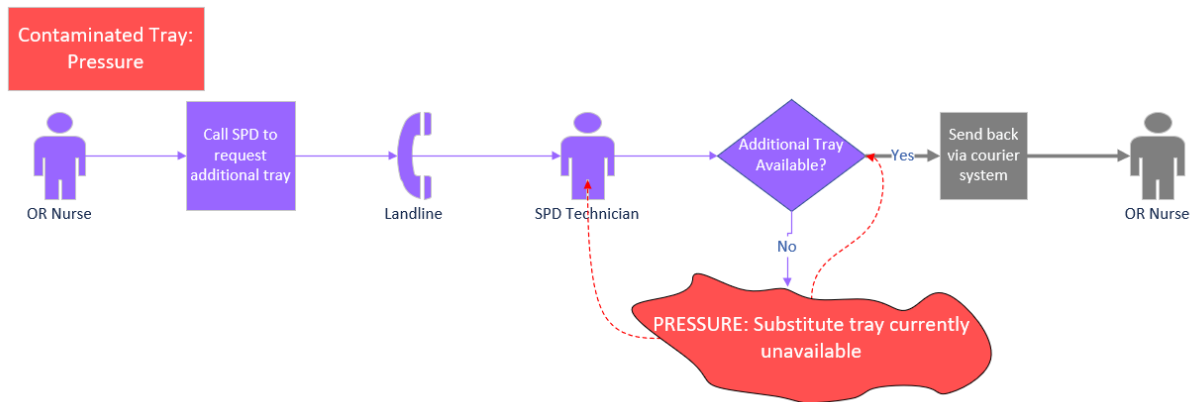
Figure 7. The introduction and effects of a pressure, (unavailable tray substitutions), in the scenario of replacing a contaminated tray.

An additional pressure for this situation is the lack of an available tray substitution in the SPD. This constrains the system, as the SPD cannot follow through on the request for rework made by the OR. This can be attributed to a variety of factors, notably a lack of inventory, as there are one-of-a-kind trays with no substitutions, vendor trays with only the one tray in-house, or the available trays are all actively being used for cases. All these scenarios present different challenges and elicit different responsive adaptations.

Figure 8. Two adaptive workflows in the case of bioburden on an instrument with a pressure: malfunctioning landlines between the OR and the SPD.

There have been two adaptive workflows that have been frequently used to navigate the pressure created when the landlines between the OR and the SPD are not working. The first is for OR personnel to physically walk to the SPD to inform them of the situation while delivering the tray. This is where an identical tray in inventory would be given to the OR to be used. This comes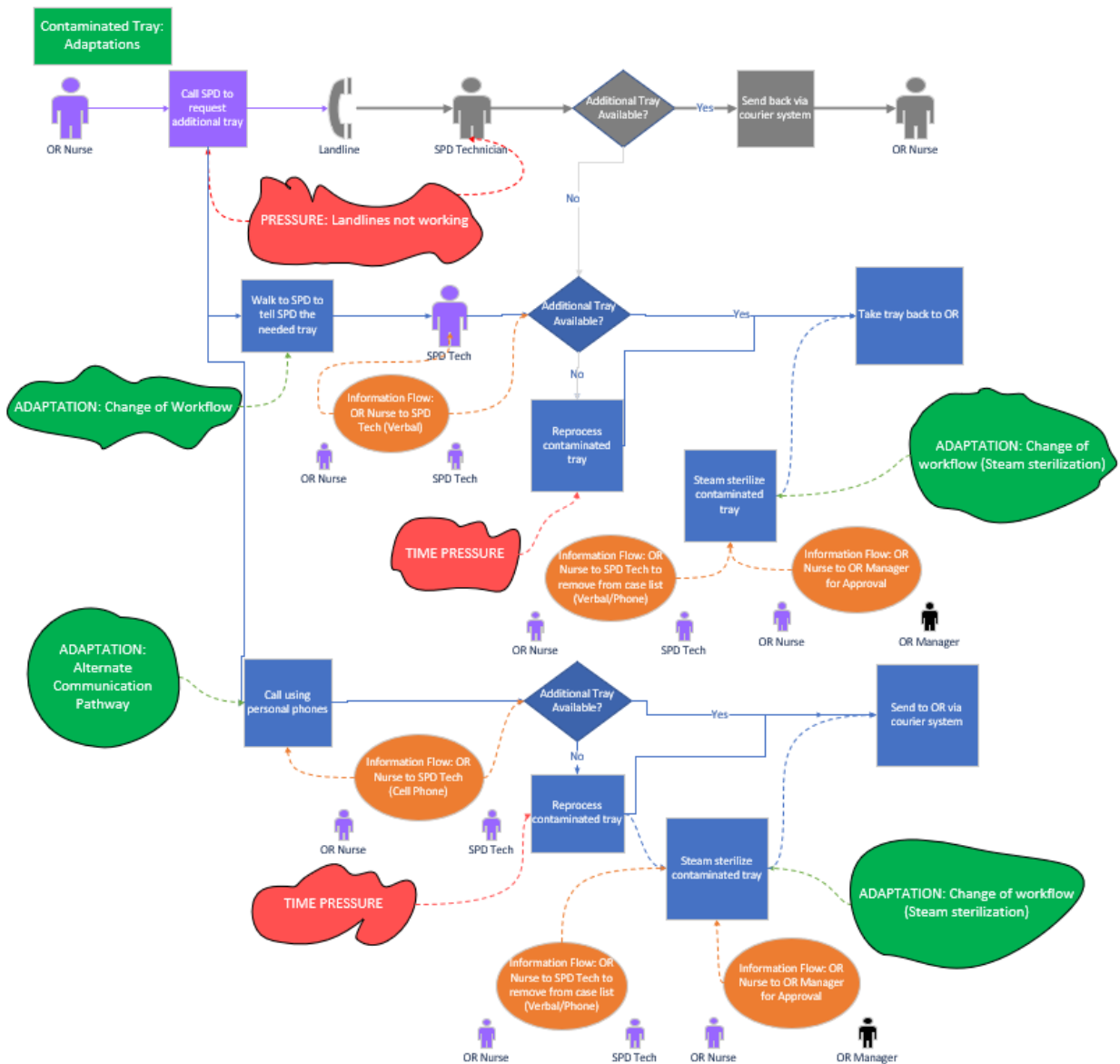 at the cost of time, which is concerning when the patient is under anesthesia or to an extreme extent: open. Furthermore, there is a pressure present if there is no substitution tray available. This results in the SPD beginning to reprocess the contaminated tray. There is a time pressure present when reprocessing trays. In the event of these situations, additional adaptations may occur, with the use of immediate-use steam sterilization (IUSS) of the tray in the OR. Any use of IUSS requires OR manager approval, an additional channel of communication that must be had to resolve this pressure. As previously discussed, this adaptation is a trade-off, as it comes at a cost of potentially inadequately sterilized instruments.

