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Vision, Mission, and Purpose

The ***Health Environments Research & Design Journal*** (HERD) is an interdisciplinary, peer-reviewed journal whose mission is to enhance the knowledge and practice of evidence-based healthcare design by disseminating research findings, discussing issues and trends, and translating research into practice.

The vision of HERD is to improve measurable healthcare outcomes as a result of enhancing healthcare environments for those receiving and providing care.

HERD is the only journal featuring evidence-based articles on the design of health environments and the design-related outcomes associated with safety, clinical results, organizational performance, economics, and the human experience. The commitment to an interdisciplinary design process is reflected in HERD's interdisciplinary Editorial Board, with representatives from healthcare (including nursing, medicine, and healthcare administration), the design industry (architecture, engineering, interiors, graphics), environmental and behavioral psychology, neurosciences, systems and organizational effectiveness, art, music, and other complementary fields. The journal centralizes knowledge about healthcare innovations and design while addressing significant industry challenges to improve patient outcomes, reduce errors, and enhance the work environments of healthcare professionals.

As a translational journal linking research to practice, HERD features both rigorous research from academic sources and applied research from practice. Submissions from both scholars and practitioners are welcome. All will be held to high standards.

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Going Forward: A Lean Way to Design

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"That's not what I meant." Generally speaking, this phrase does not mean the end of the world, and the affected parties can quickly come to terms and remedy the misunderstanding. In the world of design, however, such a phrase can imply disaster for the designer and client, if not resolved early enough in the process of a building project. And in the history of design, this phrase is probably heard more often than many designers are willing to admit.

As with many areas where inspiration evolves organically with the passing of time, the world of design and build is undergoing a renaissance. New tools and approaches, including patient-centered design, computer simulation and iterative data-driven design are being applied in the healthcare setting, and this issue of *HERD* is dedicated to examining them. In each of these thought-provoking articles, we challenge conventional approaches to design—and conventional wisdom—and offer new techniques that promise to create more effective environments in which to practice and receive care.

The idea that conventional wisdom must be challenged in the world of design grew from the very successful application of Lean and Six Sigma principles in hospital operations, dating back over a decade. In 1999, nobody in healthcare had heard of these methods, and it might not be unusual to hear in the halls of the hospital "who is Sigma and why is she sick?" Today, two separate studies, one by the American College of Healthcare Executives and the other by the American Society for Quality, indicate that over 40% of hospitals have applied Lean and Six Sigma to improve quality and reduce costs.

My own experience with these methods has been consistent with industry. In 2000, I earned a "Blackbelt" in Six Sigma and went about helping hospitals to realize their full potential in operational, workflow and quality changes. Unfor-

tunately, even the smallest amount of data can be intoxicating to managers, who are often quick to conclude that they understand the root cause of performance problems. Executives were absolutely convinced they knew how to improve processes and many initiated performance improvement efforts with a solution in mind. The industry became replete with examples of performance improvement efforts that actually had a deleterious effect because they were based on flawed data. It would take another several years before the industry realized that for data-driven design to work, it must demand accurate data, patience, and the ability to surrender to the process of discovery before rushing to solutions.

Fortunately, such patience has paid off. In a study conducted by Creative Healthcare including over 150 projects conducted by 10 healthcare systems over the past 10 years, Six Sigma projects were shown to yield an average return on investment (ROI) of 7:1. With this compelling evidence to embolden us, it's time to take these methods as far as they can go.

How does one begin the process of undertaking a Lean or Six Sigma journey in an environment where such concepts are potentially new and unproven? A research paper offered by Maartje van Reedt Dortland et al. in this issue of *HERD* discusses the findings from an exploratory survey with options for construction that facilitate understanding of the contemporary view of available options, while another research paper by Vanessa Okken et al. examines the impact of light on the quality of patient–provider relationship

Next, Michael White et al. offers a meta-anlysis of evidence-based design lighting senior living environments. Then we take a deep dive into the concepts of both Lean *and* Six Sigma, the latter made famous by Jack Welch from General Electric and, as noted above, now is in the mainstream of healthcare performance improvement: Wendy Novicoff helps us understand how Lean and Six Sigma methods add value to the traditional process of design.

Laurie Wolf et al. demonstrate a very straightforward application of the Lean principles in reducing patient injuries. Much can be said about the benefit of a "quick win" in improving quality indicators when it comes to introducing a new approach such as Lean and Six Sigma. In this regard, this article informs the reader what can be done quickly, at low cost, and with significant results.

Lindsay McCunn and Robert Gifford give us an examination of environmental design in acute care settings, specficially a neurological rehabilitation unit, comparing the NRU and acute care setting design considerations. Then Patricia Morrill discusses risk assessment as a standard in the design process, including a look at interviews that exposed facility solution concerns.

Finally, we conclude this issue exploring Six Sigma and Lean with Kurt Hanft's review of *Lean Hospitals: Improving Quality, Patient Safety and Employee Engagement* (2012), by Mark Graban. A veteran in the practice of data-driven design, Kurt Hanff reviews the salient message of this important new resource available to healthcare executives and describes how the book can be used, and is used at Sharp Healthcare in San Diego, CA, to advance the knowledge and compe-

tencies of healthcare executives and clinical leaders in using Lean processes to improve quality. Sharp is one of only 11 hospital systems to have won the prestigious Malcolm Baldrige Award, and its commitment to the "Sharp experience" demanded attention to patient-centered design.

