Balancing the Human Touch with the Need for Integrating Technology in Ambulatory Surgical Environments: Barriers and Facilitators to Nursing Work and Care Team Interactions

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ABSTRACT

Ambulatory surgical environments are dynamic and complex, involving coordination across multiple groups of care providers and requiring numerous sources and handoffs of information. As in other areas of healthcare, these settings have grown increasingly complex over the years with the integration of new equipment and technology such as electronic medical records. However, little thought has been given to the design of workspaces in these settings to support evolving work processes and emerging technologies. The purpose of this research study was to understand nurses’ work patterns in preoperative and postoperative workspaces of ambulatory surgery centers, and to identify environmental design strategies that support or act as barriers to critical interactions between care teams due to the integration of new technologies. In-depth case studies were conducted at two ambulatory surgery centers using a multimethod approach consisting of behavior mapping, shadowing, spatial analysis, and semi-structured interviews with nursing staff. The study data were collected over two consecutive days at each site. The majority of patient care activities such as bedside care and charting were carried out directly with the patient in the patient bays. Nurses were observed standing or walking for approximately 70% of the observations, and face-to-face interactions were dominant in both case studies regardless of the technology implemented. Key environmental facilitators and barriers to nurses’ work in surgery centers include: accessibility, flexibility, visibility, size, and privacy. Architects and interior designers can play an important role in designing human-centered work environments for nurses in surgical settings that effectively support the critical tasks and interactions that must take place. Designing work systems requires a human-factors approach to design that examines the range of activities, interactions, people, technology, and design of the workspace and its elements.

Background

The number of surgical procedures conducted in outpatient environments, such as ambulatory surgery centers (ASCs), has risen significantly over the last couple of decades due to changes in the Medicare reimbursement policy, with more than 3600 types of procedures being performed in over 23 million surgeries annually (Ambulatory Surgery Center Association, 2016). This rapid growth has been supported through innovations in technology and advances in surgical and anesthesia techniques, allowing surgical procedures that once required lengthy inpatient hospital stays to now be performed in outpatient settings where the patient is able to go home the same day (Cullen, Hall, & Golosinskyi, 2009). Benefits associated with increased efficiency...
While there is a growing body of research on inpatient environments, there is a dearth of research to support the design of these rapidly proliferating ambulatory surgery environments being built across the country.

Ambulatory surgical environments are dynamic and complex, involving coordination across multiple groups of care providers and requiring numerous sources and handoffs of information (Ren, Kiesler, & Fussell, 2008). Additionally, ASCs are technology-intensive environments with a range of equipment and technology used for care delivery. Any breakdowns or interruptions in this carefully calibrated and planned system can result in significant delays that not only have financial implications for the health-care organization, but may also impact patient care quality, safety, and satisfaction (Coiera, 2006). Effective management of the flow of information, people, supplies, and equipment is critical to successful operations in this environment.

However, ambulatory surgical environments also need to be very human-centered and customer-oriented in design. Patients and their families are often stressed and anxious about upcoming procedures and their potential outcomes (Trimm & Sanford, 2010). This is especially true for pediatric patients and their families. In addition to providing patient care, nurses are regularly educating patients and care partners about the intended process (or follow-up postsurgery) to alleviate unnecessary fears and concerns (Sadeghi, Nayeri, & Abbaszadeh, 2015).

The need for efficient coordination of information, supplies, and equipment as well as effective collaboration with patients and their families are constantly at play in the work of surgical nurses. Research conducted in other health-care settings clearly shows the impacts of the design of the built environment on health-care outcomes, including staff efficiency, patient stress, and satisfaction (Ulrich et al., 2008). However, there is nominal research on how the built environment of ambulatory surgical environments impacts critical interactions between patients, staff, and families. This study seeks to explore these relationships, focusing on the environmental barriers and facilitators to interactions, with the intent of informing future research and design in ambulatory surgery settings.

Environmental Facilitators and Barriers to Interactions

Very little research has focused on staff-to-staff interactions within preoperative (preop) and postoperative (postop) environments in surgical settings, and none was found that looked at the role of the physical environment on staff interactions and behaviors. However, research conducted in other health-care environments suggests that the physical layout of clinical workspaces can impact interactions between staff members. For example, Coiera and Tombs (1998) observed inefficiencies within team communication, as well as difficulties with cooperative tasks due to geographic separation between teams. When looking at communication practices in three Australian hospitals, Gum, Prideaux, Sweet, and Greenhill (2012) found that both physical and visual distance impedes interprofessional communication between health-care team members. A study conducted by Cai and Zimring (2012) in two neurology intensive care units found that increased visual proximity between peers and teamwork increased awareness between care team members. These findings suggest that design strategies focused on reducing visual and physical distances between team members can increase efficiency and effective communicative practices between care team members.

Technology Integration

The move to electronic health records and the use of computers and other technology in health-care
This study aims to fill a crucial gap by understanding the relationship between the design of the built environment of ASCs and the critical interactions between care nurses, patients, and care partners.

settings (including ASCs) has significantly changed workflows and processes. Technology is increasingly being used to complement and even replace the need for face-to-face communication in health-care facilities (Parker & Coiera, 2000). For example, wireless communication devices and hands-free communication devices (HCDs), such as Vocera, allow nurses to communicate verbally with team members even if they are in different spatial locations (Richardson & Ash, 2010). While HCDs may allow for more decentralized workspaces and spatial configuration by helping to mitigate large distances placed between staff due to expansive floor layouts, it is not clear whether such layouts and technologies result in fewer face-to-face interactions between nursing staff and the consequences, if any, for team dynamics and staff satisfaction (Tang & Carpendale, 2009; Yang & Rivera, 2015).

While these new technologies are being rapidly implemented by many health-care organizations, in most cases, little thought has been given to the impact of this new technology on user ergonomics, resulting in severe workflow and safety challenges. For example, a qualitative exploratory study of 20 attending physicians at two Midwest hospitals found postimplementation of the hospitals’ electronic health records systems often cluttered workspace due to the placement of new technology into old spaces, lacked privacy during computer use, left insufficient space for paper charting, and resulted in computer stations ill-suited to tall users—all factors within the physical environment that compromised or prohibited the physicians’ ability to deliver quality care (Holden, 2011a, 2011b).

Impact of Technology on Interactions

There is some research that shows how the design of the built environment impacts interaction between health-care staff and patients in outpatient environments. A study by Almquist et al. (2009) evaluated how a design intervention in an outpatient clinic focusing on the placement of the computer screen, seating arrangement, and the type and position of the desk influenced patient and care partners’ perceptions of their visit. Findings from this study suggest that patients in the room with the design intervention had a significant increase in their ability to see the computer screen. Additionally, patients in the design intervention room reported increased sharing of information from the medical record and the internet between patients and clinicians when using the computer. An investigation by Pearce, Dwan, Arnold, Phillips, and Trumble (2009) found that the addition of the computer into the consultation room influences patient and clinician interactions by changing the nature of the relationship. McGrath, Arar, and Pugh (2007) found that physicians’ ability to express non-verbal communication that conveyed attention and understanding was increased when the physician’s physical position in relation to the computer screen allowed for eye contact with the patient as well as the computer screen, and the physician took “breakpoints” of sustained eye contact in between data entry during the medical interview. Findings from these studies suggest that patient care spaces should incorporate design strategies that support information sharing between patient and provider through the strategic placement of information displays.

