An Ergonomic Evaluation of Preoperative and Postoperative Workspaces in Ambulatory Surgery Centers

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Abstract. Healthcare organizations are faced with the challenge of renovating existing infrastructure or building new facilities to enable the inclusion of computer workstations and address growing technological demands. The majority of existing ergonomic tools for evaluating computer workstations primarily focus on the interface between the care provider and the computer. This paper describes the development and application of an expanded ergonomic evaluation framework that focuses on the work system versus the workstation. The tool was tested and refined through visits to five facilities where the ergonomic evaluation tool was used to assess five preoperative and seven postoperative rooms/bays in surgical suites with varying spatial configurations and types of workstations. The comparative evaluation showed that all workstations met most of the basic checklist requirements, but there were significant differences related to the location of the workstation and adjacencies to other zones in how effectively the workstations were integrated into the space.

Keywords: Healthcare · Ergonomic · Workstation · Evaluation · Work system

1 Background

The number of ambulatory Surgery Centers (ASCs) has rapidly expanded over the last two decades from 1,000 in 1998 to over 5,400 in 2016 due to the dramatic increase in the number of surgical procedure being conducted in outpatient settings in the United States each year [1].

To improve the quality of care, an influx of $20 billion for the investment of infrastructure and systems to support the implementation of health information technology (HIT) was inserted in 2009 into the US healthcare system with the American Recovery and Reinvestment Act [2]. As a result, computers have been incorporated into the clinical workflow in a diverse range of healthcare settings. The inclusion of healthcare information technology (HIT) has transformed the ambulatory surgical environment by increasing the amount of computer work that is done by care team members while in the presence of patients and their care partners.

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Healthcare facilities are faced with the challenge of renovating existing facilities to enable the inclusion of computer workstations, incorporating solutions that may work within the constraints of their existing environments or building new facilities that are able to address growing technological demands. While some tools exist to provide guidance for comparing ergonomics of alternative computer workstation configurations, these tools primarily focus on the interface between the care provider and the computer [3–5]. Given the significant impacts of the computer workstation on the interactions between care provider and patient and care provider and family members in healthcare settings [6, 7], there is an urgent need for an expanded ergonomic evaluation framework that considers the ergonomics of the workstation within the broader work system within which it may be placed. This paper aims to fill the gap through the development and application of an expanded ergonomic evaluation framework that focuses on the work system versus the workstation.

1.1 Study Objectives

The key objectives of this study include:

1. To develop an ergonomic evaluation framework and design tool that focuses on the work system versus the workstation in preoperative and postoperative work spaces in ambulatory surgery centers
2. To compare various applications of technology integration within preoperative and postoperative work systems in ASCs

2 Methods

This study included literature reviews and evaluation of existing tools to develop an expanded ergonomic evaluation framework and tool. The tool was tested and refined through visits to five facilities where the ergonomic evaluation tool was used to assess five preoperative and seven postoperative rooms/bays in surgical suites with varying spatial configurations and types of workstations.

2.1 Development of the Clemson Healthcare Work System Ergonomic Assessment

Existing tools for evaluating workstations within a healthcare context were first identified through the literature. Design criteria established in the literature for designing ergonomic medical equipment, healthcare environments and HIT were also reviewed. From this review, the Cornell Healthcare Computer Wall-Station Ergonomic Checklist [3] was chosen as the base for developing the Clemson Healthcare Work System Ergonomic Assessment. The Cornell Healthcare Computer Wall-Station Ergonomic checklist is comprised of 20 items that are formatted as a series of questions that require a "yes" or "no" response [3]. To modify the existing tool, items pertaining specifically to a wall mounted system or individual technology were first removed. Questions around visual and auditory connections between patient, provider and family were then added to the checklist based upon design principles identified in a previous study conducted by the authors [8, 9]. The checklist was further expanded to include concepts identified in the literature as enhancing staff work performance through flooring attributes associated with comfort underfoot and slip resistance [10], the inclusion of horizontal workspace [8, 11], criteria regarding spatial connectivity to medication and central supplies [12], as well as views to the outdoors [13].

