Title of Project: Realizing Improved Patient Care through Human-centered Design in the OR (RIPCHD.OR)

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The PSLL allowed the RIPCHD.OR team to mobilize the expertise of this incredible multidisciplinary group of experts, faculty, and students to understand the OR work system in greater depth than has been attempted previously. Further, the systems engineering framework of the PSLL facilitated the transition from understanding to design innovation and implementation. The

1. Structured Abstract

a. Purpose
The purpose of this project was to use a systems engineering approach to develop ergonomic and safe operating room (OR) design solutions that improve staff workflow and perioperative outcomes.

b. Scope
The operating room is a very high-risk, problem-prone patient care environment. Surgical site infections and errors are key concerns in ORs. Distractions

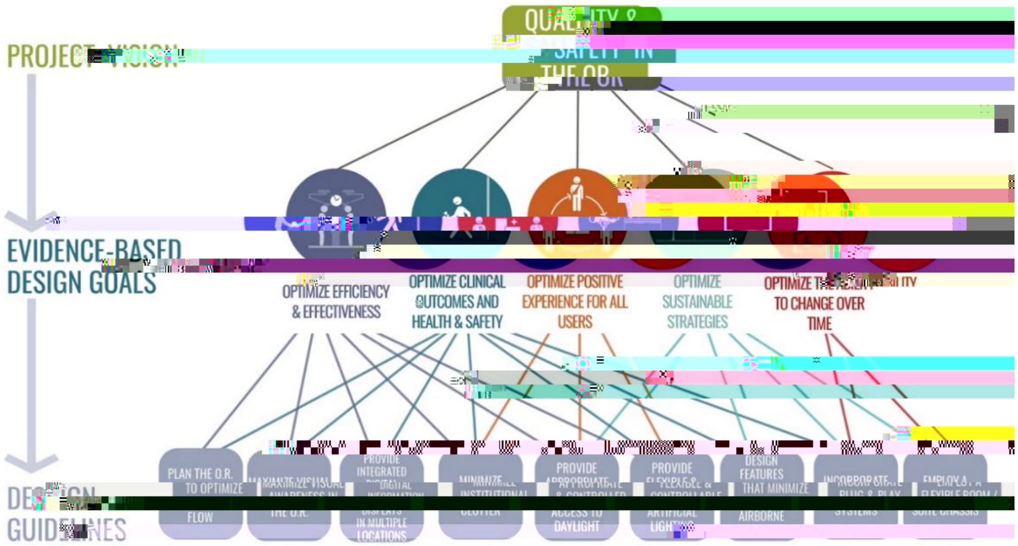
2. Purpose

The Realizing Improved Patient Care through Human F

Environmental sources of disruption in the OR include frequent door openings, loud noises and alarms, environmental clutter and constrained spaces. Coupling small and cluttered ORs with high foot traffic inside the OR as well as movement in and out of the room may contribute to flow disruptions (e.g., people or equipment blocking visibility and communication between surgical team members) and increase infection risks (e.g., nonsterile surgical personnel bumping into a sterile instrument table). Additionally, poorly organized storage spaces and the lack of proximity nurses, scrub nurses, surgeons and anesthesia providers) and objects (e.g., instrument tables) in each surgery. Door openings and surgery phases were also recorded.

To optimize coding and make results more meaningful, each OR was organized into location zones based on the primary functions within each zone (e.g., surgical table zone, circulating nurse workstation zone, supply zone), and activities performed by team members were categorized D V patient, equipment, materials and supplies and information related (PEMSI). Flow disruptions were categorized as they related to layout (inadequate .011 Tc -0.483 Tw -0.484 aipmenf 9

phases (preoperative, perioperative, postoperative and turnaround phases), and OR configurations (e.g., with one or two doors with or without adjacent rooms such as the induction room). Always including end users (e.g., surgeons and nurses), the toolkit defined a simulation director, participant roles and tasks, equipment and tools involved, and a simulation schedule involving a sequence of discrete/shorter simulations (e.g., patient bed entry/ exit sequences). Each simulation was immediately followed by debriefings and focus groups to discuss Tj , was support clinicians, designers, and researchers in better understanding how to design a safer and more ergonomic OR. Project teams worked closely during content development to ensure the information disseminated through the tool is a comprehensive representation of the RIPCHD.OR project as a whole. The Safe OR Design Tool was developed using a systems approach that provides design strategies related to desired safety outcomes. The tool creation process included the development of evidence-based design strategies linked to design features (e.g., booms, layout), desired outcomes (e.g., improve movement and flow) and systems components impacted (e.g., people, built environment, tools) [illegible]



Figur e 3: Diagram of framework guiding the design of the OR prototype.

OR Size and Shape

The overall

the surgical table orientation and placement away from the patient entry door facilitates maneuvering and minimizes effort during patient bed flow in and out of the room.

Figure 4: Annotated floor plan of the final OR prototype.