As more inpatient surgical procedures move to the outpatient environment, patients and their care partners become increasingly responsible for both the preparation and recovery stages of the surgical process. This creates a need for spaces within ASCs that can support education and training to assist patients and their care partners during the preparation and recovery phases. No research was found that specifically examined how ASCs’ built environments impact the critical interactions between patients, staff, and care partners. This study aims to fill a crucial gap by understanding the relationship between the design of the built environment of ASCs and the critical interactions between care nurses, patients, and care partners.

Study Objectives

ASCs are complex environments where the increasing use of technology is significantly changing patterns of
interactions between the care team (care providers, patients, and care partners). The purpose of this research study was to identify environmental design strategies that support or act as barriers to critical interactions between care teams and to address the impacts of technology when integrated into existing workspaces on care team interactions. Specifically, this study seeks to address these questions:

1. What are the types of interactions between staff as well as staff and patients/care partners in the preoperative (preop) and postoperative (postop) workspaces of ASCs, and where are these interactions occurring?
2. What are the characteristics of the spaces that either support or impede these interactions?
3. How does spatial layout and configuration impact the integration of technology, such as electronic medical records and associated work processes, in ASCs?

Methods

Study Design

This study examined the impact of the built environment on interactions and movement patterns of nursing staff in the preop and postop spaces of two ASCs. In-depth case studies were conducted using a multimethod approach consisting of behavior mapping, shadowing, spatial analysis, and semi-structured interviews with nursing staff. Both facilities studied are part of a large health system in South Carolina. This study received approval from the health-care organization’s institutional review board. The protocol was pilot tested at both sites prior to conducting the study. During the pilot, adjustments were made to the behavior mapping codes to ensure ease and accuracy of data collection. Researchers found it difficult to identify staff members other than preop and postop nurses during behavior mapping sessions without interacting with the staff. As behavior mapping is a form of nonparticipant observation, behavior mapping codes in the person category referring to staff members other than preop and postop nurses were compressed into an “other” category (see list of persons in Table 1). In addition, the researchers observed, after conducting multiple test interviews at both sites, that the use of imagery during the interview process would be helpful for staff to identify in detail the ways in which their workspace inhibited or supported their ability to perform their work. The structure of the interviews was redesigned to incorporate photo elicitation. The amendments were approved by the Institutional Review Board (IRB).

Settings and Subjects

This study was conducted in the preop and postop areas of two freestanding ASCs within a large health system in South Carolina. Figure 1 and 2 show the layout and description of each study site with a focus on the preop and postop spaces. As part of a larger health system, each surgery center had similar operational and managerial protocols. Both had undergone the transition from paper records to an electronic medical record system two weeks prior to the research study, providing a unique opportunity to assess how the design of the workspace supported the initial integration of the new technology into the physical design.

Site 1 was built in 1990. It has seven preop and seven postop bays, with one of the postop bays flexing between preop and postop, and four operative suites. The preop area has two workstations, one of which was retrofitted to be a preop bay. The postop area contains a central nurse station as well as three additional smaller workspaces. A shared storage room and linen station are located between the preop and postop areas. Additionally, the postop area contains two private consultation rooms and a nourishment station for patient care. The preop and postop areas are connected by an L-shaped corridor that serves both patient and staff flow in and out of the Operating Room (OR).

To assist in the implementation of the electronic medical record system, each preop and postop bay has a designated work on wheels (WoWs) station
### Table 1. Behavior mapping and shadowing codes and definitions

<table>
<thead>
<tr>
<th>Person</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Patient</td>
<td>The person who is having an operative procedure. This includes adults and children</td>
</tr>
<tr>
<td>Care partner</td>
<td>The person(s) accompanying the patient during the surgery process. This includes family members and friends</td>
</tr>
<tr>
<td>Preop nurse</td>
<td>The staff member who is guiding the patient care process within the preoperative area</td>
</tr>
<tr>
<td>Postop nurse</td>
<td>The staff member who is guiding the patient care process within the postoperative area</td>
</tr>
<tr>
<td>Other</td>
<td>Staff members of unknown designation consisting of surgeons, anesthesiologists, OR nurses, charge nurses, nurse anesthetists, and administrative personnel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Posture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>An individual who is upright and not moving</td>
</tr>
<tr>
<td>Sitting</td>
<td>An individual who is in a seated position</td>
</tr>
<tr>
<td>Walking</td>
<td>An individual who is upright and moving</td>
</tr>
<tr>
<td>Other</td>
<td>An individual who is pushing medical equipment or patients, bending down, or reaching to perform activities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Behavior mapping activities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer work</td>
<td>The use of laptops, WoWs, desktop computer in the preoperative and postoperative areas</td>
</tr>
<tr>
<td>Paperwork</td>
<td>The use of paper forms, charts, and consents during the preoperative and postoperative care process</td>
</tr>
<tr>
<td>Patient care</td>
<td>Activities related to admission, preparing patient for procedures, discharge instructions, and consultation</td>
</tr>
<tr>
<td>Talking to person</td>
<td>Face-to-face verbal communication between individuals</td>
</tr>
<tr>
<td>Room preparation</td>
<td>Activities related to preparing the patient room or bay. This includes moving and adjusting beds, refreshing linens, cleaning surfaces</td>
</tr>
<tr>
<td>Listening</td>
<td>Face-to-face communication where an individual is engaged and focused while another person is talking</td>
</tr>
<tr>
<td>Other</td>
<td>Activities related to general cleaning, eating, using electronic devices, talking on the phone, and reading</td>
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<table>
<thead>
<tr>
<th>Shadowing activities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charting</td>
<td>Care assessments, reports, charts, reviewing and clarifying orders. Includes time needed to fax orders, find charts, and communications related to clarify orders and medications</td>
</tr>
<tr>
<td>Reporting</td>
<td>Reporting to team update on patients. Includes vitals, goals, and care status during the outpatient surgical process</td>
</tr>
<tr>
<td>Coordination</td>
<td>Planning, organizing, and scheduling of patient procedures, tests, and services. This activity will include the time spent to physically locate team members, supplies, forms, or equipment</td>
</tr>
<tr>
<td>Medication</td>
<td>Activities related to medication preparation</td>
</tr>
<tr>
<td>Supplies</td>
<td>Activities related to retrieving or distributing supplies</td>
</tr>
<tr>
<td>Bedside care</td>
<td>Patient care in the patient room, bay, or hallway in close proximity to the patient’s room, such as transport</td>
</tr>
<tr>
<td>Socializing</td>
<td>Activities related to nonwork issues</td>
</tr>
<tr>
<td>Preparation</td>
<td>Activities related to preparing patient for procedure. Includes surgical site preparation, anesthetic preparation, and lab tests</td>
</tr>
<tr>
<td>Admission</td>
<td>Patient admission activities, including administrative functions and communications</td>
</tr>
<tr>
<td>Discharge</td>
<td>Patient discharge activities, including administrative functions and communications and follow-up care instructions</td>
</tr>
<tr>
<td>Consultation</td>
<td>Reporting to care giver(s) and/or patient the status of surgical procedure. Includes time spent providing instructions for home care</td>
</tr>
</tbody>
</table>
Figure 1. Spatial configuration of preoperative and postoperative areas and workstations in Site 1.

Site 1

- Total area facility (GSF): 15,882 SF
- Total area pre-operative (NSF): 1,544 SF
- Total area post-operative (NSF): 1,799 SF
- Size of pre-op bays (NSF): 83 SF
- Size of post-op bays (average NSF): 62 SF
- Size of central workstation pre-operative (NSF): 83 SF
- Size of central workstation post-operative (NSF): 148.7 SF
- Width of hallway (NSF): 8’
- Distance between central pre-operative and post-operative workstations (Walking Distance): 60’

Site 1: Pre-op station
The central nurse station is a retrofitted pre-operative bay. While the visual display is visible to staff from a standing position, it is difficult to read from the charge nurse’s workspace.