Furthermore, the checklist was modified to facilitate rating of multiple, usable configurations for the same workstation for select criteria. Sections were then added to the ergonomic assessment pertaining to workstation usability and the spatial context surrounding the workstation. The Clemson Healthcare Work System Ergonomic Assessment is organized into the following 5 key sections to support a holistic work system analysis, as shown in Table 1.

Table 1. Components of The Clemson Healthcare Work System Ergonomic Assessment

Components	Assessment criteria
Context and task analysis	Questions regarding facility area, workstation type, task sequence and task identification and identification of usable configurations
28 item checklist	16 general questions and 12 questions for each usable configuration
Photo protocol	A minimum of 8 photos of from varying perspectives within the space
Documentation of insights and challenges	Additional notable aspects of the environment, such as the existence of excessive electrical cords
Physical assessment of space	Marking the location of 12 environmental features, a minimum of three standard measurements and information regarding the type of enclosure around the room/bay to scale on graph paper

2.2 Application of Ergonomic Assessment

The ergonomic assessment was conducted, along with a task analysis, semi-structured interviews with nurses and a physical and photo assessment in five facilities with varying workstation configurations in their preoperative and postoperative workspaces to identify the facilitators and barriers to each workstation design. For this study, three types of workstation designs were evaluated: a wall mounted workstation, workstation on wheels (WoW) and a boom mounted workstation. These workstations were selected for this study as they represent the most typical type of platforms for integrating technology into new and existing ambulatory surgical workspaces.

The task analysis involved asking nurses to walk through and verbally describe the sequence of activities that they would typically perform in their workspace. Semi-structured interviews were conducted with a preoperative or postoperative nurse following the task analysis in the workspace to identify facilitators and barriers related to workstation functionality/usability. This was followed by the evaluation of the workspace using the 28-item checklist, photo documentation and physical assessment of the space.

3 Analysis

Based upon the location of seven essential environmental features within each workspace, a zoning distribution plan, consisting of five key zones, was first developed for each workspace. Table 2 shows the zones and their definitions.

Table 2. Zone distribution and definitions

Zone	Definition
Workstation	Area that encompasses the workstation and vital monitors
Staff Movement	Area around patient bed where direct patient care activities occur
Care Partner	Area where seating for the care partner is located
Support	Area that supports the movement of equipment and care team members
Supply	Area where direct patient care supplies, sharps and hand sanitizer are located

The zoning distribution was first anchored by demarcating a 1½ ft. area around all sides of the patient bed for the staff movement zone, designating the space required to comfortably support direct patient care activities from a standing position, as identified during the task analysis and interviews with staff. Where a 1½ ft. area was not viable, the staff movement zone was occluded at the nearest enclosure, piece of equipment or furniture. The workstation zone was then demarcated in plan based on the greatest extent to which any of the usable configurations could extend into the workspace. The supply and care partner zones were then overlaid into the plan based on the maximum square footage required to accommodate manufacturer design specifications. The support zone was then inlaid into the remaining available space. Measurements regarding the minimum space requirements (3 ft.) from the side and foot of the bed to the adjacent enclosure as identified by the FGI guidelines [14] were then placed into each zoning distribution plan to determine the availability of adequate space between the patient bed and surrounding enclosure.

The 12 preoperative and postoperative configurations were then visually compared to understand differences in spatial configuration and size of different zones, and the potential impacts of these configurations based on criteria developed from the interviews and evaluation. Table 3 shows the criteria associated with each zone for evaluating their effectiveness in supporting nursing work practices and the patient and care partner experience.

The work systems were also compared in terms of how the workstation design and usable configurations afforded clear sightlines between the care provider and patient, care provider and care partner and patient and care partner. The strengths and limitations of different individual workstations are also compared and discussed.