It is worth pointing out that contemporary approaches described in these pages will demand a lot of an organization. As one CEO rightly pointed out, "when you start applying Six Sigma, you may learn some things about your organization that you did not necessarily want to know." And because not everyone embraces change—either in approach or final design—it is critical for an organization's leadership to be fully on board with these methods, or staff will withdraw their own support. To be sure, Lean and Six Sigma may appeal most to organizations that are fully committed to going from good to great. Others need not apply.

For those that work in the field of healthcare design, these are exciting times. Speculation, assumptions and modeling can give way to approaches that combine data-driven findings with "the voice of the patient." When the objective and subjective come together to inform the physical environment, we can create patient care environments that truly sing.

IAN R. LAZARUS is Founder and Managing Partner at Creative Healthcare, a firm that provides technologies and training to healthcare organizations, including Lean Six Sigma and ISO deployment and certification. www.creative-healthcare.com.

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Applying Different Processes for Evidence-Based Design

Jaynelle F. Stichler, DNS, RN, NEA-BC, EDAC, FACHE, FAAN

Jaynelle F. Stichler, DNSc, RN, EDAC, NEA-BC, FACHE, FAAN

There continues to be confusion in the healthcare design industry about the differences between the processes of research, evidence-based design, and process improvement. While there is significant overlap between these three processes, there are distinctive differences as well. This issue of *HERD* features articles on the process improvement and quality improvement processes referred to as *Lean Six Sigma.* While these two processes are often used together, they are two separate processes used to improve projects, performance, throughput, and outcomes. Lean Six Sigma is not only a philosophical and belief system, but it is also widely recognized as a strategic change process with a suite of tools that can be used to make improvements to the physical work environment or work processes (Graban, 2012). Lean Six Sigma is all about change and how to ensure that you change, or "fix," the right problem as opposed to applying precious resources to solve the wrong problem. Lean Six Sigma is not about "quick fixes," although some of these can be recognized and adopted early in the process as rapid cycle changes. Lean Six Sigma is about identifying the root cause of problems and the other interrelated variables that influence the problem.

How does Lean Six Sigma relate to architectural and design research or the use of an evidence-based design (EBD) approach in the planning and design of healthcare facilities? The Lean Six Sigma process should be used prior to commencing the planning and design process to prevent designing process and/or operational failures in a new or renovated building. All too often, designers are influenced by healthcare professionals who approach design with the "this is how we do it here" mentality. What's curious about this approach is that they are often unhappy with "how they do it here" and have even developed numerous "workarounds" to make the existing facility work for them.

Recently I was invited to meet with some physicians and nurse leaders from a large healthcare organization who had recently completed a new building addi-

tion that included a large new emergency department (ED). Nurses and physicians had been involved in the design and they had used the "this is how we do it here" approach. Now they were finding that their new facility simply was not working for them, and patients were waiting in the large waiting area for up to an average of 8 hours before being moved through the ED care process. The patients were often quickly assessed in a triage area and sent back out to the waiting room to stay until they were called. The new ED had been designed much larger than the previous one to solve the problem of long wait times for patients, but the wait times were longer than ever. Patient satisfaction in the new ED was surprisingly low and patient comments validated their discontent with being moved back and forth between the waiting room, triage, diagnostic and treatment areas, and the laboratory before they were ever seen by a physician.

The Lean Six Sigma process should be used prior to commencing the planning and design process to prevent designing process and/or operational failures in a new or renovated building.

The hospital leadership employed consultants to assist them with a Lean Six Sigma process to improve patient flow and to reduce long waiting periods for patients in their new ED. The Lean Six Sigma process, using multiple tools and approaches, broke the problem down to determine root causes using Fishbone diagrams, process flow charts, the 5S process, and other methods to improve patient flow and minimize the wait time to be seen by a physician and ultimately discharged home or admitted to an inpatient bed in the hospital. This example is the reality of a number of different departments throughout hospitals all across the U.S. If Lean Six Sigma processes had been used prior to planning and design, the "this is how we do it here" approach that is memorialized in concrete and steel could be eliminated.

The Lean Six Sigma process should be recognized as the new first phase of the planning and design process for healthcare design. Lean Six Sigma should be employed after the visioning for the new facility and before space programming occurs. The output of the Lean Six Sigma process can dramatically affect the amount of space that might be needed because processes can be changed or improved and less space needed, or it could be that more space might be needed because of process improvement that could ultimately affect the patient experience or the providers' work processes.

Research, Evidence-Based Design, and Process Improvement: Overlapping Processes

Research, evidence-based design (EBD), and process or quality improvement have different purposes or aims, structures, processes, and outcomes. The purpose of research is to generate new knowledge because evidence does not exist to support or answer your research question. The purpose of EBD is to use existing evidence to inform decisions or practice when designing a new hospital or health care facility, and EBD answers a PICO or clinical question. The purpose of process or quality improvement is to answer the question, "How can we do this better to achieve improved outcomes?" One can readily see that the aim and

The Lean Six Sigma process should be recognized as the new first phase of the planning and design process for healthcare design.

purpose of these three methodologies are different. Research creates new knowledge that informs the EBD and process improvement processes. All of the three processes use methods of measuring or statistical analysis to determine outcomes. A comparative chart of differences among the structures, processes, and outputs/outcomes of research, EBD, and process improvement can be seen in Figure 1.