Mobile Circulating Nurse Workstation

The analysis of surgery video data found that the circulating nurse makes frequent trips to the surgical table and to storage areas to support the team. Further, many disruptions occur at the foot of the table, often involving the circulating nurse (Bayramzadeh, Joseph, San, et al., 2018; Neyens et al., 2018). Another study found that areas of high traffic in the OR were correlated with higher microbial load (Taaffe et al., 2018), indicating the need to reduce unnecessary travel inside the OR. Based on feedback from mock-up- based simulations and video observations, the OR prototype proposed a mobile circulating nurse workstation that allows flexibility in the positioning of the nurse during surgery, allowing repositioning based on visibility and flow needs. The mobile workstation minimizes the need to move around constantly during the surgery. This enables the circulating nurse to optimally position the workstation to view the procedure while documenting or monitoring the surgery in the computer. A parking alcove is provided for this workstation when it is not in use (e.g., during turnaround or postoperative phases). Observations and focus groups also highlighted the importance of cord management, outlet positioning and the location of environmental control devices (e.g., lighting) with regard to the mobile workstation, because the unit requires a power outlet for charging and some staff reported a preference for having the workstation plugged in at all times.

Information Displays

The OR prototype was designed with integrated patient information retrieval and display technology in addition to adjustable boom mounted displays around the surgical table. Proposed wall-mounted information displays were located on three walls of the prototype, envisioning a continuous band of digital display integrated into the wall panels surrounding the entire room. The prototype was fabricated with three wall mounted monitors one on each long wall and one on the foot wall of the room. Aiming to enhance situational awareness, displays were positioned to allow optimal visibility for the entire surgical team at any time during the surgery, on either side of the surgical table, and while moving around the room. Simulations found that displays were initially installed too high for comfortable viewing and that sight lines were blocked from some points by overhead surgical booms and lights (Joseph et al, 2021).

OR Flexibility

Based on observations at one of the case studies visited and simulations conducted during the design process, the prototype chassis was designed to accommodate the option of an adjoining induction room for pediatric cases. Given that most pediatric surgeries are of a short duration with a longer preoperative stage involving induction, a separate room allows the next case to begin the induction process with a separate anesthesia team outside of the OR while a procedure is in progress. This enables parallel processing with quicker turnaround times and throughput of surgical cases each day. The separate induction room also allows family members to be with the child during the intimidating induction process without the need for gowning.

Simulations showed that the configuration of the OR prototype was able to accommodate these different configurations with minor changes, incorporating adjoining ancillary rooms such as an induction room or postoperative instrument breakdown room and a scrub sink/entry alcove. The prototype was tested in simulation for both postoperative instrument breakdown associated with orthopedic surgeries and induction outside the OR for pediatric surgery. The induction room scenarios were viewed as beneficial for short duration pediatric cases and ultimately were adopted in the subsequently built facility as a means to improve room turnover and overall productivity (Joseph et al, 2021).

The prototype was built with a modular and adaptable overhead structural frame to support surgical booms, surgical lights and other ceiling-mounted items. It was designed to enable the relocation of these overhead elements with minimal effort and cost. The simulations did not explicitly evaluate the original placement of overhead surgical booms and lights, although anecdotal feedback indicated that there was some difficulty in optimally positioning the surgical boom and lights across different procedures and clinician positioning. Insights indicated that the mounting locations of the booms were too close to the center of the OR table and would be better placed further apart to minimize conflicts in boom rotations.

Safe OR Design Tool

The interactive web-based Safe OR Design tool provides an opportunity to interact with components in an OR environment through a 3D model. The web interface also allows users to explore design strategies and their associated desired outcomes for a series of design elements commonly found in OR environments. Additionally, users of the tool may filter design strategies by the type of strategy it is within the work system and access citations associated with each design strategy. The 6DIH 2'5 HVLJQ 7RRO KWWS RUGHVLJQ FOHPVRQ HGX RUBGHVLJQBWRRONLW contains the following components:

- Design Elements: A series of 14 design elements provide a focused platform for accessing design strategies and desired outcomes for commonly found features within the OR environment.
- Design Strategies: These actionable statements provide guidance on how to implement a design strategy into the OR environment to support a desired outcome.
- Rationale: An associated description is provided for each design strategy addressing why that specific strategy is important to consider based on current literature or PSLL findings.
- Desired Outcomes: Desired outcomes that have been linked with evidence to the associated design strategy are provided to ad

) L J X U H : ORs in the MUSC pediatric ambulatory surgery center, featuring integrated design concepts generated over several years of the PSLL

Post R Fcupancy (valuation

The size, dimensions and configuration of the OR prototype enabled an effective and efficient use of its space. As a major finding validated by simulations as well as the POE, placing the surgical table diagonally and off center in the rectangular shaped room, away from the entry door, improved movement and flow in the OR, facilitating patient entry, transfer and positioning. Additionally, this position of the surgical table facilitates movement around the room without interfering with the anesthesia and sterile zones around the patient, avoiding flow disruptions in these areas, such as bumps, trips, and related safety risks for patients and staff (Joseph et al., 2021).

the mock up design in terms of infection control. Based on similar limitations, the study did not evaluate the impact of artificial lighting scenes, daylight or connections to nature for either patients or staff, even though considerable attention went into considering these attributes in the prototype design. Likewise, the study could not test issues of flexibility beyond accommodating the select range of pediatric ambulatory surgery procedures. These issues all deserve further consideration and evaluation in the future.