A similar adaptive workflow would be using staff personal phones to communicate with the SPD. This entails a similar workflow to the previous scenario but requires a preexisting relationship with members of the SPD to be able to call them on their personal phones. This displays the coordination present between the two departments, as both sets of staff understand the effects of the landlines not working. Additional pressures coming from relying on personal phones are the potential for the calls not being completed due to service issues and the need for additional actions if the tray does not have a substitution available. Potential actions in the event of this scenario

include an OR personnel traveling to the SPD to deliver the contaminated tray or utilizing IUSS.
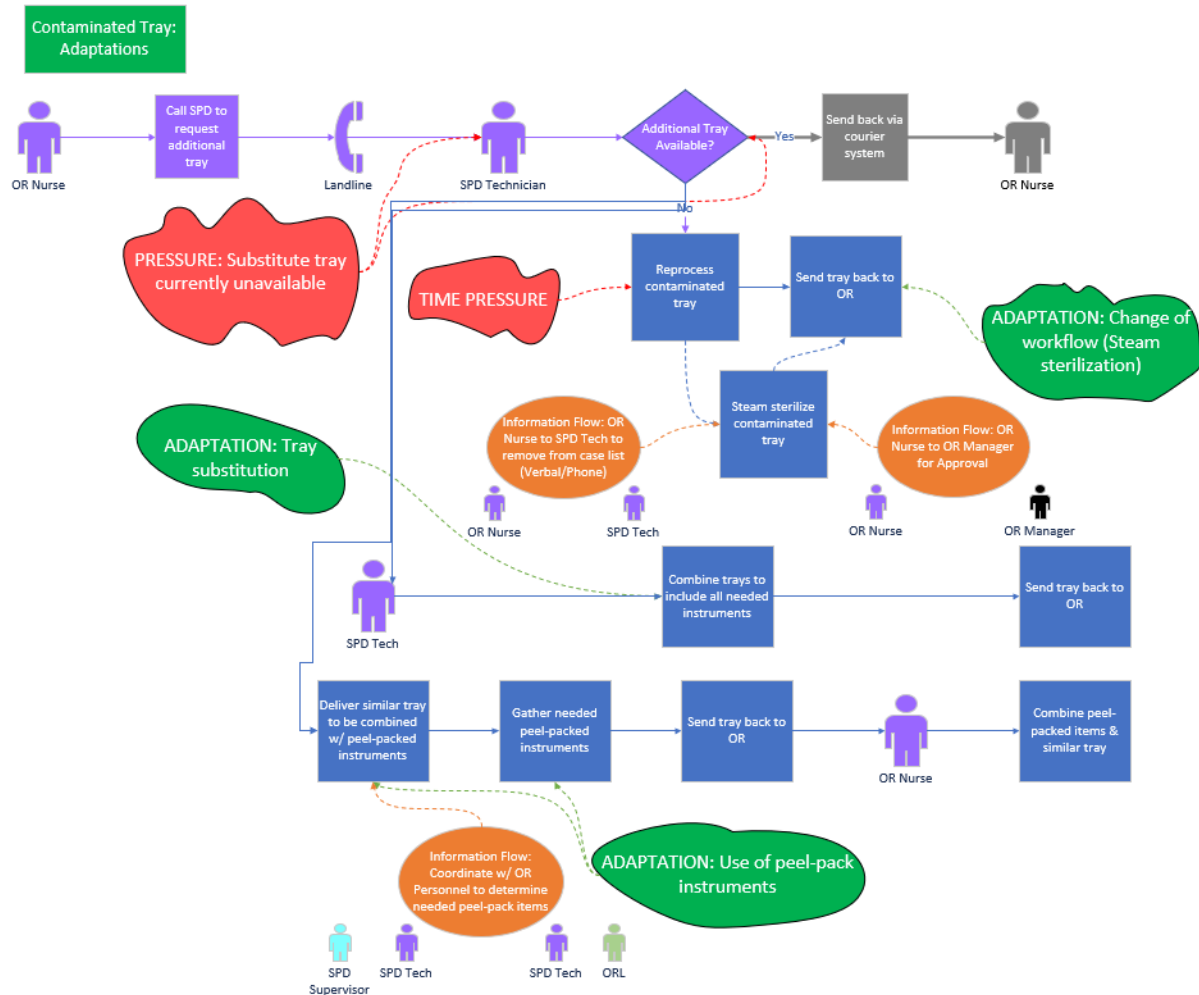
Figure 9. Two adaptive workflows in the case of bioburden on an instrument with the presence of a pressure: a replacement tray is unavailable.