Research Structures, Processes, and Outcomes

Research begins with a clinical or design question and a review of the literature to inform the researcher as much as possible about the concepts or variables of interest. A hypothesis is developed that is the researcher's "best guess" as to how he or she believes the relationship will exist between the concepts or variables of interest. The steps of the research process include (1) asking a research question, (2) forming a hypothesis, (3) searching for and reviewing the literature related to the research question, (4) identifying and using measurement tools (referred to as the methods section), (5) analyzing the results, (6) determining conclusions and implications for practice, (7) identifying limitations to the study, and (8) disseminating the results through publications and presentations (Polit & Beck, 2008). Research is a common language among all disciplines, so the research steps for nursing and medicine are the same as the steps for architecture, biology, psychology or any other science.

So if the research question is, "do definitive observation units (DOUs) improve patient flow through the ED and result in quicker placement to an inpatient bed?", the hypothesis might be, "The design of DOUs in an ED will reduce patient throughput from waiting room to placement in an inpatient bed from 8 hours to 90 minutes." As you can see the hypothesis is often a restatement of the initial research question into the researcher's best guess of what might be and forms what should be tested. The variables that will be tested in this hypothesis will be the number and types of DOUs or beds, time from waiting room to placement in an inpatient bed, and the volume of patients. It should also be noted that this hypotheses and the outcome of testing the hypotheses could also be affected by other confounding variables such as the number of available inpatient beds, the variability of the volume of patients presenting at one time in the ED (volume overload), and the availability of professional staff to assess and place patients in the various stages of the ED visit or the transfer to the inpatient unit. The research process is rarely ever "clean" and there are a number of confounding variables that can affect research findings. These variables should be discussed along with the findings in the discussion section, and at times they become limitations to the study.

Research, EBD, and process or quality improvement have different purposes or aims, structures, processes, and outcomes.