Conclusions and Significance

The work products and research publications developed as part of the RIPCHD.OR PSLL represent the most comprehensive body of work related to operating room work systems design. In addition to the traditional peer-reviewed publications and conference presentations, the range of other innovative products include V well-illustrated online books, a web-based tool, physical prototypes and the 'Innovations in Surgical Environments Workshop' These different modes allowed this work to be disseminated quickly and effectively and ha Y H already made a significant impact on the industry. The design, process and technology solutions that emerged from this learning lab were implemented at the new MUSC Ambulatory Surgery Center in South Carolina and at the Emory Executive Park Musculoskeletal Institute in Georgia. Plans are underway to conduct a similar POE at the Emory facility in 2022. The lessons learned from this project have also influenced the design of several surgery center projects around the US and will provide the foundation for future research related to other types of OR environments such as hybrid ORs and robotic-assisted surgeries. The research and prototype design framework and methods that were developed, employed, and refined through this project are envisioned to be applicable to other healthcare spaces where critical patient care and treatment D U H delivered and in settings that are replicated over-and-over again in the design of healthcare facilities. Work from this research project has been extended into another AHRQ grant funded research study focused on reducing errors in perioperative anesthesia medication delivery. This new research project is a collaboration between the Medical University of South Carolina, Clemson University, and Johns Hopkins University and will continue through 2022. This project has also made a significant impact on all faculty and students involved with the project, resulting in a transdisciplinary team that now has the capability to tackle similar complex problems to make healthcare environments safer.

List of Publications and Products

Publications

Joseph A, Mihandoust S, Wingler D, Machry H, Allison D, Reeves S. Comparing user perceptions of surgical environments: Simulations in a high-fidelity physical mock-up versus a postoccupancy evaluation. + H D O W K (Q Y L U R Q P H Q W V 5 H V H D U F K ' H V L J Q - R X U Q D O. 2021 September 13; doi: 10.1177/19375867211044733 https://doi.org/10.1177/19375867211044733

Joseph A, Neyens D, Mihandoust S, Taaffe K, Allison D, Prabhu V, Reeves S. Impact of surgical table orientation on flow disruptions and movement patterns during pediatric outpatient surgeries. I Q W H U Q D W L R Q D O - R X U Q D O R I (Q Y L U R Q P H Q W D O 5 H V H D U F K D Q G 3 X E O L F + H D O W K. 2021 July 31; 18 8114. doi: 10.3390/ijerph18158114 https://doi.org/10.3390/ijerph18158114

Joseph A, Reid J, Kearney J. Planning Patient Care Areas Using Simulation. In E.S. Deutsch, S.J. Perry, & H.G. Gurnaney (Eds.), Comprehensive Healthcare Simulation: Improving Healthcare Systems (pp. 97-105). Cham: Springer International Publishing, July 2021;97-105, ISBN: 978-3-030-72973-8; doi 10.1007/978-3-030-72973-8_14

Allison D, Machry H, Joseph A. Design insights from a research initiative on ambulatory surgery operating rooms in the U.S. Instituto de Pesquisas Hospitalares (IPH) Magazine. 2021 May; 17 212-229, ISSN 2358-3630.
Jurewicz KA, Neyens DM, Catchpole K, Joseph A, Reeves ST, Abernathy III JH. Observational study of anaesthesia workflow to evaluate physical workspace design and layout. British Journal of Anaesthesia. 2021 Mar; 126(3):633-641. doi: 10.1016/j.bja.2020.08.063. Epub 2020 Nov 5. PMID: 33160603 https://doi.org/10.1016/j.bja.2020.08.063
Machry H, Joseph A, Wingler D. The fit between spatial configuration and idealized flows: Mapping flows in surgical facilities as part of case study visits. Health Environments Research & Design Journal. 2020 May 29; doi: 10.1177/1937586720928350 https://doi.org/10.1177/1937586720928350
Taaffe K, Joseph A, Khoshkenar A, Machry H, Allison D, Reeves ST; RIPCHD.OR Study Group. Proactive evaluation of an operating room prototype: A simulation-based modeling approach. Journal

16)

Surgical Environments Workshop

In 2019, the RIPCHD.OR team held an ambulatory surgery center design workshop at the Clemson Design Center in Charleston (CDCC). The -day intensive event explored how different aspects of surgery center design impact patient safety, efficiency, and patient experience and provided attendees with actionable tools and approaches to support project teams in the design process. The Innovations in Surgical Environments workshop represented a culmination of the -year multidisciplinary RIPCHD.OR research effort on different aspects of ambulatory surgery center design. The event involved around 100 attendees including advisory committee members, industry experts, designers, clinicians, and healthcare administrators. The goal of the event was to provide industry leaders with in-depth knowledge of surgical center design and support others in applying a human-centered approach to their current or future OR projects.