The two most frequently discussed adaptations when a replacement tray is unavailable when there is a contaminated tray are reprocessing the tray or tray substitution. The workflow when reprocessing a tray remains constant to the previous description seen in **Figure 8.** When substituting trays, there are situations where two trays with a smaller number of instruments can be combined to replace the contaminated

tray. The available substitutions are found on the instrument tracking software used by the hospital system. Experienced SPD workers noted that in situations where the same tray had been contaminated previously, they are able to recall and adapt without first consulting the software. There are not always appropriate tray substitutions. In these scenarios, similar trays may be assembled to the best of the ability of the SPD and combined with peel-packed instruments stored in the OR to complete the tray. This requires coordination between the OR and the SPD to ensure that all essential instruments are either in the tray or peel packed.

CHAPTER FOUR

DISCUSSION

The themes found during the qualitative data analysis show the importance of communication in the OR/SPD system. Pressures were found throughout the various stages of the SPD. Frequently found pressures included missing instruments, time pressures, and staffing. Responsive adaptations included role evolution, prioritization, and anticipation. Themes involving information flows include communication with the SPD, communication within the OR, communication between the OR and the SPD, and mistrust. All of these themes contribute to the complexity of the OR/SPD system and reveal areas that are supported by adaptations and their corresponding information flows.

Pressures in the OR/SPD system make it harder for frontline workers to conduct their assignments. Pressures often were compounding, as the introduction of a single pressure can lead to multiple if not properly addressed. For example, a lack of staffing results in supervisors assembling trays as opposed to conducting quality inspections. A loss of quality inspections results in increased prevalence of bioburden on instruments found in the OR. These cascading pressures can be seen in the information flow maps, as single pressures can lead to a cascade of pressures that build off one another. The visualization of cascading pressures is an aspect of coordination and information flows not previously seen.

Threatening the adaptive capacity of the OR/SPD system is the lack of slack, or margin of error, which exists in the system. This lack of slack is exemplified when there are staffing concerns in the SPD. For example, situations where cases have to be delayed

due to the SPD supervisor not receiving the communication while they were assembling trays show the current brittle state of the SPD system. This situation also constrains the current information flow paths that exist for adaptations. There was a pressure (missing tray) that had an established adaptation (substitution tray) that could not be conducted because of a compounding pressure in the SPD, leading to a critical event (delayed case). Providing resources to rectify this, such as additional funding to increase staffing level, could potentially increase the level of slack in the SPD.

Workers were seen during observations in the SPD taking on multiple roles and discussed this in interviews. However, these adaptations can lead to pressures. During observations, multitasking was seen amongst workers. Multitasking, which is when multiple tasks are done simultaneously by a single person, is considered more difficult and can lead to information overload (Morgan et al., 2013). Information overload is one of the factors related to information chaos, which is detrimental to information flows (Beasley et al., 2011). An instance of multitasking observed is when a member of the quality assurance team participated in a huddle while simultaneously assembling a tray. This divided attention could potentially lead to incorrectly assembled trays or missed bioburden.

Disconnect between decision makers and workers can create further levels of mistrust across levels of scale within the SPD. Also elicited was the mistrust in upper-level management by lower levels of scale. During observations, adaptations in the workplace were seen to have been created by front-line workers that have become part of the everyday workflow within the OR/SPD system. However, these are unknown to

decision makers who did not initiate changes to support this adaptation. Without formal documentation of these adaptations, the knowledge of these workflows could be lost to future staff members. This concern is increasingly significant with the awareness of high staff turnover. To rectify this, it will be beneficial to have increased coordination between decision makers and those on the floor who are creating these adaptations. Codifying adaptations that have been established in the workplace will allow for management to have a better understanding of the true workflow.

Many adaptations facilitated by more experienced staff members were attributed to their past failure. This ability to respond appropriately in the event of the pressure recurring displays the resilience of the system when relying on experienced workers. Reliance on experience also alleviates time pressures, as an understanding of substitutions and adaptive flow paths were found to drastically reduce the time pressures on experienced staff members. This reliance also transcends the individual, with increased expectation of production placed on more senior SPD members. While this currently increases the adaptive capacity of the SPD, the prominent levels of staff turnover pose a threat to this current understanding of coordination across levels of scale.