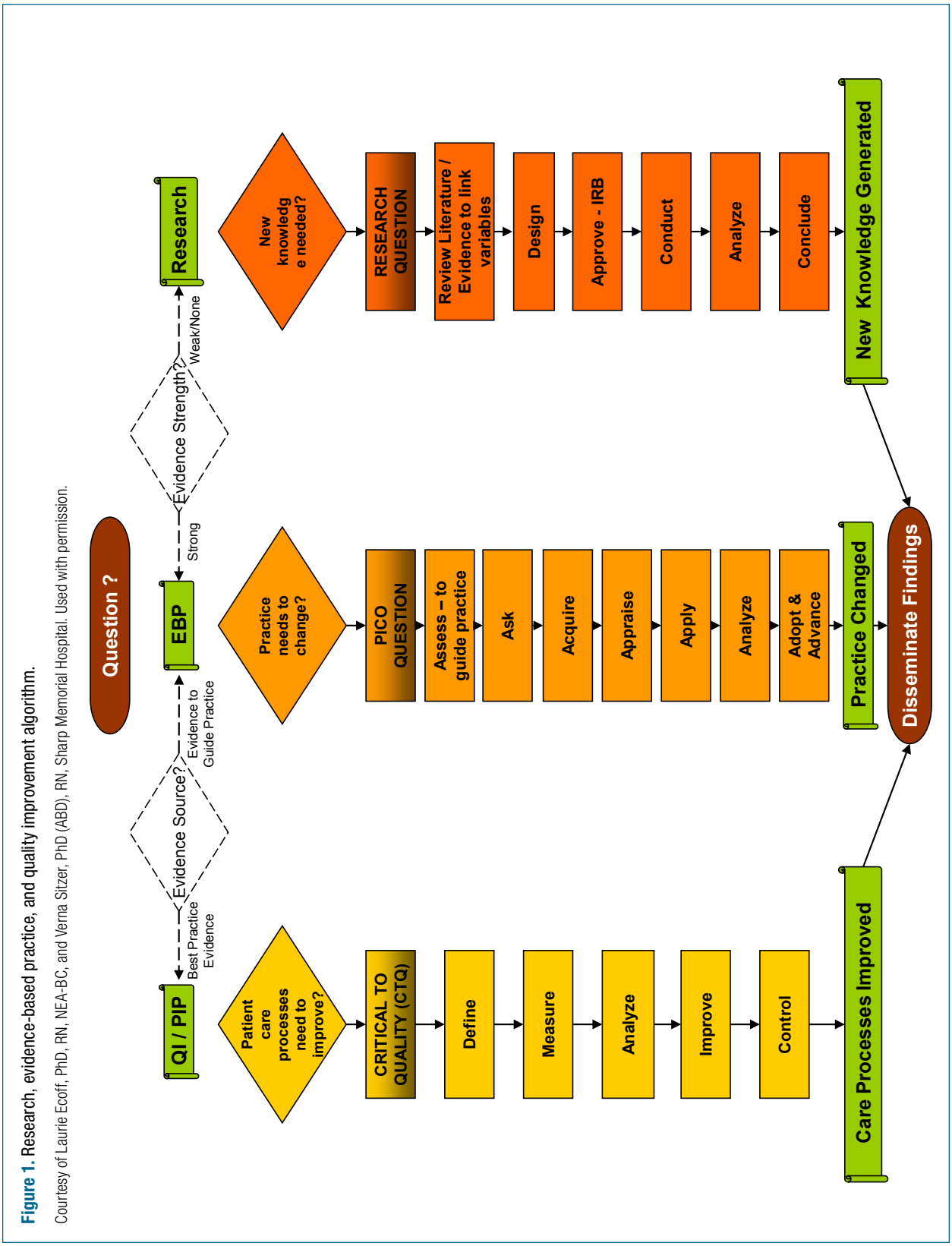

Figure 1. Research, evidence-based practice, and quality improvement algorithm.

Courtesy of Laurie Ecoff, PhD, RN, NEA-BC, and Verna Sitzer, PhD (ABD), RN, Sharp Memorial Hospital. Used with permission.

EBD Structures, Processes, and Outcomes

EBD begins with a clinical or design question as well, but the question is posed in a slightly different manner than the research question. Typically the EBD question is formed from a framework of change—"if I make this change will a desired outcome occur?" The next step is to review the literature and other sources of evidence to support or answer the PICO (see Figure 1) question. If there isn't any literature or evidence available, the process must default to the research process, because by definition EBD is the judicious use of available evidence to inform design decisions. A hypothesis is not developed in the EBD process, because EBD doesn't answer a research question, but it uses available evidence to inform decisions and then measures whether or not those decisions or physical changes achieved the desired outcome as expected. So in contrast to research, the steps of EBD include (1) **asking** a PICO question; (2) **acquiring** available evidence (searching for the evidence in the literature, design standards and guidelines, and case studies); (3) **appraising** the level of evidence; (4) **applying** the evidence to practice/design decisions; (5) **analyzing** the outcomes of the design decisions; (6) **adopting** the new practice/design feature as the standard and an accepted practice change; (7) **disseminating** the EBD results in publications, presentations or new practice/design standards (Ecoff & Sitzer, 2013; Melnyk, Fineout-Overholt, Stillwell, & Williamson, 2010). Notice, the work isn't done until the outcomes are disseminated which is critical to inform other design decisions in the future. This final step prevents us from making the same mistakes over and over in new building projects and allows us to make great decisions based on others' experiences that are critically measured against pre-determined criteria.

Process Improvement Structures, Processes, and Outcomes

Process improvement also begins with a question as to how the steps of a specific process can be changed to achieve desired outcomes. Sometimes these processes include an analysis of changes that could occur in the physical environment to improve workflow. The 5S process reorganizes the workspace so that it is more supportive of work processes and includes the following steps: (1) **sort**—keeping only what is needed for the work process; (2) **straighten**—creating a place for everything and everything in its place; (3) **shine**—making certain that the work environment and the equipment in the work environment are all working appropriately; (4) **standardize**—creating systems and procedures will be the same for everyone in the work process; and (5) **sustain**—maintaining the work environment over time. The 5S process is just one tool that is commonly used in process improvement (Arthur, 2011). Other tools include value stream mapping where you identify "value" as defined by the customer and develop processes to deliver the product or service when the customer needs or asks for it. The focus is on the on the customer, whether that be the patient and family, healthcare professionals using a specific space, or the hospital leadership as a design client. The second step of value stream mapping is to ignore existing beliefs and knowledge or the "this is how we do it here" mentality and to visualize how the workflow should be using spaghetti diagrams or other tools to identify essential steps of the process.

The Lean Six Sigma process uses data to inform the process as well as to measure whether or not the process actually made a difference. Data can consist of existing evidence disseminated by others in published articles or presentations or it can include quantitative data related to admissions, patient outcomes, or anything else that is appropriate for the process that you want to improve. Charts, figures, and tables create visual representation of the data pre- and post-change or process improvement. The real goal of the Lean Six Sigma process is to sustain the change over time.

Your design decisions are memorialized in concrete and steel and effect patient outcomes, how care is provided by nurses, physicians, and other healthcare professionals, and the survivability of healthcare organizations who often must add additional resources to fix design mistakes.

As you can see there are many similarities as well as differences in the structure, processes, and outcomes of research, EBD, and process improvement. All three processes rely on evidence and data that can be measured and demonstrate if a hypothesis or the researcher's best guess was supported to create new knowledge (research); existing evidence that informed a design change or intervention actually made a difference (EBD); and the process change actually made an improvement and was sustained over time (process improvement such as Lean Six Sigma). What is most important is that one or all of these processes should be used prior to commencing design for any healthcare facility. We could no longer afford to base design decisions on unsubstantiated beliefs or myths about what works. Your design decisions are memorialized in concrete and steel and effect patient outcomes, how care is provided by nurses, physicians, and other healthcare professionals, and the survivability of healthcare organizations who often must add additional resources to fix design mistakes. There is a growing body of evidence that has been published in this journal and other scholarly journals or presented at refereed (peer-reviewed) research presentations at national conferences that can be accessed and reviewed to inform important design decisions. We simply need to use the evidence that already exists and commit to formal research to develop new knowledge for future projects.