Site 1: Post-op station
The central nurse station has visibility to all post-operative bays and serves as the coordination hub between pre-operative, post-operative, and operative staff.

Site 1: Pre-op bay
To accommodate the transition to electronic medical records, each pre-operative bay has a WoW for electronic charting and a bedside table for signing paper consents and setting supplies.

Site 1: Post-op bay
Wows are moved between post-operative bays, and can be adjusted to accommodate standing or seated positions.
Figure 2. Spatial configuration of preoperative and postoperative areas and workstations in Site 2.

Site 2

- OR
- PRE-GP
- POST-OP
- STAFF WORK AREA
- FLEX
- CONSULTATION ROOM
- PLAY ROOM
- WAITING ROOM

<table>
<thead>
<tr>
<th></th>
<th>Site 2: Post-op bays</th>
<th>Site 2: Post-op station</th>
<th>Site 2: Pre-op room</th>
<th>Site 2: Pre-op station</th>
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<tr>
<td>Total area facility (GSF)</td>
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<td>Total area pre-operative (NSF)</td>
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<td>Total area post-operative (NSF)</td>
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<td>Size of pre-op bays (NSF)</td>
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<td>Size of post-op bays (average NSF)</td>
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<td>Size of central workstation pre-operative (NSF)</td>
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<td>Distance between central pre-operative and post-operative workstations (Walking Distance)</td>
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</tbody>
</table>

Each post-operative bay or room has a WO/W. Supplies for patient care are stored in the moveable drawers.

The central nurse station is a congregating area for post-operative and operative staff, and serves as the coordination hub for staff in pre-operative, post-operative, and operative areas.

Adjustable workstations were integrated into each pre-operative room to accommodate the transition to electronic medical records.

The central nurse station serves as a landing spot for pre-operative and operative staff. Medications are stored in the back area of the station.
and a bedside table, as well as desktop computers at the central and smaller workstations. During the 2 days of data collection, 38 surgical procedures were performed (26 on Day 1 and 12 on Day 2), with a total of nine staff working in the preop and postop areas (four nurses in preop, four nurses in postop, and one preop nurse who transitions to postop during the course of the day).

Site 2 was built in 2000. It has nine preop rooms, six postop bays and two postop rooms, and six operative suites. Both the preop and postop areas have a central nurse station, supply closet, medication dispenser, and linen station. The postop area contains windows with adjustable shades along the headwall of the patient bays, which allow for controlled natural lighting and views of the outdoors. Additionally, the postop area has one smaller workstation, three rooms that flex between preop anesthesia procedures, such as blocks and postop care, and a nourishment station for patient care. Four consultation rooms are also integrated into the postop area. The pre- and postop areas are separated by a hallway that serves as an offshore passage for staff between the OR and support areas while separating patient flow in and out of the OR.

Within the preop area, a playroom provides toys, games, and learning materials for children waiting to undergo a procedure and their family members. Wall-mounted, adjustable workstations were placed into the preop rooms to accommodate the new electronic medical record system. In addition, four WoWs were placed outside the preop rooms to provide additional space for physicians to chart. In the postop area, each bay or room has a designated WoW in addition to the desktop computers at the central and smaller workstations. During the two days of data collection, 48 surgical procedures were performed (25 on Day 1 and 23 on Day 2) with a total of 11 staff working in the preop and postop areas (five nurses in preop, six nurses in postop, and one preop nurse who transitions to postop during the course of the day). Data were collected from all nursing staff working in the preop and postop areas of the two ASCs.

Data Collection Process
The study data were collected over two consecutive days at each site. The days were selected based on typical throughput and workflow variations experienced within the individual sites. Both sites were visited on two occasions prior to data collection to obtain general facility information, photographs, and for pilot testing. The methods used in this study include behavior mapping, shadowing, spatial analysis, and semi-structured interviews with staff.

Behavior Mapping
Behavior mapping is a systematic observational method for assessing behavioral dynamics in relation to the physical space of the built environment (Cosco, Moore, & Islam, 2010). For this study, behavior mapping was conducted to capture patterns of staff distribution and interactions between staff and other participants, as well as the various types of activities that staff members engage in during the preop and postop stages of the outpatient surgery process. Behavioral observations at each site were recorded early morning, mid-morning, late morning, and early afternoon on two different days by one researcher. Each behavior mapping session consisted of four 40- to 100-minute rounds of behavioral observations along a predetermined route at designated observation locations. At each observation location, the researchers observed the designated field of view in a counter-clockwise motion (Figures 1 and 2). Any behavioral observations simultaneously occurring outside the researchers’ predetermined field of view were not collected.

The behavior variables of interest were the various types of activities in which the individuals engaged; the individual’s posture during the activity; and the interactions between staff, patients, and caregivers (Table 1). Coding criteria and definitions were developed based on literature review (Gurascio-Howard & Malloch, 2007; Patel, Pettitt, & Wilson, 2012). In addition, the role and gender of each participant were recorded. All individuals at the surgery center in the waiting/registration areas and preop and...
Researchers chose the staff member to shadow based on availability and area in which they delivered care to ensure equal distribution between the preop and postop observations.

postop areas were included in the behavior mapping. For this study, only the data points associated with preop and postop nurses were selected for analysis. Although one researcher collected behavioral observations during this study to test the predetermined codes for interrater reliability, two researchers simultaneously conducted observations in one area of the facility. During this observation session, high interrater reliability was achieved with an intraclass correlation coefficient of 0.939.

Each round of behavioral observations lasted between 40 and 100 minutes depending on the number of scheduled surgeries at the time of the day the observation was conducted as that impacted the number of people that needed to be coded in the different spaces. In total, 80 rounds of behavioral observations were collected between the two sites. The research team employed DOTT® (Detailed Observation Task and Time), a proprietary application developed by BBH Design, to collect behavioral observation and time–motion data via tablets (http://www.dott-tool.com/app). The DOTT application, containing floor plans of each site along with the variables of interest, was uploaded on to a hand-held tablet. All behavioral observations were then recorded on the tablet by the researcher. During behavior mapping, the researcher marked a dot on the plan to indicate the position of the observed participant. The researcher then selected role, gender, activity, and posture from predefined drop down menus. Upon entering the data, each observation was automatically date and time stamped, and the spatial location of the observation was identified through x, y coordinates. The DOTT tool allowed for the data to visualize instantly, displaying relationships between the variables of interest through graphs, charts, and spatial locations in the plan.

**Shadowing**

Preop and postop nurses were shadowed to obtain an in-depth understanding of the types of activities they performed and the location of those activities during patient care encounters at each site between the hours of 6:00 a.m. and 4:00 p.m. on two different days by one researcher. Shadowing is a qualitative observational method that captures the intricacies of a specific experience by linking an individual’s actions with the purpose behind those actions (McDonald, 2005). Each shadowing session was conducted in 2-hour increments during the early morning, mid-morning, early afternoon, and mid-afternoon and started when the nurse was receiving a new patient. All patient care activities, along with the location and duration of the activity, were recorded during the observation period (Table 1). Coding criteria and definitions were developed based on a review of the literature (Gurascio-Howard & Malloch, 2007; Patel et al., 2012). The role and gender of each participant were also recorded. Additional information pertaining to an activity that fell outside the predetermined codes was captured in a comments section associated with the observed activity.