Table 3. Zoning distribution and evaluation criteria

Zone	Criteria for evaluation
Workstation zone	Easy access to supplies for direct patient care activities; visibility to both patient and care partner simultaneously from the most commonly used configuration; space optimization; ease of physical access to patient
Staff Movement zone	Ability to access patient from all sides; accessibility to direct patient care supplies
Care Partner zone	Visibility to patient and staff simultaneously; not in the direct path of staff travel patterns
Support zone	Unobstructed space to accommodate the circulation of multiple care team members; unobstructed space to accommodate the flow of additional equipment
Supply zone	Co-location of direct patient care supplies; accessibility of sharps to direct patient care activities; accessibility visibility of hand sanitizer to care team members

4 Findings

4.1 Overall Workstation Design

Across all sites, each type of workstation accommodated standard anthropometric measurements for both standing and seated positions, independent component adjustments, ergonomic keyboard positions, easily cleanable surfaces, integrated horizontal work surfaces and multiple usable configurations. Additionally, all workstations provided integrated cord management other than the wall mounted workstations at Site 3 and Site 5.

Each pre and postoperative workspace met the minimum spatial requirements of an overall clear floor area of 80 sq. ft. for a pre or postoperative bay and an overall clear floor area of 100 sq. ft. for pre or postoperative rooms as outlined by the FGI guidelines [14], with the exception of the postoperative bay at Site 2. Although all workstations afforded a seating position, three of the preoperative workspaces (Site 1, Site 2 and Site 4) and three of the postoperative workspaces (Site 1, Site 4 and Site 5) did not provide a seating option due to space constraints. While all workstations did provide a horizontal work surface, the workspaces in Site 2 that utilized WoWs for the workstation added bedside tables into the work system to provide additional horizontal surfaces for setting paper charts and signing consent forms. The addition of the bedside table added clutter to the already spatially constrained area at this site. While each workstation provided a viable ergonomic design solution for integrating technology into the workspace, differences were found in terms of how the workstation was integrated within the work system.

4.2 Integration of Workstation into the Work System

The type of workstation that was used, its location within the space and adjacencies between workstation and other zones impacted how well the workstation was integrated within the work system. The design of the workstation and the size of the bay impacted how well the different zones functioned in supporting different tasks. Figure 1 shows the relationship between zones for the pre and postoperative workspaces at the five sites.