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Project Coalitions in Healthcare Construction Projects and the Application of Real Options: An Exploratory Survey

Maartje van Reedt Dortland, PhD; Geert Dewulf, PhD; and Hans Voordijk, PhD

ABSTRACT

OBJECTIVE: Exploring the impact of the type of project coalition on types of flexibility by analyzing considered and exercised flexibilities in separated and integrated project coalitions in the design and construction phase and the operations and maintenance phase of a healthcare construction project.

BACKGROUND: Flexibility in healthcare construction projects is increasingly needed in order to deal with growing uncertainties. Until now, little research has been carried out on how and to what extent flexibility is incorporated in different types of project coalitions chosen by healthcare organizations.

METHODS: An exploratory survey was conducted among health organizations in both cure and care. Questions were asked on the position of the real estate department within the organization, the type of project coalitions chosen and the rationale behind this choice, and the extent to which flexibility in terms of a real option was considered and to what extent it had been exercised in a project coalition.

RESULTS: Integrated project coalitions pay more attention to flexibility in advance in both the process and the product, but exercise them to a lesser extent than separated project coalitions. The economic feasibility of real options is higher in integrated project coalitions.

CONCLUSIONS: The study shows that real options thinking is already incorporated in real estate management of healthcare organizations, although more flexibility is considered in advance of the project than is actually realized during and after construction.

KEYWORDS: Built environment, construction, decision making, hospital, planning, strategy

AUTHOR AFFILIATIONS: Maartje van Reedt Dortland works at the Kadaster (Cadastre, Land Registry and Mapping Agency), the Netherlands. Prof. Geert Dewulf is a Dean in the department of Construction, Management, and Engineering at the University of Twente, Enschede, the Netherlands. Hans Voordijk an associate professor in the department of Construction, Management, and Engineering, University of Twente, Enschede, the Netherlands.

CORRESPONDING AUTHOR: Maartje van Reedt Dortland, Eendrachtstraat 30, 8012 VX Zwolle, the Netherlands; Maartje.vanreedtdortland@live.nl

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The Need for Flexibility in Real Estate Management

Worldwide, healthcare is confronted with many uncertainties, such as changes in populations, patterns of disease, opportunities for medical intervention with new knowledge and technology, as well as in public and political expectations (McKee & Healy, 2002). Because of these changes, healthcare assets need to be flexible. In most western countries, flexibility is becoming a vital strategy due to the increasing healthcare costs and major policy changes that are stimulating marketization, a more businesslike operation of health organizations. In the Netherlands, for instance, marketization is seen as a major means by which to limit costs. In 2008, marketization received a fresh impulse with new regulations resulting in an increase in the importance attached to efficient and professionalized real estate management (Bellers, 2008; Raad voor de Volksgezondheid en Zorg, 2006). Real estate decisions involve balancing the flexibility needed to meet an organization's and its users' needs, now and in the future, with controlling time, costs, and quality by not allowing excessive flexibility, to which we refer as Corporate Real Estate Management (CREM).

Real estate decisions have a long-lasting effect while the demand for clinical services will fluctuate during the lifetime of a hospital. Healthcare assets require long-term investments and the risks are inevitably high. For this reason, given the uncertainties surrounding healthcare, flexibility has become an important issue in healthcare real estate management (Blanken, 2008; de Neufville, Lee, & Scholtes, 2008; Rechel, 2009). Flexibility in healthcare assets is needed in order to enable easy adaptation to the demands of the changing environment (Kreiner, 1995; Olsson, 2006; Rechel, 2009; Van Iersel, 2005). The way assets are provided has a major impact on future flexibility.

The way assets are provided has a major impact on future flexibility.

Healthcare assets may be procured in various ways ranging from traditional or conventional procurement towards integrated service delivery. Dewulf and Wright (2009), when discussing procurement systems, showed that project coalitions are an important mechanism for creating flexibility in health organizations. A "project coalition" concerns the organization of resources needed for a construction project, and the division of tasks, risks, and responsibilities between phases and among the parties involved (Winch, 2010). The different phases of a building process are development, construction, maintenance, and operation. The project coalition, and the way it is shaped by agreements among the participating parties, determines the extent to which real estate can be adapted, and thus the types of flexibilities that can be exercised.

Health organizations may opt to organize construction projects using traditional procurement and construction approaches in so-called separated project coalitions (Winch, 2009). In a separated project coalition all subsequent tasks are procured after each phase of a building process, requiring a number of separated contracts. The client bears most of the risks and the responsibilities remain in-house. In an integrated project coalition, several tasks are integrated into a single contract between client and external provider of assets. Integrated project coalition forms, including the transfer of risks and responsibilities to external providers—such as Public Private Partnerships (PPP) or Design Build Finance

Maintain and Operate (DBFMO)—are argued to be beneficial for health organizations (Van Beek et al. 2010). However, given the mixed experience with Private Finance Initiative (PFI) schemes in the United Kingdom, and the lack of experience in the Netherlands with such approaches, integrated forms of project coalitions are applied less often.