Seen in the results from this study is a vicious cycle that occurs in the OR/SPD system. A vicious cycle as it applies to adaptations, participants in the cycle can overuse the available resources, reducing their ability to adapt in the future (D. Woods & Branlat, 2017). The pressures that the workers at the hospital face result in adaptations that negatively affect others in the system. For example, a pressure faced in the OR is trays containing bioburden. This creates the level of mistrust previously discussed and leads to

OR nurses ordering excessive amounts of trays. The increased workload results in increased turnover time of trays in the SPD and reduces the amount of slack in the system. The reduced slack and increased time pressure results in more trays sent to OR containing bioburden. This can be due to SPD technicians rushing to finish trays, reduced quality inspections, or other time-related factors. Situations like the one described contribute to the theory of an adaptation being locally adaptive, but globally maladaptive (Branlat & Woods, 2010). This is the concept that refers to an adaptation that benefits the system in the short term but can harm it due to an overexertion of resources overall. The conflicting pressures seen throughout the OR/SPD system result in the creation of vicious cycles that need to be addressed via an intervention or policy change. The presence of vicious cycles throughout the SPD calls for administration to identify how pressures such as staffing and lack of efficiency within the SPD lead to the creation of these cycles. An increased level of trust could lead to increased coordination between the two departments.

Application of Findings

This study provides insight to the organization on how to improve coordination in the SPD. Through this study, communication and coordination point to being drivers of adaptive capacity. To maintain a level of control, a complex system must be adaptive (Provan et al., 2020). This control can be had through defined adaptive pathways throughout the system. While studies have been conducted focused on understanding information flows, these studies do not look at adaptations and variability in the system.

(Bonaconsa et al., 2021; Pennathur et al., 2014). The information flow maps provide a deeper look into how coordination supports these adaptive pathways. The results of the qualitative data analysis and the maps revealed patterns in information flows. Making the extant information flows during adaptive events clearer across the system is the goal of the mapping, as well as developing a way to concretely visualize how coordination is supported by information flows. The impact of the patterns is the assistance these existent patterns provide during time pressures. Knowledge of these pathways by OR and SPD staff can help these adaptations occur faster and eliminate the need for developing new ad hoc flow paths. While the creation of new adaptive pathways is beneficial in the long-term, it takes time, which is typically unavailable in the SPD.

The themes presented in this study can help better the OR/SPD system by providing a gateway to understanding for hospital management. We identified stresses and strain in the system that can be shown to management for a better understanding of the entire system. These findings can be presented to policy makers to make improvements in the SPD to account for the adaptations currently used. Recommendations from the researchers should not be the sole perspective on changes to be made in the SPD system. The ability to listen to front-line workers and enact policies based on WAD would help facilitate adaptations throughout the system. Participants recanted scenarios where they had to adapt to pressures in the system and discussed the channels of communication utilized throughout these adaptations. Changes to the SPD system to increase the availability of these channels could allow workers to adapt to pressures with more ease. Supporting these pathways could also suppress these pressures.

A straightforward way to do this is by providing easier ways for those in high-communication roles, such as ORLs and OR coordinators, to communicate with each other. A pressure noted in interviews is that phone calls will drop in the middle of important conversations or restrict the calls from coming through. Instances where phone calls are unable to be finished during essential communication events can severally handicap workers in a system. Switching phone types or providing an alternative communication pathway (i.e., a pager), would potentially reduce these issues. The introduction of the ORL role was said to be an extremely helpful addition to the OR/SPD system. The ability of the ORL to take on multiple responsibilities at once and provide a physical presence of the SPD within the OR was said to benefit the rate of coordination between the two departments.

The findings in this study are unique, as there has been little research regarding the role information flow has on the adaptive capacity of a healthcare system. The methodology of the interviews used during the collection of data was innovative as it required the blending of multiple knowledge elicitation methods (SCAD, CDM) with a focus on the role of information flows. This interview technique can be used to elicit adaptations and associated information flows in complex systems not exclusive to healthcare.

Major pressures in the SPD include missing instruments, staffing issues, and time, all of which are interconnected. To assuage these pressures, the adaptations that are currently used to overcome them must be supported. These solutions can range from tangible changes—such as an improved phone system—or organizational changes such

as programs that educate both OR and SPD staff about each section of the OR/SPD system. Having the workers in the system gain a greater perspective can allow for increased shared awareness. While shared awareness will be present in complex systems, a heightened degree of shared awareness can help limit disruptions caused by a lack of coordination.

Limitations

A limitation of this study was that it was conducted at one hospital system. The adaptations and information flows studied were specific to this system. To gain a further understanding of frequently occurring pressures and adaptations across SPDs, this process of data collection and analysis should be conducted at multiple hospital systems. Further limitations in this study include constraints on the roles interviewed, as no surgeons or scrub technicians were interviewed during this study. However, other OR roles—OR nurse, OR coordinator—and ORLs were interviewed, allowing for the perspective of the OR as an entity to be heard. Furthermore, observations occurred mostly in the assembly and decontamination subdepartments in the SPD. Future observations and interviews focused on other areas of the SPD would be beneficial to understanding the extent of coordination throughout the SPD. Finally, members of the courier system were not interviewed as a part of this study. Insights into this part of the SPD system were gained through those not directly a part of the network. Furthermore, a limitation of semi-structured interviews is that the perspective gathered is Work as Reported (WAR) rather than a true WAD perspective. However, while conducting on-

the-job interviews and observations, we were able to align the WAR per the results from the interviews to WAD.