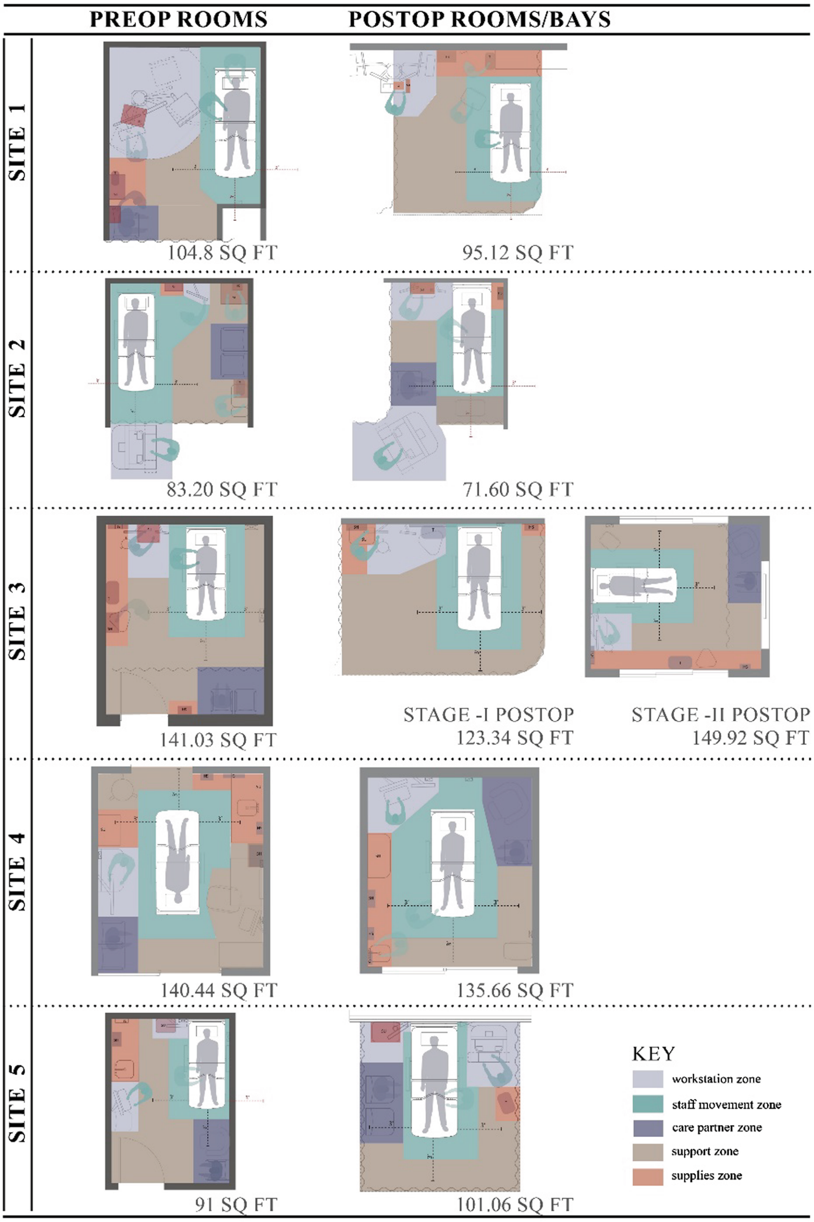

Fig 1. Relationship between zones for pre & post op workspaces at the 5 sites

Workstation Zone. Experientially, the varying workstation designs and their placement within the pre and postoperative workspaces resulted in varying effectiveness for supporting key perioperative tasks for care team members. While the boom mounted workstations in the preoperative room at site 1 provided co-location of workstation, direct patient care supplies and vital monitors, the boom protruded into the support and staff movement zones, leaving a significant amount of unusable space behind the boom. Additionally, the shared boom in the postoperative bay did not provide co-location of direct patient care supplies, creating decreased accessibility to those supplies.

The WoWs at site 2 introduced constraints into the work system due to their size and placement. Limited space within the pre and postoperative bays required the WoWs to be placed outside the bays in the hallway, making it difficult to access vital monitors as well as direct patient care supplies from the workstation. This fragmentation extended into the support zone in the postoperative bay, leaving nominal room for additional care team members.

Although the wall mounted workstations integrated into sites 3, 4 and 5 utilized the least amount of space within the work system, not all provided usable configurations that supported communication between care team member, patient and care partner simultaneously. However, due to the limited spatial requirements needed by the wall-mounted workstations, the sites with integrated wall mounted workstations resulted in more continuous support zones with greater area to support the presence of additional care team members.

Staff Movement Zone. While the size and location of the staff movement zone varied between the different types of workstations and room/bay configuration, two of the sites that utilized the wall mounted workstations (Site 3 and Site 4) afforded the placement of the bed to be central to the pre and postoperative rooms/bays. This centrality provided closer adjacencies to components in the work system such as the sharps container, direct patient care supplies and gloves that support direct patient care activities. The central location of the bed also supported greater access to multiple surgical site locations on either side of the patient.

Limitations with the staff movement zone were identified in pre and postoperative bays at Site 2 and the postoperative bay at Site 5. Due to the integration of the WoWs into the work system, both sites were unable to achieve an adequate staff movement zone, restricting the ability of care team members to perform direct patient care activities without impeding on the care partner zone. The placement of the staff movement zone in the preoperative room at Site 1 with the integrated boom did not impede the care partner zone. However, access to the patient was primarily restricted to the right side of the patient, as access to the patient's left side would place undue strain on the care team member due to lack of space.

Care Partner Zone. Across all sites, the location of the care partner zone varied greatly. In addition to impeding staff movement around the patient bed at two of the sites, the location of the care partner zone was found to restrict care team members access to supplies in the preoperative bay at Site 1. In this bay, the care partner space is located directly under the hand sanitizer, requiring care team members to ask care partners to move each time they use the hand sanitizer. Although the placement of the care partner zone did not impede on the staff movement zone in the preoperative room at Site 4, it was found that the zone itself was spatially constrained for accommodating two adults. This is notable for this particular workspace, as this work system was designed to operationally support parent participation during induction for both parents.