The type of project coalition between the client and the external provider of assets includes mechanisms that provide flexibility in both the product and the process. This can be enabled by agreements with contractors within the contract (Madhok, 1995) and in the way cooperation functions within the coalition. Flexibility can be created through flexible innovations designed by the coalition. Making adjustments within the building during its operational life might also be a task for a project coalition. Further, within the early phases of a construction project, uncertainties are still high (Winch, 2010) and therefore flexibility is important.

Until now, little research has been carried out on how and to what extent flexibility is incorporated in different types of project coalitions chosen by health organizations. This applies to both the design and construction phase of a project, and to the operations and maintenance phase of real estate. It is expected that there will be a difference between separated and integrated project coalitions in terms of types of flexibility considered and actually exercised. Furthermore, it is expected that considered and exercised flexibilities in project coalitions will be different in the design and construction phase of a project compared to the operations and maintenance phase.

The aim of this article is to explore the impact of the type of project coalition on the types of flexibility by analyzing considered and exercised flexibilities in separated and integrated project coalitions in the design and construction phase and the operations and maintenance phase of a healthcare construction project. We carried out an exploratory survey among Dutch organizations involved in cure and care services because there is no information available on how health organizations currently deal with flexibility in their real estate projects. Further, there are no overviews of which project coalition forms are being selected and used and which considerations underpin these decisions. The survey aimed to answer the following research questions:

1. What types of project coalitions are chosen for the development, construction, and operation of real estate in both cure and care sectors?
2. What is the rationale behind the type of project coalition chosen?
3. What types of flexibility are considered within separated and integrated project coalitions and to what extent are they actually exercised within these project coalitions?

To be able to analyze the types of flexibility we applied the real option theory to healthcare real estate decisions (Amram & Kulatilaka, 1999).

In the following section, "Conceptual Framework," we elaborate on the abovementioned subjects. After the methodology section, which also discusses the lay-

out of the survey and the respondents, the results are presented and the research questions answered. We then conclude with general remarks on the findings and suggestions for future research.

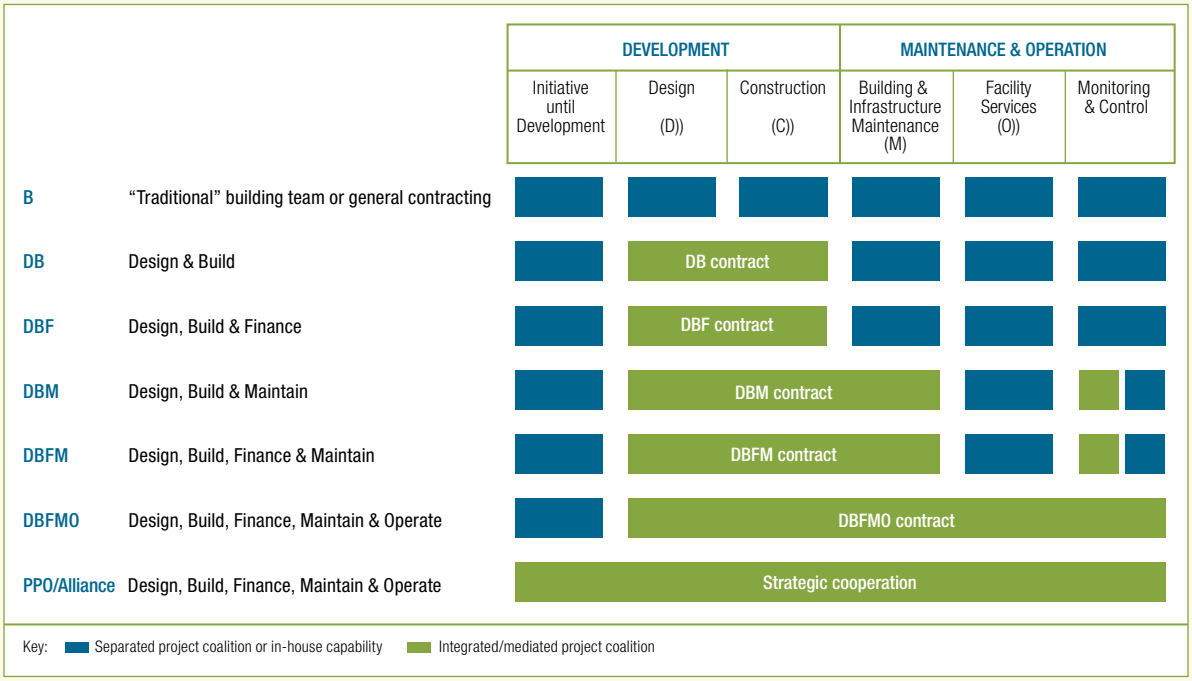
Conceptual Framework

In this section, we define the types of project coalitions that we investigated. Further, we present the considerations that are mentioned in the literature that should be involved when deciding on the type of project coalition. This section concludes with the discussion of real options and flexibility.