Future Research

The adaptations found in this study form patterns because they make sense in the situations, they arise from in order to address the disruption in the system. How these adaptations, some of which are workarounds, may affect overall performance metrics in the SPD, such as turnover time or rate of contamination, remains to be studied. Finding the effect of these workarounds may reveal adaptations that are suboptimal from an efficiency standpoint. To further understand information flows in the SPD and how they support adaptive capacity, more mapping of the system can be done. Understanding how information flows supports adaptations across all levels of scale within the SPDs throughout the hospital system would increase the number of themes to be analyzed. Multiple levels of scale were studied, with a focus on front-line workers, supervisors, and managers, but a focus on higher levels, such as hospital administration, can provide insight into the WAI perspective and elicit scenarios that they hear from those across levels. Additionally, conducting interviews with roles in the OR and the courier network system would add perspectives on how adaptations in the SPD are viewed and how these adaptations affect the workflows of these unexplored roles. Conducting a similar study at more hospital systems would provide more insight into pressures that occur at all SPDs. A similar study conducting at a standalone hospital with a single SPD would provide another unique perspective, as there are not the added dimensions of courier services and

multiple locations, but there is also no slack in terms of relying on other SPD locations to supplement needs.

Further applying the interview protocol, whether it be healthcare related or in a different field entirely, would again expand this research. The interview protocol was designed to be versatile and elicit pressures and adaptations and their responsive information flows. This protocol can be applied to other complex systems that require elevated levels of coordination across levels. The mapping of information flows can also support other models designed to understand complex systems. Simulation and mathematical models designed to map these systems could be enhanced with the added context information flow maps can provide. The information flow maps created in this study represent deviations from the typical workflow that are often mapped in these simulation models. Further collaboration with other models can address questions that were raised during this study. A point of further research could be predicting when communication breakdowns will occur. While the results of this study did not lead to a point of having the ability to predict breakdowns, future research into this topic could expand to be able to convert the qualitative relationships established between pressures and adaptations in this study to quantifiable ways to predict disruptions.

APPENDICES

Overall General Questions

- Just talk about yourself and your role

- Can you tell me about the people you talk to and what their roles are, both overall and in the sense of how you interact with them?

  - What methods do you use to interact with these people?

    - If the method is calling, what constitutes that as opposed to sending a message over teams or a text or a message on SPM?

  - Do you interact with upper SPD management? Managers, supervisors

  - Do you look at the Microsoft Teams chat?

- What is your relationship with the ORL?

  - What services do they provide?

  - How often do they provide these services?

  - What in your workflow indicated that you needed to involve an ORL?

  - Can you talk about a time where an ORL has helped you in your role?

- In the OR/SPD system, how much slack or margin of error is typically found or expected? If something goes wrong how much are you able to adjust to it?

  - Do you anticipate these delays?

  - How long does it take for you to typically get an instrument requested?

    - How do you communicate this to the surgeon?

- How much of these events can be monitored on SPM? Same question for your role?

  - For these events, what is monitored via talking or calling?

- What roles do display boards have in your workflow? Do they have info that you check frequently?

  - If used: What is the effect on the workflow if they are not functional?

- When addressing situations with multiple disruptions, how do you decide on which disruption to handle first? (TRADE-OFFS)

General SPD Questions

- Can you tell me about a time when communication broke down within the SPD? (OFF-NOMINAL)

  - What **signaled** to you that there was a problem? (DETECT)

  - How do you **expect** to find out about a problem like this? (INTERPRET)

  - Are there **other ways** that you would know that a tray is waiting at the window? (NOMINAL)

  - How did you receive the information that signaled to you that there was a problem at hand?

  - How was this information stored? (INFO ARTIFACT)

- Had this situation happened **before**? (OFF-NOMINAL)

  - How did you **learn** about the problem then? (DETECT)

  - How were you **able to solve** the problem then? (INTERPRET, RESPOND)

- o Were your managers and/or co-workers part of that solution? (TEAM, GOALS)

- Did this issue **delay** your workflow in the short-term? Long-term? (TIME)

  - o How do you communicate any delays to workers "down the line"? (RESPOND)

  - o Was there any way you could work around the hold up? (OFF-NOMINAL, RESPOND, NOMINAL)

- Was this issue something you needed to fix or initiate a fix right away? Later? What was your thought process for that? (INTERPRET, RESPOND, GOALS)

- Are there other types of communication breakdown / other ways communication breaks down between the two areas? (OFF-NOMINAL)

- How did you know that a tray was passed through in that instance? (DETECT, SHARED AWARENESS)

Operating Room Questions

OR to SPD Transport

- Can you tell me about a time when communication broke down between the OR and the SPD [while transporting trays to the SPD]? (OFF-NOMINAL)

  - o What **signaled** to you that there was a problem between the SPD and the OR? (DETECT)

  - o How do you **expect** to find out about a problem like this? (INTERPRET)

  - o Are there **other ways** that you would know that the **? (NOMINAL)

- How did you receive the information that signaled to you that there was a problem at hand?

- How was this information stored? (INFO ARTIFACT)

- Had this situation happened **before**? (OFF-NOMINAL)

  - How did you **learn** about the problem then? (DETECT)

  - How were you **able to solve** the problem then? (INTERPRET, RESPOND)

  - Were your managers and/or co-workers part of that solution? (TEAM, GOALS)

- Did this issue **delay** your workflow in the short-term? Long-term? (TIME)

  - How do you communicate any delays to workers in the SPD as well as workers at the front end of the OR? (RESPOND)

    - Same type of cases going into different rooms**

  - Was there any way you could work around the hold up? (OFF-NOMINAL, RESPOND, NOMINAL)

- Was this issue something you needed to fix or initiate a fix right away? Later? What was your thought process for that? (INTERPRET, RESPOND, GOALS)

  - Time pressure (stress)

  - Comparative with what you would have done if more time (focus on comm)

- Are there other types of communication breakdown / other ways communication breaks down between the two areas? (OFF-NOMINAL)