If a patient had been taken into the operating room (OR) or discharged, and the nurse being shadowed was no longer involved in patient care activities (i.e., waiting for the next patient to arrive), the observations were stopped until a new patient arrived or the 2-hour shadowing session was completed. Researchers chose the staff member to shadow based on availability and area in which they delivered care to ensure equal distribution between the preop and postop observations. A total of 21 hours of shadowing data were collected between the two sites, with 11 and 10 hours collected in the preop and postop areas, respectively.

Data were collected using the DOTT application described earlier. An observation was recorded each time the staff member changed either location or activity. For the shadowing observations, activities were not mutually exclusive. Therefore, multiple activities could be entered in the same location. Each activity was date and time stamped and took approximately 10 seconds to enter into the hand-held tablet. Any activity that occurred while entering a prior observation into the application was not included.
... the DOTT interface was particularly useful for visualizing the location of nurses over the course of a day or identifying where certain types of activities or interactions took place.

**Interviews**

During nonpeak times of patient volume in the preop (mid-afternoon) and postop (early morning) areas, semi-structured qualitative interviews were conducted, with staff using photo elicitation to gain contextual insights into the nature of their work. Photo elicitation is a method for interviewing that uses imagery to support collaboration between the individual being interviewed and the researcher by guiding the dialogue of the interview based on the authority of the individual being interviewed rather than the researcher (Harper, 2002). Participants were asked the following questions to capture their roles, the tasks they perform, and ways in which their workspace supports or inhibits their work performance:

- *In your current role, what tasks do you most commonly perform?*
- *Where are you most likely to perform those tasks?*
- *In what ways does your workspace support your ability to perform those tasks?*
- *In what ways does your workspace inhibit your ability to perform those tasks?*

During the interviews, the interviewer took photographs that highlighted the workspace characteristics referenced by the staff as either supporting or inhibiting their work. Both the staff member and researcher then collectively annotated the images using the Skitch app, which allows text and graphic elements to capture staff perceptions of the space. Interviews lasted between 15 and 20 minutes, were audio recorded, and transcribed for analysis. Annotations from the images were also included in the analysis.

**Analysis**

The data collected via DOTT were sorted and visualized directly on the DOTT interface to analyze patterns and identify preliminary findings. For example, the DOTT interface was particularly useful for visualizing the location of nurses over the course of a day or identifying where certain types of activities or interactions took place. The behavior mapping and shadowing data were also exported as an excel file and then moved to SPSS for further analysis. Descriptive statistics and cross-tabulations were run to obtain an understanding of patterns of behavior (activities, interactions, and postures) in space. Additionally, the shadowing data were further organized as direct care activities (conducted in the bays with the patient) and support care activities (conducted during the patient care experience but outside the bay) and analyzed further to understand the behavior of nurses during these two broad categories of activities.

The plans of both sites were analyzed in detail to obtain key information about overall square footage of preop and postop spaces, size of individual bays, location and size of central and decentralized nursing work areas, distance between central preop and postop nurses’ stations, and width of corridors. Also, the plans of the patient care bays were drawn up with furniture in use during staff patient interactions in order to do a spatial ergonomics analysis of the space usage during interactions.

Interviews were transcribed verbatim and analyzed using qualitative content analysis (Hsieh & Shannon, 2005) for statements pertaining to facilitators or barriers. Facilitators and barriers were considered factors, conditions, or circumstances within the workspace that enhanced or impeded staffs’ ability to provide quality patient care, respectively. The identified facilitators and barriers were then divided into individual workstation and central nurse station groups for each site. From these statements, the following four categories of facilitators and barriers were identified for both sites for both types of workstations (individual workstation and central nursing station): (1) accessibility, (2) flexibility, (3) visibility, and (4) size. In addition, a fifth category was identified in Site 1 pertaining to privacy. At each stage in the coding process, the codes were reviewed by both the first and second authors to ensure agreement before moving to the next stage in the coding process.
Findings
At Site 1, 1758 behavior observation data points were obtained over the course of two days. Of these observation points, 268 (15.2%) were of preop nurses, and 235 (13.4%) were of postop nurses. The remaining data points were associated with patients, care partners, and other care providers (surgeons, OR nurses, anesthesiologists, and cleaning techs) who were not included in this analysis. From Site 2, 1257 data points were obtained. For Site 2, 72 data points (5.7%) were for preop nurses, and 242 (19.2%) data points were for postop nurses. The preop bays in Site 2 had doors, and when patients were present in the room, the doors were closed. A total of 30 such instances of “door closed” were recorded at Site 2. Thus, the preop nurses’ activities could not be recorded for those instances. Six nurses from preop and postop participated in interviews in Site 1 and Site 2, respectively. All nurses in the study were female.

For both sites, a combined total of 125 interview statements were identified as facilitators (40) or barriers (85). At Site 1, staff reported a total of 17 facilitators and 63 barriers, with 12 facilitators and 44 barriers at their individual workstations, along with 5 facilitators and 19 barriers regarding the central nursing station and surrounding areas. At Site 2, staff reported a total of 23 facilitators and 22 barriers. Nine facilitators and 15 barriers were reported by the staff regarding their individual workstations, while 14 facilitators and 7 barriers were reported for the central nursing station and surrounding areas.

Overall Workflow and Activities
Location of Nursing Staff over Time
There is a distinct ebb and flow of activities that can be observed at the surgery center over the course of the day. Figure 3 shows the locations of nursing staff in the preop and postop areas at both sites during different times of the day (early morning, mid-morning, late morning, and early afternoon). The preop area at both sites is significantly busier during the early morning (between the hours of 6:30 a.m. and 10:30 a.m.) as new patients are prepared for surgery. The trend is reversed in the early afternoon, with preop activities coming to an end by around 2:00 p.m. We observed preop nurses primarily in patient bays/rooms or corridors (Site 1) engaged with patient care activities and communication in the early morning and mid-morning. During late mornings and early afternoons, more preop nursing staff was observed in the central nurses’ station sitting down, taking a break, or talking to each other.

The postop area starts receiving its patients around 8 am and tends to be at its busiest between 10:30 a.m. and 3:30 p.m. depending on the volume of surgeries scheduled. The spatial location of nurses in their units also changes over the course of the day. In contrast with the preop nurses, postop nurses were observed congregating at the central nurses’ station or the satellite nurse station (Site 2) during early morning and late afternoon (end of day) when their patient care tasks are less intense.

Nurses indicated that there were no designated workstations where they worked during the course of their workday and that their work is in multiple, different locations. The following statements from the nurses highlight the diversity of locations and spaces for nursing work in ASCs.

There is no specific place. It is just wherever I am needed to go to. (Site 2 Postop Nurse)

My workspace is this entire hallway, all of it! (Site 1 Preop Nurse)

Distribution of Nursing Activities
The types of general activities that the nurses were engaged in were similar across both sites and also across preop and postop nurses. At both sites, the most common activity that was observed among all nurses was talking to someone in person (face-to-face) [Site 1 = 37% (preop) and 38% (postop); Site 2 = 47% (preop), 39% (postop)]. Listening was also noted as an activity for nurses at Site 1 (preop =
Figure 3. Staff flow within the preoperative and postoperative areas at Site 1 and Site 2 throughout the day.