Types of Project Coalitions

Because real estate development is not the core business of health organizations, most related activities are outsourced to external parties within a project coalition. We follow Winch's (2010) definition of a "project coalition" as the organization of all the various supply-side human and equipment resources needed for a construction project, and the division of risks and responsibilities among the stakeholders. Besides the relatively short-term activity of construction, other tasks such as exploitation and maintenance can also be outsourced to external parties within a project coalition through relatively long-term agreements. Figure 1 illustrates the division of tasks in the various project coalition forms seen in modern large construction projects.

Figure 1. The division of tasks in the various project coalition forms seen in modern large construction projects.



Winch (2010) describes four basic types of project coalition structures: separated, integrated, mediated, and unmediated. The *separated* form of project coalition is often referred to as traditional, in which all subsequent tasks are procured after each phase is completed. Most risks and responsibilities remain with the client. In an *integrated* project coalition, several tasks covering aspects such as design (D), build (B), finance (F), maintenance (M), and operation (O) (DBFMO) are integrated into a single contract, and these can be observed in several forms. Here, certain risks are transferred by the client to the contractor for a given price. In general, the influence of the client on the process is less than when using a separated project coalition. In a mediated project coalition, the client and the contractor together seek solutions and allocate risks to those best able to bear them. Pries et al. (2006) speak of a strategic cooperation when all the DBFMO tasks reside within a single coalition, often organized as an alliance. In a mediated project coalition, the client has more influence over the process than in an integrated project coalition. An unmediated project coalition requires significant in-house capabilities for real estate development and is therefore generally avoided by health organizations. In contrast to the other project coalitions, clients directly appoint and co-ordinate several contractors and contractors themselves.

The Rationale Behind the Type of Project Coalition Selected

Several considerations should be involved in choosing the type of project coalition (Adler, 2003; Hilmer & Quinn, 1994; Kakabadse & Kakabadse, 2000). Van Iersel (2005) distinguishes between three categories of considerations: the external context, the internal context of the organization, and the project context:

1. In the external context, we distinguish four considerations for choosing the type of project coalition. First, governmental law and regulations might enforce a certain type of procurement procedure including the form of project coalition and outsourcing, and uncertainty regarding policy might also influence the course of a project. Second, politics and society might enforce other policies and other demands on healthcare facilities. Third, trust in cooperating parties plays a role since it is an important factor in successful cooperations between parties (Laan, 2008). Fourth, the availability of competent parties is an important consideration when outsourcing.

2. Internal considerations such as the organizational structure and culture have an influence on outsourcing policy regarding real estate assets and therefore on the project coalition selected. Further, the financial position of an organization may be important, as might organizational changes such as mergers and acquisitions (Buono, Bowditch, & Lewis, 1985; Kiers, 2011). Finally, knowledge, experience, and capacity will influence decisions on which tasks to keep in-house and which to contract out.

3. The project context is the third contextual perspective. Common performance indicators such as money, time, and quality cannot be ignored. A client's influence on a project will be less with certain project coalition forms and outsourcing strategies, and a loss of control over critical functions might be considered undesirable. A complex project involves

many risks and often a desire for innovative solutions. Therefore, with a complex project, a client may opt for an integrated or a mediated project coalition since these are thought to generate innovative solutions (Eaton, Akbiyikli, & Dickinson, 2006; Winch, 2010). The division of risks in a specific project coalition has also to be considered here since this is related to the coalition form selected.

The internal, external, and project considerations will influence the choice of project coalition type since they offer various potential organizational structures regarding the management of real estate. In this study, the survey provides an indication of considerations that are important in selecting the type of project coalition, in both cure and care organizations, using these three contextual perspectives.

We also investigate the relation between the position of the CREM department in the health organizations and the types of project coalitions selected. Based on research in the services and production industry, Krumm (2001) provides a typology of corporate real estate units having different positions within the organization:

- Centralized real estate department, enabling production and corporate expansion. Here, the main task is to control construction activities, both technically and financially. All activities are kept in-house.
- Decentralized real estate unit, resulting in the establishment of internal service departments to provide services to the users with regard to accommodation. Most services remain in-house.
- Renting rather than owning real estate, often as a consequence of needing to allocate more money to core activities. As a result, services can be outsourced, and corporations increasingly outsource the organization of non-core activities.
- A coordinated corporate knowledge center, aimed at "the external coordination of alliances with service providers and the internal alignment of real estate resources and capabilities to obtain maximum added value for the organization."

We use these categories to provide an indication of the position and development of the CREM departments of health organizations.

Flexibility and Real Options

Flexibility is a broad concept (Olsson, 2006) and various types of flexibility can be recognized and categorized, as for example for healthcare facilities by Carthey et al. (2010). De Neufville, Hodota, Sussman, and Scholtes (2008) focused on managerial considerations related to flexibility, and distinguished strategic, tactical, and operational product flexibility. "Strategic flexibility" refers to changing the configuration of an asset to enable long-term real estate strategies. For instance, a hospital can be designed in a way that an expansion of the hospital can take place incrementally, by leaving sufficient space on the site to meet pos-

ROA provides a language on flexibility that facilitates communication between different decision-making levels.

sible needs (Blanken, 2008, p. 96). Tactical flexibility enables adaptation of the building without changing the overall size and functionality. Operational flexibility involves changing building use on an *ad hoc* basis. The type of project coalition chosen is an important factor in creating different types of flexibility in both the product and the process. A promising approach for providing insight into and categorizing different types of flexibility is the real options theory (Gehner, 2008; Olsson, 2004; Vlek & Kuijpers, 2005). A real option is defined as a right, but not an obligation, to exercise an option, and derives from the idea of financial options (Black, 1973). Myers (1977) applied options to *real* investments: so-called real options. Real options provide value through the ability to be flexible, a value that increases as uncertainty increases.