Support Zone. The greatest restriction to the movement of additional equipment and care team members was found in the pre and postoperative workspaces at Site 2. This fragmentation of the support zone can be partially attributed to the spatial constraints of the bays in addition to the placement to other components in the work system. However, this same fragmentation can also be observed in the preoperative roommate Site 4. Interestingly, this is one of the preoperative workspaces with the greatest overall clear floor area at 141.03 sq. ft. This fragmentation can be attributed to the anesthesia workstation that permanently resides in the preoperative workspace at this site, restricting the movement of any additional equipment within the workspace. Interestingly, only pre and postoperative workspaces at Site 3 and the postoperative roommate Site 4 allow for the continuous flow of additional equipment and care team members around three sides of the staff movement zone. These work systems were identified as providing maximum support for direct patient care activities.

Supply Zone. Fragmentation of the supply zone also created challenges in the flow of the work system. Due to the position of supplies on opposite sides of the bed in the postoperative bays at Site 2 and Site 5 and preoperative room at Site 4, care team members are required to go around the bed to retrieve supplies for performing direct patient care activities. While this fragmentation can be seen in the preoperative room at Site 3, the distance between supplies was reduced by being positioned at the foot of the patient bed instead of near the head of the patient bed. The greatest support for direct patient care activities was found in the preoperative rooms at Site 3 and Site 5 and the postoperative rooms at Site 3 and Site 4 where the supply zone was non-fragmented and adjacent to the workstation zone.

Visibility. Maintaining visual connectivity between care team members, patient and care partner is vital for supporting the critical interactions that occur during the pre and postoperative phases of the ambulatory surgical process. Figure 2 shows care team member cone of vision to patient and care partner from the workstation. In the preoperative workspaces at Site 1 and Site 2, as well as in the in the postoperative workspace at site 4, there was restricted visibility to the care partner from the workstations. Additionally, restricted visibility from the workstation to the patient was observed in the postoperative room at Site 4 and the preoperative room at Site 5. Only Site 3 afforded visibility between the care team member, patient and care partner simultaneously for all usable configurations in both the preoperative and postoperative workspaces. However, Site 2 and Site 4 afforded non-restricted visibility to both the patient and care partner in the postoperative and preoperative workspaces, respectively.