Preop and postop nurse locations early mornings (6:30–8:00 am)

Preop and postop nurse locations mid morning (9:00–10:00 am)

Preop and postop nurse locations late morning (10:00–12:30 pm)

Preop and postop nurse locations early afternoon (1:30–3:30 pm)
The study found that the majority of interpersonal interactions for preop and postop nurses were with other staff members (around 66% at both sites). Together, these findings underscore the importance of face-to-face communication in healthcare. Computer work was also observed as a frequent activity among the nurses, especially at Site 1 (20% of all observations). This could potentially be attributed to the WoWs being visibly located in the corridors in Site 1, so staff activities related to charting were more observable as compared to Site 2 where the computer stations were inside the rooms or bays and not observable if doors or curtains were closed.

**Preop and Postop Nurses’ Postures**

Preop and postop nurses were on their feet (standing or walking) during a majority of the observations at both sites (Figure 4). At Site 1, more preop nurses were seen standing or walking as compared to postop nurses. The lack of space for chairs in the preop corridor at Site 1 and the nature of the tasks during preop (multiple, short duration tasks) may account for the difference. More postop nurses at Site 1 were observed sitting while charting. The WoWs were located in the postop corridor, and in some cases, nurses pulled up chairs to sit while charting and interacting with patients. However, the nurses were aware of the challenges of being able to incorporate chairs in the crowded postop area. According to one postop nurse at Site 1:

> If you have a patient and he’s going to be here a while and you need to be at the bedside, it would be nice to be able to sit, but it is just one more thing in the way.

One of the operational strategies adopted by Site 1 to facilitate an easier transition to the electronic charting system was the assignment of specific postop nurses to specific bays. Nurses were observed adjusting the height of the WoWs to their individual requirements (sitting or standing height). At Site 2, nurses indicated that chairs were not available to enable seated charting in the postop area as the charge nurse at Site 2 did not favor seated charting.

**Staff-to-Staff Interactions**

The study found that the majority of interpersonal interactions for preop and postop nurses were with other staff members (around 66% at both sites). A higher percentage of staff-to-patient interactions was observed in Site 1 (preop = 27%; postop = 35%) versus Site 2 (preop = 19%; postop = 23.9%), while the opposite was observed for staff to care partner interactions. Again, the closed doors in Site 2 might account for the fewer staff to patient interactions observed in Site 2.

**Location of Staff-to-Staff Interactions**

The central location of the nursing stations in both preop and postop at both sites made them popular gathering and landing places for all team members (nurses, anesthesiologists, surgeon, and techs). At both sites, most staff-to-staff interactions among preop nurses took place at the preop nursing stations (Site 1 = 50.6%, Site 2 = 53.6) and preop corridors (Site 1 = 29.9%, Site 2 = 39.3%). Similarly, at both sites, most staff-to-staff interactions among postop nurses took place in the postop nursing stations (Site 1 = 48.9%, Site 2 = 53.6%) or postop corridors (Site 1 = 38.6%, Site 2 = 39.3%). The most common activity observed among both preop and postop nurses during
The key themes that emerged around the design of the central workstations, such that they facilitated or acted as a barrier to staff activities, included accessibility, ... and access to outdoors and sunlight.

The L-shaped configuration of the unit in Site 1 where postop and preop bays are physically connected supports more interaction between the nursing teams as personnel move from one space to another and intermingle socially and professionally. In Site 2, a considerable distance physically separates preop and postop areas, and nurses have to move through three different doorways to travel from preop to postop areas and vice versa. Few instances were observed of preop nurses in the postop area and vice-versa. Nurses at Site 2 indicated during interviews that they primarily used Vocera to communicate with their colleagues in the other areas.

I do communicate with them usually 4-5 times a day. I call them on Vocera mostly, or walk over there. (Site 2 Postop Nurse)

Accessibility

At both sites, the nurses indicated several barriers to accessing supplies, equipment, and medication at different locations. For example, preop staff at Site 1 suggested that they could achieve greater efficiency if a printer was located closer in proximity to their workstations instead of being remotely located in the postop area, which increased the amount of travel and time associated with getting the patient ready for surgery. In addition, the staff talked about the challenges of finding and getting needed supplies when they arrived at the storage location.

I get my medicines here and get the supplies there. But, you always have to move something around in order to get what you want to get. To get to the medicine, you move away this stuff. (Site 1 Preop Nurse)

Access to information was also mentioned as an area of importance for the preop nurses. At the central nursing station and surrounding areas, staff reported that accessibility to information was sometimes a hindrance to providing care. In Site 1, the electronic boards are placed directly over the charge nurse's chair in the preop nurses' station, making it hard for her to see the board while at her desk. In Site 2, staff within both the preop and postop areas stated that the new whiteboards were positioned for them to be able to easily see and respond to the information contained.

Central Nurses’ Station Design

The key themes that emerged around the design of the central workstations, such that they facilitated or acted as a barrier to staff activities, included accessibility, which encompassed access to supplies, medication, materials and equipment, access to information, and access to outdoors and sunlight. Issues pertaining to flexibility, visibility, size, and privacy were also discussed. Additionally, the integration of the new technology, such as the electronic whiteboards, into the existing central work areas was discussed within the context of these themes. Furthermore, nurses mentioned the importance of sunlight and windows in their workspace.

The new electronic whiteboards, which are automatically updated through the Electronic Health Record (EHR) system, were reported as helpful in visualizing the patient status and location throughout the
In addition to the spatial configuration offering greater visibility, staff at Site 2 stated that the flexibility of the space to accommodate both children and adult needs created a much more conducive environment for both patients and staff.

In addition to the surgical process. However, the staff reported that the electronic whiteboards did not allow them to communicate with each other on the board through written notes as they had done prior to the new installation. In addition, while the electronic whiteboards did help to keep track of where a patient was in the system, it was not helpful in coordinating specific details within the process.

Access to outdoors and sunlight was also discussed by nurses at both sites as something that was highly desirable. The nurses in Site 1 mentioned that the lack of access to natural light and to respite areas made their job less enjoyable:

In all my years, I don’t know if we’ve had a place where you can just do that. That has never been part of my work. I do enjoy when I can look out of a window. I think it would be fun to have a little picnic table or something outside in the spring and summer, and to eat your lunch out there in the fall. (Site 1 Postop Nurse)

While the postop area in Site 2 had windows and natural light, the preop areas did not have access to any daylight. A preop nurse at Site 2 stated:

Oh my God. I miss the sunlight! We are in the center of the building, so we are not going to have it. They did a good job with the lights, but more natural light would be good. Light increases happiness. (Site 2 Postop Nurse)

Visibility

Staff within both the pre- and postoperative areas at Site 2 stated that the ability to see the flow into and out of their respective areas due to the position of the central nursing station and the configuration of the surrounding bays/rooms greatly enhanced their awareness of what was happening in their respective pediatric ambulatory care units (PACU).

The PACU is a big circle where you can put kids at one end and adults at another. There is a big table right where the OR comes out and you can see everybody coming and going. I love that. You can’t really miss anything. (Site 2 Postop Nurse)

Size

Staff at both sites indicated the size of the central workstation to be a key barrier to delivery of quality care. Nurses at Site 1 stated that the size of the central nursing areas made it difficult to accommodate all the staff and their associated activities without the space feeling crowded or at times overtaken. In addition, the staff noted that the addition of new technology into this small space created clutter that made it difficult to access other supplies that were still stored in the same area.