- How did you know this situation was occurring? (DETECT, SHARED AWARENESS)

SPD to OR Transport

- Can you tell me about a time when communication broke down between the SPD and the OR [while transporting ready trays to the OR]? (OFF-NOMINAL)
- ^missing trays, peel packs, missing/broken instrument
  - What **signaled** to you that there was a problem between the SPD and the OR? (DETECT)
  - How do you **expect** to find out about a problem like this? (INTERPRET)
  - Are there **other ways** that you would know***? (NOMINAL)
  - How did you receive the information that signaled to you that there was a problem at hand?
  - How was this information stored? (INFO ARTIFACT)
- Had this situation happened **before**? (OFF-NOMINAL)
  - "Can you tell me about a unique event."
  - How did you **learn** about the problem then? (DETECT)
  - How were you **able to solve** the problem then? (INTERPRET, RESPOND)
  - Were your managers and/or co-workers part of that solution? (TEAM, GOALS)
- Did this issue **delay** your workflow in the short-term? Long-term? (TIME)

- o <mark>How do you communicate any delays to workers "down the line"? (RESPOND)</mark>

- o Was there any way you could work around the hold up? (OFF-NOMINAL, RESPOND, NOMINAL)

- Was this issue something you needed to fix or initiate a fix right away? Later? What was your thought process for that? (INTERPRET, RESPOND, GOALS)

  - o "By prioritizing this, what had to be done later."

- Are there other types of communication breakdown / other ways communication breaks down between the two areas? (OFF-NOMINAL)

  - o Wi-Fi? How to communicate without Wi-Fi/other issues

- How did you know that this situation was occurring? (DETECT, SHARED AWARENESS)

1. Tray passes through window.

   Can you tell me about a time when communication broke down **between** Decon and Assembly? (OFF-NOMINAL)

   - <mark>What **signaled** to you that there was a problem between Decon and Assembly? (DETECT)</mark>

     - o <mark>How do you *expect* to find out about a problem like this? (INTERPRET)</mark>

     - o <mark>Are there **other ways** that you would know that a tray is waiting at the window? (NOMINAL)</mark>

- How did you receive the information that signaled to you that there was a problem at hand?

  o How was this information stored? (INFO ARTIFACT)

- Had this situation happened **before**? (OFF-NOMINAL)

  o How did you **learn** about the problem then? (DETECT)

  o How were you **able to solve** the problem then? (INTERPRET, RESPOND)

  o Were your managers and/or co-workers part of that solution? (TEAM, GOALS)

- Did this issue **delay** your workflow in the short-term? Long-term? (TIME)

  o How do you communicate any delays to workers "down the line"? (RESPOND)

  o Was there any way you could work around the hold up? (OFF-NOMINAL, RESPOND, NOMINAL)

- Was this issue something you needed to fix or initiate a fix right away? Later? What was your thought process for that? (INTERPRET, RESPOND, GOALS)

- Are there other types of communication breakdown / other ways communication breaks down between the two areas? (OFF-NOMINAL)

- How did you know that a tray was passed through in that instance? (DETECT, SHARED AWARENESS)

2. Priority information check

Can you tell me about a time when you had to do something a little bit **differently**, or something a bit different happened, related to the priority of trays coming through assembly?

- How did you know that there was a **situation** at hand?

- How was this **knowledge** communicated to you?

- Has this situation happened previously?

  o If so, how did you **handle** this situation **differently** than the first time you encountered this situation?

  o Who was **involved** in the communication/what was their concern/how were they **notified**?

  o A/synchronous, e.g., **documentation**, missing documentation

  o Notification up the **chain of command** / down the workflow

- How did this **affect the workflow** immediately afterwards? Overall?

- Was this issue **addressed** immediately?

  o Who was **notified** that this prioritization issue was resolved or was to be resolved?

  o How were they notified?

- Describe a typical occurrence of **prioritizing** trays.

  o How is a tray prioritized?

- Did this lead to any **cascading failures** down the line?

- How do you **pass along** the prioritized trays?

    o Who do you inform that the trays have been successfully prioritized?

    o If there is an issue, who is **informed** immediately?

    o **How do you inform** the appropriate parties after successful prioritization?

    o **How do you inform** the appropriate parties when there is an issue?

- Is there an area of prioritization that we have yet to discuss?

3. Tray assembled

Can you tell me about a time where you had to do something differently regarding tray assembly?

- How did you **know** that this problem was occurring?

- How was this situation **different** than the usual workflow for assembly? (Define problem)

- How did this **affect** your workflow? (now)

- What did you have to do differently to **get back on track**? (recovery)

- How **common** is this? Does it **always happen** this (different) way?

- Did this **delay** the overall assembly process?

    o If so, how did you handle this delay?

- If you were the one to discover the problem, how would you relay that information to other people in the process? (Info flow for coordination)

- Who else would need to know, or would want to know, about this situation? What are they concerned about? (Info flow for coordination)

- How do you know when you're done with the assembly of that tray? (process)

- Does a completed tray trigger any sort of communication to your coworkers? (coordination)

4. Bioburden inspection

Can you tell me about a time where there was a **breakdown** of communication involving bioburden inspection?

- **How** did you know this breakdown was happening?

- Who did you inform about this issue?

- How did you communicate this?

- Is this how information is **typically** communicated during this step?

- Has this happened before?

   - If so, how did you handle this specific instance **differently** than the previous occurrence?