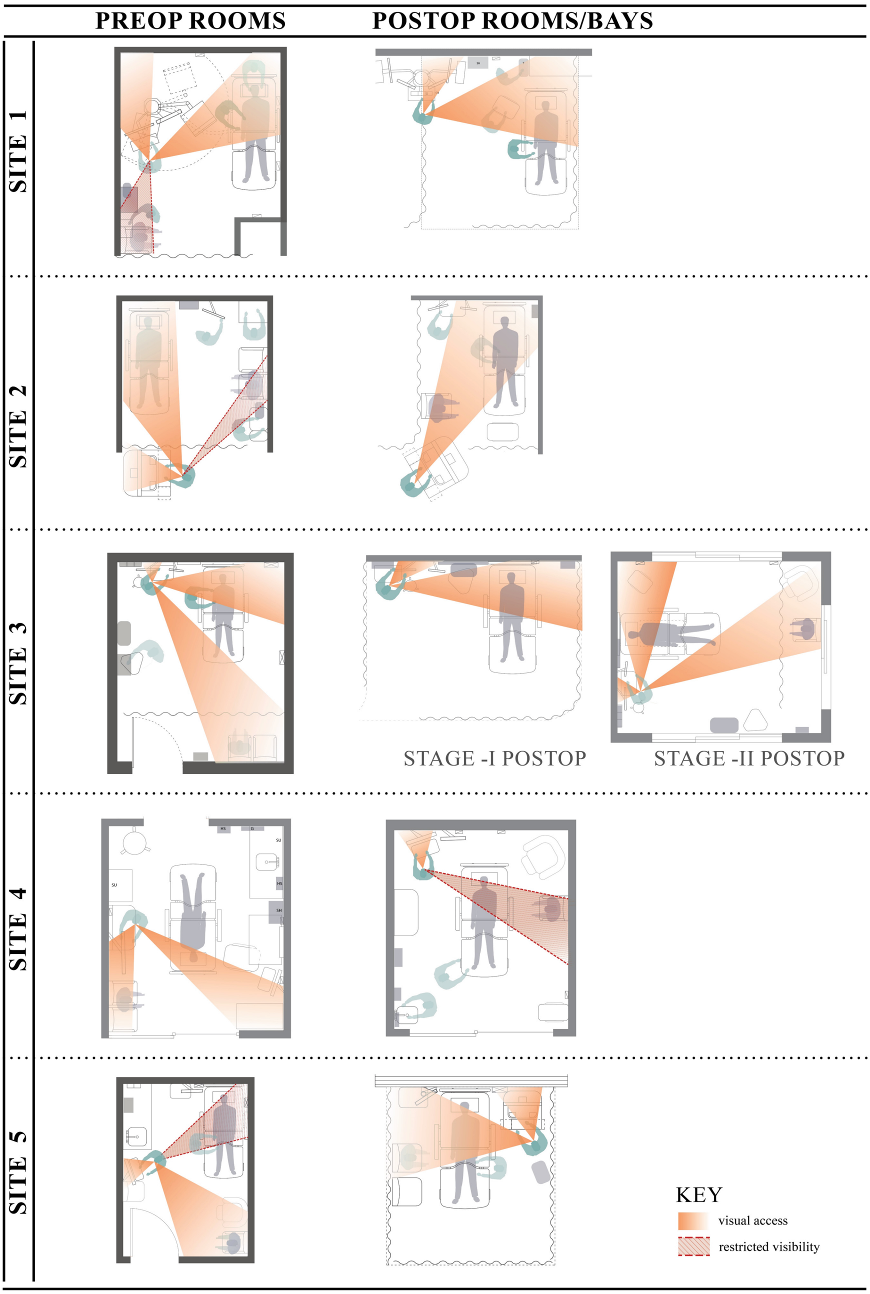

Fig 2. Care team member cone of vision to patient & care partner

5 Discussion

The comparison of the 12 work systems highlighted the critical impacts of the workstation design (type, location) on task performance in the space. By applying the Clemson Healthcare Work System Ergonomic Assessment tool in the five ambulatory surgery facilities the team was also able to assess the effectiveness and usability of the tool. This comparative study also helped in the development of a visual analytic technique (zoning diagrams) to support comparison among alternative configurations.

The comparative evaluation showed that all workstations met most of the basic checklist requirements, but there were significant differences in how effectively the workstations were integrated into the space. These differences related to the size of the overall space, the location of the workstation, adjacencies to other zones and the extent to which the workstation zone intruded into and fragmented other zones within the work system. Thus, the study highlights the fact that it is not enough to evaluate the ergonomic and anthropometric properties of the workstation in isolation while making implementation decisions. Rather, it is critical to consider key relationships between the workstation and other zones that staff members need to access physically and visually. Such an evaluation also allows the team to be aware of potential conflicts or tradeoffs that might need to be made.

The analysis of the room via the zoning diagrams was not part of the original tool but was an analytic technique developed by the research team as a way of evaluating the impact of the workstation on other zones (defined through the tasks analysis) within the system. This spatial analysis was critical in understanding the relationship of the components within the workstation. As a result, the steps undertaken by the research team to conduct the visual analysis was incorporated into the tool to guide future users in moving from the evaluation to analysis.

While the tool was not used in this study to design a new space, the elements in the checklist as well as the process developed to create the zoning diagrams may support a proactive approach to evaluating evolving design ideas. The assessment tool and zoning diagrams are useful both as a proactive design tool and also as part of an ergonomic evaluation of an existing workstation.

6 Limitations

This study evaluated three different types of workstations implemented in multiple different settings. As a result, we were not able to separate the impact of the workstation from the constraints of the different layouts (e.g. area, type of enclosure) in which they were implemented. The comparison could have been stronger if the three different types of workstations had been implemented into the same space. While this would be possible in an experimental environment, this study focused on understanding existing work systems within their contextual reality. A future next step might be to design a single bay with different workstation configurations and evaluate their relative performance through virtual reality or physical mock-up simulations.

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