It is just too cramped because people go to make copies and you are trying to work on the computer, and that is too cramped. (Site 1 Postop Nurse)

When the doctors are in here, they take over our space and it gets difficult for us. (Site 1 Preop Nurse)
Staff at Site 2 reported that constraints in size and space limitations at the central nursing station in the preoperative area made it difficult to accommodate the number of staff who used the space at times. In this area, staff fill out portions of the paper charts, access medications and fluids, retrieve paper charts, and coordinate between OR and preoperative staff. The lack of counter space and tightness requires an unspoken, yet understood, hierarchy for who uses the available space as highlighted in this quote from a preop nurse at Site 2:

*They (postop) have that nice big area, where all we have is this small area, and sometimes it gets crowded. Especially when we have our fluids and stuff. It can definitely be hard in that space, but most people who go in there are the ones that need to be in that space. So, most people who don’t use that space, like our doctors, don’t really go there. They know it is our space.* (Site 2 Preop Nurse)

### Privacy

Staff at Site 1 indicated that the location of a small desk that is slightly removed from the main traffic flow in the postop area helped to provide auditory privacy for nurses who were conducting follow-up phone calls.

### Staff-to-Patient and Care Partner Interactions

#### Location of Interactions

Most staff-to-patient interaction at both sites was observed in the preop bays (Site 1 = 39.5%, Site 2 = 21.4%) or the postop bays (Site 1 = 24.2%, Site 2 = 27.2%). In both sites, preop nurses engaged with patients in the preop bays (Site 1 = 66.0%, Site 2 = 36.4%) and occasionally in the preop corridors (Site 1 = 36.4%). In both sites, most postop nurses engaged with patients in the postop bays (Site 1 = 72.2%, Site 2 = 36.4%) and less frequently in the postop corridor (Site 1 = 25.0%, Site 2 = 36.4%).

| Table 2. Proportion of direct and support patient care activities at Site 1 and Site 2 |
|-----------------------------------------------|----------------|----------------|----------------|----------------|
|                                               | Site 1 Direct care (%) | Support care (%) | Site 2 Direct care (%) | Support care (%) |
| Charting                                      | 44              | 3              | 30              | 17             |
| Reporting                                     | 2               | 12             | 4               | 4              |
| Coordination                                  | 5               | 16             | 4               | 16             |
| Supplies                                      | 0               | 23             | 1               | 22             |
| Medication                                    | 2               | 5              | 1               | 5              |
| Bedside care                                  | 28              | 0              |                 |                |
| Talking                                       | 5               | 20             | 5               | 19             |
| Room preparation                              | 2               | 1              | 9               | 2              |
| Admission                                     | 3               | 9              | 2               | 3              |
| Discharge                                     | 5               | 10             | 7               | 8              |
| Consultation                                  | 2               | 0              | 9               | 2              |

### Activities during Direct Patient Care Interactions

The data obtained from shadowing nurses during their patient care encounters show that, at both sites, nurses were primarily engaged in charting (Site 1 = 44%; Site 2 = 30%) and bedside care (Site 1 = 28%; Site 2 = 27%), accounting for the major proportion (Site 1 = 72%; Site 2 = 72%) of the time spent by the nurses in direct patient care at the bedside (see Table 2). Other activities that they were observed doing while engaged directly with patients included talking (5% in both sites) and discharge-related activities (Site 1 = 5%; Site 2 = 7%). At Site 2, several instances of consultation (9% of all activities), admission (7%), and room preparation (9%) were also observed. Less than 5% of all observed activities of reporting, coordination, obtaining supplies, and medication were observed among nurses while engaged in direct patient care in the patient bays at both sites. Nurses in Site 1 were observed multitasking (defined as performing more than one activity at the same time) during 7% of all observations of direct patient care, while nurses in Site 2 were observed multitasking during 15% of all direct patient care observations.
The lack of adequate space and limited possible configurations impacted the nurses’ ability to access equipment and supplies in the patient bays.

Activities during Support Patient Care Interactions

Coordination (16%), supplies (23%), and talking (20%) were the most common activities observed among nurses at Site 1 while involved in support care activities during patient encounters. Charting (17%), coordination (16%), obtaining supplies (22%), and talking (19%) were the most common activities observed among nurses at Site 2 while involved in support care activities during patient encounters (see Table 2). The proportion of time on support care activities during patient encounters mirrored the frequency of activities observed at both sites. Nurses in Site 1 were observed multitasking during 7% of all observations of support patient care, while nurses in Site 2 were observed multitasking during 6% of all support patient care observations.

Few instances of staff to care partner interactions were observed among preop nurses in both sites (Site 1 N=10 and Site 2 N=7). Most of these behaviors took place in the preop bays and in a couple of instances in the preop corridors (Site 1 N=2, 28.6%). Similarly, very few instances of postop nurses’ interactions with care partners were observed in this study (Site 1 N=8, Site 2 N=7).

Individual Workstation Design

Nurses perform critical patient care-related activities, such as charting and bedside care, while at the same time communicating with patients and care partners at the individual workstations in or adjacent to the patient bays. Technology in the form of the computer workstation plays an important role in these interactions. Figure 6a and b show the layout of preop and postop bays in Site 1 during the course of a patient interaction (the dotted lines indicate the path of the bed being wheeled out for surgery or brought into the postop bay after surgery). Figure 7a and b shows the same information for Site 2. The key themes that emerged around the design of the individual workstations (WoWs and wall-mounted workstations) from the interviews as well as spatial analysis, such that they facilitated or acted as a barrier to staff activities, included access to supplies, medication and materials, workstation flexibility, visibility, size/area of workstation, and privacy.

Accessibility

Barriers. The lack of adequate space and limited possible configurations impacted the nurses’ ability to access equipment and supplies in the patient bays. For example, at Site 2, configuration of the postop bays required the WoWs to be located on one side of the patient and the bedside table with supplies to be on the other side (same side as chairs for care partner; Figure 7b). As a result, the postop nurse needs to walk around the patient and reach over the care partner to access supplies and sometimes to adjust monitors. The postop nurses described the importance of placing oxygen and suction on the same side as the workstation and within easy access to them, so they can monitor and react quickly.

Staff reported that the integration of the WoWs into their workspace required a constant movement and shuffle of supplies and equipment to accommodate their tasks.

It takes a little bit longer to get the patient ready. You’ve got to move things around to accommodate what you are doing. So, we’ve had to reposition and pattern … (Site 1 Preop Nurse)

Additionally, very little counter space is available on the WoW. As patient consent forms are still signed on paper, nurses need additional workspace and are using bedside tables to support this activity. Thus, in addition to the WoW, there is an additional bedside table at the entrance to each preop bay in Site 2, which needs to be moved out of the way (often into the adjacent bay) when the bed has to be wheeled out (Figure 6a).

At the individual workstation level, staff reported that the integration of the new EHR changed the placement of supplies in relation to the location of
where the nurse stood to chart, hindering their ability to care for the patient at times. The nurses expressed a desire for supplies to be brought closer to where the nurse could more easily access them without going around the patient and past the care partner to locate them.

Facilitators. However, nurses in preop in Site 1 reported that having their workstation and bedside table for signing consents in close proximity to the patient assisted in their ability to deliver care. In addition, staff in Site 1 stated that they preferred having curtains in the preop bays instead of doors as the...
curtains assisted in being able to hear and respond to patient monitors when they go off.

Flexibility

Facilitators. Staff in both preop and postop areas in Site 2 stated that the WoWs contained features that assisted staff during patient care. Staff reported the ability of the workstations to accommodate different heights and the smoothness of the design as positive attributes of the workstations.

There aren’t things that people can really get caught on or snagged on. (Site 2 Preop Nurse)

They are all different heights. On the cart there is a thing where you can log in and
Staff at Site 2 also shared that while the private rooms in preop provided uninterrupted time for direct patient care activities, the lack of visibility to what was going on in the central area at times could hinder their ability to connect with another staff member regarding one of their patients.