- Can you tell me about a time when an instrument in a tray you assembled needed **rework**?

   - In this scenario, **who** did you inform?

   - **How** did you inform them?

   - How does this affect the **downstream process**?

   - How do you document that a tray needs rework?

5. Cannulated instrument identification

Can you tell me about a time when there was a **problem** related to cannulated instruments?

- **How** do you **find** out that a particular tray has a cannulated instrument? (communication/workflow)

  - ○ Have you ever opened up a tray and been surprised to find one?

  - ○ **Who** do you inform if there is a "surprise" cannulated instrument?

- How was this situation **different** than usual?

  - ○ What are the **unique** assembly concerns for the cannulated instruments?

  - ○ How does a problem with a cannulated instrument **affect** your **workflow** any **differently** than a non-cannulated instrument?

- If a cannulated instrument is found with excessive bioburden, **what would you do**?

  - ○ **Who** would need to know, or want to know, about that instance? What would they be **concerned** about?

- What was the **outcome** of this problem?

  - ○ How did this situation affect the **downstream** processes immediately? Later on?

- How **common** is this issue? Does it always happen this (different) way?

- Is there anything else you'd like to discuss concerning cannulated instruments?

6. Missing instrument check

- Could you tell me of a time when you discovered a tray was missing an instrument?

    - **How** did you learn an instrument was missing?

        o (SPM?)

        o (Decon?)

        o (First-hand?)

        o (OR after the fact?)

    - What are your first **steps after** finding the missing instrument?

        o **Who** do you tell about the missing instrument?

        o Do you need to **record** any data about this tray?

    - How does this **interrupt** your normal workflow?

        o Is the situation usually **easily** fixed?

        o What takes the most amount of **time** when dealing with a missing instrument?

    - How do you know if an instrument can be readily replaced?

        o Do you ask your coworkers/managers for help in finding a replacement?

    - If it can't be immediately **replaced**, what do you do?

        o Do you order the replacement?

        o Is the missing instrument just **logged** through SPM?

        o If not, how is this recorded?

- What is the **worst-case** scenario with a missing instrument?

    o (OR rescheduling?)

    o (Getting significantly behind on tray assembly?)

- Is there anything else you think is important to mention regarding missing instruments in tray assembly?

7. In-house repair identification

- Will you walk me through a time where you found a broken instrument with the tray you are about to assemble?

- What are your **first steps** after finding the broken instrument?

    o **Who** do you tell about the broken instrument?

    o **How** did you inform them?

    o Do you need to **record** any data about this tray?

- How does this **interrupt** your normal workflow?

    o Is the situation usually easily **fixed**?

    o If **not**, how do you and the rest of your team respond?

    o What takes the most amount of **time** when dealing with a broken instrument?

- **How** do you know if an instrument can be readily replaced or fixed in-house?

    o Do you need to **tell** someone if you take a replacement instrument or utilize the in-house repair shop?

        ▪ Who do you tell?

- How do you tell them?

- If it can't be fixed in-house, how do you go about **scheduling** an offsite repair?

  - Does this occur through management?

- What is the worst-case scenario with a broken instrument?

  - (OR rescheduling?)

  - (Getting significantly behind on tray assembly?)

- Is there anything else you think is important to mention regarding broken instruments in tray assembly?

8. Inventory and assembly storage area checked (any)

- Could you tell me about a time when tray storage didn't go exactly according to **plan**? For example, maybe a tray wasn't in the right place or there was not enough room to store a tray? (OFF-NOMINAL)

- In your example, how did you become **aware** of the situation? (INFORMATION FLOW / SHARED AWARE.)

  - Should you have found out in a different manner? (WAI)

- If you do find a tray in the wrong location, would you normally **relocate** it right away? (PRESSURES)

  - How does this issue **affect** your work-routine? (WORKAROUND DURATION)

- Have you ever **had** to store a tray in the "wrong area"? (QUICK DECISIONS / TRADE-OFFS)

- What situations would cause you to not store a tray in its designated storage area? (TRADE – OFFS)

  - Is this a common issue? (PREVALENCE)

- If you relocate a tray because of storage issues, do you let anyone **know**?

  - Why do you let them know?

  - How did you inform them?

- What **effects** do these issues have on building carts for the ORs?

- Is there anything else you'd like to talk about concerning trays checked into storage?

9. Off-site location instrument repair check

- Can you tell me about a time when the process for off-site repair of broken instruments **didn't go** the way it usually does? (OFF-NOMINAL)

- What are the different ways the **process** usually happens? Or the usual way it happens? (NOMINAL, VARIATION)

  - WAI: identify broken instrument à transport to pick up location à offsite repair à return to hospital à return to SPD instrument (à = Before)

  - WAD:

  - Is this information captured or stored in any kind of **document or report**? (INFO ARTIFACT)

- How did the off-site repair station **know** that there were instruments to be picked up? (DETECT)

- o Are there **other ways** they could find out?