**Barriers**: However, nurses in Site 2 reported that while the adjustable workstations in both the preop and postop areas provided flexibility for adjusting to the user, these features were not usually utilized due to other ergonomic and spatial constraints.

*I don’t move it. I leave it where it is. It is tricky to turn this thing all around. Maybe we’d prefer something that came down or something* (Site 2 Preop Nurse)

However, there were several ergonomic limitations to using the WoWs that made it difficult for staff to work:

*The main issue with the computers is that they are ergonomically causing problems for me because I am 70 and I wear bifocals. So, to look up, by the end of the day your neck hurts and you can’t get high enough on one of those chairs. And, the keyboard is high, but it’s doable.* (Site 1 Postop Nurse)

Staff in both the preop and postop areas in Site 1 also noted that at the individual workstations, there was a lack of electrical infrastructure to support their current needs.

*Every time we have to bend down to plug in, and you can’t see them. If I were designing it, I would put more electrical sockets in. I would make them around the room and more of them.* (Site 1 Preop Nurse)

**Visibility**

**Barriers**: Both preop and postop nurses at Site 1 reported that the integration of computerized medical records made them feel as though they were not spending as much face-to-face time with their patients due to the need to interface with the computer system as well as the patient during the encounter. Additionally, nurses stated that the configuration of the space made it difficult to make eye contact with the patients and care partners.

*At times I am not looking at the patient, even if I am trying hard to, because I try to do the computer stuff and try to concentrate on my patient. Sometimes I don’t make eye contact too much just because I have to look at the computer to document. But I do try to not focus on the computer. That takes a little adjusting, especially when you are in a room and the computer is facing away from the patient, but with the limited space we have only three specific places where we can put the computers. But that’s a change in behavior, not a change in workspace though, or a maybe a little of both.* (Site 2 Preop Nurse)

Nurses in Site 2 also mentioned similar problems arising from the increased focus on the computer. Staff at Site 2 also shared that while the private rooms in preop provided uninterrupted time for direct patient care activities, the lack of visibility to what was going on in the central area at times could hinder their ability to connect with another staff member regarding one of their patients.

*In the preop, we can have doctors coming in here and not even see them. I like keeping my eye on all that is happening. That’s not often, but it does happen that I miss the doctor because I am in another room.* (Site 2 Preop Nurse)

**Size**

The average size of a preop bay in Site 1 was 87.5 SF, while in Site 2, it was 93.6 SF. Also, several of the preop bays in Site 1 are about the same size as those in Site 2. There is adequate wall space in the preop bays in both sites to accommodate a wall-mounted workstation. The average size of the postop bay in Site 1 was 67.1 SF, while the bay in Site 2 was 78 SF in area. While both the preop and postop bays in Site 2 are larger, the difference is not great for the preop
There may be opportunities to consider workflow patterns (nursing ratios flexing throughout the day) as well as spatial organizations (e.g., physical proximity and adjacencies between preop and postop spaces) that allow flexibility in the use of space and staffing resources at ASCs.

Nurses brought up the lack of adequate space in the patient bays repeatedly as a key barrier to providing care to patients. The bays that were slightly larger were often indicated as favorites among the nurses. According to one postop nurse in Site 1:

*Now I will say that this room and this little workspace is nice because there is a desk right here. This is room 10. There is actually room in there to bring families. This is a bigger space, and bit more conducive.*

They encountered significant challenges in integrating the computer workstations into these already crowded bays:

*It is tight. When you are giving patients in PACU their discharge instructions and then they have to get dressed, it’s tight! (Site 1 Postop Nurse)*

*They are very small. When you get a family member back and try to get the EKG machine in with the computer and the bedside table, it’s just difficult. (Site 1 Preop Nurse)*

**Discussion**

By understanding the location of different activities and interactions and environmental barriers and facilitators to nurses’ work, this study puts forth new information to support the design of preop and postop workspaces in ambulatory surgery facilities. This study highlights design challenges and opportunities that arise while integrating computer workstations in existing health-care environments. The built environment, technology, and the people are part of a closely interlinked system, and understanding how these different parts of the system work together is critical for delivering high-quality care in preop and postop areas of surgical facilities.

**Activities and Interactions**

The study found that there is a distinct ebb and flow of activities and space usage at both surgery centers, with postop areas underutilized during the morning and preop areas underutilized in the afternoon. There may be opportunities to consider workflow patterns (nursing ratios flexing throughout the day) as well as spatial organizations (e.g., physical proximity and adjacencies between preop and postop spaces) that allow flexibility in the use of space and staffing resources at ASCs.

The study found that during all observed interactions, the most common activity by nurses (preop and postop) was face-to-face communication (talking or listening). This was also true when we looked at staff-to-staff interactions alone or staff-to-patient/care partner interactions. Both sites studied had a range of technology to support synchronous and asynchronous communication, including HCDs,
phones, computers, and electronic whiteboards. However, in this study, we found more instances of face-to-face verbal interactions over other interactions using technology. Several other research studies conducted in different health-care settings have also seen a preference for synchronous face-to-face communication (Coiera & Tombs, 1998; Gum et al., 2012; Moss & Xiao, 2004). Nurses who responded to a survey in a study by Bayramzadeh and Alkazemi (2014) felt that most communication in their unit occurred through face-to-face communication and was less technology-oriented.

The two sites have distinctly different configurations in terms of the physical proximity and adjacency between preop and postop areas. Nurses tended to move between preop and postop areas to coordinate and problem solve in Site 1. There were few instances of that occurring in Site 2. Interestingly, the instances of talking and listening activities during interactions are about the same across both sites. Nurses interviewed at Site 2 did indicate they used HCDs to communicate with team members, and the lack of proximity to preop did not impact their work.

Other studies have found that the distribution of workforce as a result of decentralized workstations can increase physical distance among nurses and reduce in-person interactions between staff (Tyson, Lambert, & Beattie, 2002). The current study did not measure team dynamics and staff satisfaction. However, given the similarities in patterns observed during interactions, it would be interesting in a future study to see if the different spatial configurations impact team dynamics (between preop and postop nurses) and other coordination measures in any significant way.

The observations highlighted the fact that nurses in ASCs are spending a lot of time during their workday on their feet (standing and walking). This is consistent with findings from other studies conducted among nurses in inpatient settings that show that nurses spend a lot of their time walking (Hendrich, Chow, Skierczynski, & Lu, 2008). The only time they were observed sitting was when they were taking breaks between patients. Additionally, they are involved in physical tasks such as moving patient beds and WoWVs that contribute to fatigue. While the WoWVs are height-adjustable, such that a nurse could sit while charting, space constraints as well as the nature of the nurses’ work did not allow for them to sit. This study finding also raises the possibility of considering other design features (in addition to workstation design) such as flooring that may help to reduce standing fatigue.

Barriers and Facilitators

Technology was frequently mentioned as a factor impacting staff activities at the central nurses’ station as well in the individual patient bays. The key themes that emerged around the design of the central nurses’ station and the individual workstations (WoWs and wall-mounted workstations) included (1) access to supplies, medication, and materials; (2) workstation flexibility; (3) visibility; (4) size/area of workstation; and 5) privacy. These themes could be perceived as either barriers or facilitators based on implementation.

Accessibility emerged as a key theme related to the design of the workstations and encompassed access to supplies, medication, materials and equipment, access to information, and access to outdoors and sunlight. Easy access facilitated interactions and activities, while obstructed or constrained access negatively impacted those same activities. For example, in Site 2, the design of the nursing station allowed nurses to easily view the electronic whiteboard and facilitated communication within the team. However, at Site 1, space constraints impacted visual access to the electronic whiteboards.

A recent study (Lavender et al., 2015) evaluating environmental challenges for multiple health-care professionals in inpatient surgical patient rooms has identified similar barriers to staff activities. Lavender et al. (2015) found that limited access to information, supplies, and amount of space for performing patient care activities to be environmental factors
This study highlights the need to design work systems rather than isolated work stations.

Implementing new technology in existing environments can be very challenging as existing work systems (physical environment, processes, staff training, and culture) may not be flexible enough to allow for an effective integration (Holden, 2011b; Holden, 2011a; Holden, 2012). The preop and postop areas were not originally designed to support computerized charting, and as such, the size of the bays as well as the configuration of the bays created workflow challenges once the WoWs and built-in displays were added. In Site 1, the only way for the nurses to work at the WoWs while also talking to patients and families was to position themselves in the corridor at the foot of the patient’s bed. As a result, the corridors in Site 1 were usually very crowded with people, WoWs, and other equipment (such as bedside tables). The new technology (whiteboards, built-in computer displays, WoWs) associated with the electronic medical records seemed better integrated in Site 2, and the availability of space in Site 2 was a significant factor supporting this integration. Even here, the new computerized systems interfered with workflow and staff–patient/care partner communication.

**Limitations**

The combination of behavioral observation, shadowing, spatial analysis, and staff interviews yielded rich data that allowed us to triangulate information to understand the role of the built environment in supporting tasks and interactions in ASCs. Each of the methods used in this study has its own challenges and strengths. While the behavior mapping with the DOTT tool allowed us to collect a sizable quantity of detailed information about spatial usage of surgery workspaces by nurses, it was less effective for explaining the reasons behind the patterns observed. Shadowing was effective in obtaining in-depth information about the behavior of one subject, but some of the information about the broader context was harder to discern. For both observational methods, some of the more intimate interactions between patients and care providers could not be observed or recorded when the curtain was drawn or the door was closed. While each of these methods has its limitations, the strength of this study is in using these observational methods along with interviews with staff to provide a more complete picture of the behaviors observed.

The study used a convenience sample of two surgery centers that were similar in organizational structure and processes and were at the same phase with regard to technology integration. Both facilities were in the initial phase of technology integration (two weeks prior to data collection). Further follow-up research should be conducted at six months to a year postimplementation to understand the ongoing impact of technology integration and any accommodations made both in the physical environment or workflow to address problems.

While similar patterns were found at both facilities, for the findings to be widely relevant, it would be important to repeat the study at a different ASC to understand if similar patterns were observed. Due to the exploratory nature of this study, environmental variables could not be clearly defined at the outset of the study. As a result, it was difficult to make strong comparisons between the two sites in terms of environmental features.

**Key Findings and Design Implications**

Table 3 summarizes the key findings from this study and their associated design implications. This study highlights the need to design work systems rather than isolated work stations. Designing work systems requires a human-factors approach to design that examines the range of activities and interactions the nurse is involved in, the people that are part of the nurses’ work system, the types of technology that may
Table 3. **Key study findings and design implications**

<table>
<thead>
<tr>
<th>Key study finding</th>
<th>Design implications</th>
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<tbody>
<tr>
<td>There is a distinct ebb and flow of activities and space usage at both surgery centers, with postop areas underutilized during the morning and preop areas underutilized in the afternoon.</td>
<td>Locate preop and postop areas in close proximity to enable flexible use of bays during off-peak times.</td>
</tr>
<tr>
<td>The most common activity observed among both preop and postop nurses were talking and listening, indicating the importance of face-to-face interactions and communication in ambulatory surgery centers.</td>
<td>Provide adequate space and furniture arrangement in central nursing areas to facilitate activities such as team briefings and discussions. Locate workstations in patient care areas such that there are direct sightlines from the care provider to both patients and care partners.</td>
</tr>
<tr>
<td>Preop and postop nurses spend a majority of their time on their feet (standing and walking).</td>
<td>Provide flooring and furniture that allow nurses to rest their feet and reduce fatigue at the individual workstation level as well as in the central nursing areas.</td>
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<tr>
<td>Nurses’ work is everywhere—in the central work areas, in corridors as well as in patient bays—and they perceive all these spaces as their work areas.</td>
<td>Provide a range of shared landing spaces in central work areas that can accommodate multiple direct and support patient care activities.</td>
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<tr>
<td>The majority of direct patient care activities, such as bedside care and charting, are done directly with the patient in the patient bays, thus making these spaces the primary work areas for nurses.</td>
<td>Provide adequate space around the patient bed to allow caregivers to access the patient from all sides. Provide surfaces and storage for supplies that support a range of patient care activities. Locate supplies within easy reach of the workstation in the patient care bays/rooms.</td>
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<td>The size and configuration (walls vs. curtains) of the patient bays impact the ability of a facility to effectively integrate wall-mounted computer workstations for charting and patient care.</td>
<td>Conduct ergonomic analysis prior to making decisions about integration of technology and equipment into patient bays to ensure proper placement.</td>
</tr>
<tr>
<td>The integration of EHR does not eliminate paper from the system.</td>
<td>Provide adequate horizontal surface area in central nurses’ stations and patient care areas (bays/rooms) for paper-based communication (discharge and consent forms).</td>
</tr>
<tr>
<td>The key environmental facilitators and barriers to nurses’ work in surgery centers include: size, access, flexibility, visibility, and privacy.</td>
<td>Provide adequate space in work areas and patient bays based on task analysis and ergonomic needs of staff, patients, and care partners. Locate information, medication, supplies, and equipment, such as printers, such that it is easily accessible to nurses. Provide electrical infrastructure to support current needs for connectivity and charging (e.g., electric outlets at multiple heights and locations) as well as future needs for wireless and emerging technology. Provide visual sightlines between staff, patients, and care partners Balance needs for visual and auditory connections between staff working in patient care bays and central work areas with patients' needs for privacy.</td>
</tr>
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</table>
Considering the factors identified in this study as well as understanding staff processes and needs when integrating technology into new and existing work systems can help in developing ergonomic design solutions that address the needs of the different stakeholders in ambulatory surgical environments.

Designing health-care environments to support the use of new and emerging technology is a significant challenge in healthcare today. While health-care providers are focused on providing the best possible care to the patients, they are faced with ever increasing requirements to interact with a computerized electronic record system as part of their work process. As observed in this study and others, this poses significant problems, especially if the environment poses additional barriers to the different types of desired interactions (nurse-to-technology, nurse-to-nurse, nurse-to-patient, or nurse-to-care partner). The design considerations highlighted in Table 3 provide guidance to designers on integrating the computer workstation within the larger context of the preop or postop bay/room in an ASC such that it supports desired workflows as well as patient care activities and interactions.

For example, there is a need to consider carefully the location and design of storage, outlets, and work surfaces so that nurses can easily access what they need without leaving the patient. The location and adjustability of the workstation is a critical factor that facilitates visual connections between nurses and patients and care partners. Being able to make visual and auditory contact during a patient care interaction is essential for building trust and reducing patient anxiety.

Architects and interior designers can play an important role in designing human-centered work environments for nurses in surgical settings that effectively support the critical tasks and interactions that must take place. This study identified five key factors impacting individual and central workspaces that can either facilitate preop and postop nurse activities and interactions or create barriers to effectively delivering care. Considering the factors identified in this study as well as understanding staff processes and needs when integrating technology into new and existing work systems can help in developing ergonomic design solutions that address the needs of the different stakeholders in ambulatory surgical environments.

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