- Is there someone who "owns" that process or is the **point person** for that process? (RESPONSIBILITY)

  - o If yes, how does it work when that person is unavailable or overwhelmed? (CONTINGENCY)

- How do the broken instruments **get to** the pickup location? (NOMINAL)

  - o Can you tell me about how these instruments are **tracked**? Or who **knows** that instruments are going and coming? (INFO ARTIFACT)

  - o Can you tell me about a time when that tracking process **didn't go** as expected? What happened to that/those instruments? (OFF-NOMINAL)

- Can you tell me a bit more about how the instruments **get back** to the hospital? (NOMINAL)

  - o Is there any communication from the off-site repair place about the **status** of the instruments they're working on, or are done with? (DETECT, INTERPRET)

  - o Do you have an expected **turnaround time** for repairs? What are you concerned about, and what do you do, when it's been longer than that time? (INTERPRET)

  - o **Who** else needs to know, or often wants to know, about the status of broken instruments? What are they **concerned about**? (TEAM, GOALS)

- Is there anything else we should know about broken instruments, or the off-site repair process, that we haven't asked about?

10. Sterile indicator placed in tray

- Can you tell me about a time when there was a **problem** at some point in the process of the indicator being placed in the tray? (OFF-NOMINAL)

- How does that process **usually go**? (NOMINAL)

    o Is this information captured or stored in any kind of **document or report**? (INFO ARTIFACT)

    o **What else can happen** during the process that can become a problem? (OFF-NOMINAL, VARIATION)

- How did you (or someone with another role in the process) come to **find out** that there was a problem with the indicator? (DETECT)

    o Are there other people in the process who could (be the first to) **discover** a problem with the indicator? (DETECT)

        ▪ How would they **know** there is a problem? (INTERPRET)

    o Is this information captured or stored in any kind of **document or report**? (INFO ARTIFACT)

    o How does an indicator problem **affect** your workflow? (RESPOND)

        ▪ Is it something that needs to be **addressed now**, or can it wait? (INTERPRET, RESPOND)

- Do you **always find out** when there are problems with the indicator? (DETECT)

    o What other kinds of **problems** might you encounter with indicators? (OFF-NOMINAL)

- **Who** else in the process needs to know, or often wants to know, about indicators? (TEAM, GOALS)

    o What happens when you're **running low** on indicators? (NOMINAL)

        ▪ Has the department ever **run out** of indicators? (OFF-NOMINAL)

        ▪ How would you **know** if there is a bad batch of indicators? (DETECT)

    o **Who** do you get phone calls from about indicators? What are they **concerned about**? (TEAM, GOALS)

- Can you tell me about the process for **documenting** anything about the indicators? (INFO ARTIFACT)

    o E.g., tracking of lot numbers

    o E.g., problems with indicators

11. Transition steps

    Can you tell me about a time when the process for sanitizing trays **didn't go** the way it usually does? (OFF-NOMINAL)

- How did you (or someone in another role) come to **find out** something was different? (DETECT, INTERPRET)

  - Is this information captured or stored in any kind of **document or report**? (INFO ARTIFACT)

- What does the **process** usually look like? (NOMINAL)

  - How is this **different** than the work of sanitizing **instruments**? Are scopes and cameras also sanitized differently? (NOMINAL)

  - Are there other ways the tray sanitizing **process breaks down**? (OFF-NOMINAL)

    - Are there other points where you or your coworkers sometimes have to **intervene** to get the process back on track? (RESPOND)

  - Is this information captured or stored in any kind of **document or report**? (INFO ARTIFACT)

- **Who** needed to know, or would have wanted to know, about the different situation with sanitizing the trays? What would they have been **concerned about**? (TEAM, GOALS)

  - How would they have been **notified**? (DETECT)

- What was the first thing you thought of when this happened? (INTERPRET)

- - Or what were you (**immediately**) **concerned about**? (INTERPRET)

  - What needed to be done? How did you help **mitigate** the situation or fix the issue? (RESPOND)

    - What was in the front of your mind for what needed to be done? (INTERPRET)

    - How did you **manage** your other work while you were dealing with this situation? (INTERPRET, RESPOND)

    - What were your coworkers or your supervisor doing while this was happening? (TEAM, RESPOND)

      - What were they trying to achieve during this time, related to this problem? (TEAM, GOALS)

- How do different people in the process know the **status** of the trays at any point? (DETECT)

  - E.g., when a tray is sanitized and ready for Assembly

  - Does that notification system ever **break down**? Can you tell me about a time? (OFF-NOMINAL)

  - Are there any points in the notification process that would be especially **troublesome** if they were to break down? (INTERPRET)

Charge Nurses Questions (Nurse in Charge)

- Can you tell me about a time when communication broke down within your department? (OFF-NOMINAL)

- What **signaled** to you that there was a problem? (DETECT)

- How do you **expect** to find out about a problem like this? (INTERPRET)

- Are there **other ways** that you would know that a tray is waiting at the window? (NOMINAL)

- How did you receive the information that signaled to you that there was a problem at hand?

- How was this information stored? (INFO ARTIFACT)

- Had this situation happened **before**? (OFF-NOMINAL)

  - How did you **learn** about the problem then? (DETECT)

  - How were you **able to solve** the problem then? (INTERPRET, RESPOND)

  - Were your managers and/or co-workers part of that solution? (TEAM, GOALS)

- Did this issue **delay** your workflow in the short-term? Long-term? (TIME)

  - How do you communicate any delays to workers "down the line"? (RESPOND)

  - Was there any way you could work around the hold up? (OFF-NOMINAL, RESPOND, NOMINAL)

- Was this issue something you needed to fix or initiate a fix right away? Later? What was your thought process for that? (INTERPRET, RESPOND, GOALS)

- Are there other types of communication breakdown / other ways communication breaks down between the two areas? (OFF-NOMINAL)

- How did you know that a tray was passed through in that instance? (DETECT, SHARED AWARENESS)

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