Real options analysis (ROA) (Adner, 2004; Leiblein, 2003) is promising for three reasons. First, real options, as a way of thinking, help real estate managers recognize that uncertainty is not inherently negative, and can even provide value. Second, many uncertainties in health are unpredictable and therefore difficult to quantify. ROA can be used to assess uncertainties in an easy and qualitative way without requiring the competences to use complicated risk analysis tools. Another advantage is that the categorization of real options might simplify communication on flexibility, and the need for it, as well as helping identify appropriate mechanisms that can be mobilized to create flexibility. As such, ROA provides a language on flexibility that facilitates communication between different decision-making levels. For example, the project management team of an organization can more easily provide insights into the consequences of certain decisions for the board of the organization.

Based on Fichman et al. (2005), Sommer and Loch (2004), Winch (2010) and Amram and Kulatilaka (1999), the following major types of real options can be recognized in project coalitions:

1. The option to stage, enabling go/no-go moments in a project on whether to continue;
2. The option to abandon, enabling the project to be terminated for reasons such as being no longer commercially rentable;
3. The option to defer, creating flexibility to wait until more information is available and then adapt the project (this is enabled by the stage option and is therefore not included in the survey);
4. The option to grow, in which the initial investment leaves open an opportunity to expand the building, or to shrink it by disposing of parts if not required;
5. The option to scale up or down, creating the opportunity to capitalize on success by scaling the building up, or downsizing when spaces are not used, or scale up or down the provision of services when demand changes;

6. The option to switch, enabling a change of function within the building when in use, or a change in the design in the design phase; and
7. The option to accelerate the process, for example by executing multiple development and construction tasks in parallel. We added a further option of lengthening the duration of a project as a further option to reduce uncertainty by waiting until more information is available. The distinction to the defer option is that some aspects of the project continue while other aspects may be deferred until more information is available or disputes resolved among stakeholders.

De Neufville, Hodota, Sussman, and Scholtes (2008) distinguish between real options *on* projects and those *in* engineering systems, which can be seen as synonymous with *process* flexibility and *product* flexibility. Real options on projects relate to the process of creating flexibility and are associated with real options such as to defer, to abandon, to accelerate, and to stage. Real options in engineering systems deal with technical solutions within the products, such as real options to switch, to scale up or scale down, to grow, and to change the design. These real options can generate operational, tactical, or strategic flexibility as described earlier.

Research Design

The aim of this article is to explore the impact of the type of project coalition on types of flexibility by analyzing considered and exercised flexibilities in separated and integrated project coalitions in the design and construction phase and the operations and maintenance phase of a healthcare construction project. We conducted a survey among Dutch health organizations and distributed a questionnaire to 76 cure and 148 care organizations. The survey of cure organizations was targeted at those who had attended a conference on DBFMO. Of the potential 76 participants, 62 were from hospitals, and the remainder from other organizations. After excluding all but the first respondent from each hospital, we had 22 useable responses, equivalent to a response rate of 35%. The survey for care organizations covered the largest such organizations in the Netherlands. We contacted 150 organizations (the 50 largest health organizations in each of the elderly care, mental care, and youth care sectors) to ask for contact details of the board member responsible for real estate or the head of the real estate department. This resulted in contact details for 136 organizations. After a reminder, we ultimately received 23 responses, a response rate of 17%.

The 22 hospitals that did respond to the survey request varied in size, number of employees, turnover, beds, and floor area. Roughly half of the hospitals had an annual turnover in excess of €100 million (roughly USD$1.35 million) (see Table 1). Most care organizations cover relatively large surface areas, which can be explained by more space being needed for the living function as against hospital treatment. For this and other reasons, the care sector has many more locations than the cure sector. Most hospitals have only one or two locations, although one did claim to have two main locations and five smaller ones. One hospital with only one location noted that, in the near future, it would have three. In the

Table 1. Characteristics of Respondents

FLOORSPACE (1000 M2)	EMPLOYEES	TURNOVER (millions)	CURE	%	CARE	%
> 75	10.000+	> €500	1	5	0	0
> 75	5.000–10.000	> €500	3	14	0	0
> 75	5.000–10.000	€250–500	1	5	0	0
> 75	5.000–10.000	€100–250	0	0	1	4
unknown	5.000–10.000	€50–100	0	0	1	4
> 75	2.500–5.000	€250–500	1	5	1	4
> 75	2.500–5.000	€100–250	6	27	7	30
> 75	1.000–2.500	€100–250	1	5	2	9
> 75	1.000–2.500	€50–100	0	0	6	26
45–60	1.000–2.500	€100–250	1	5	0	0
45–60	1.000–2.500	€50–100	0	0	2	9
45–60	500–1.000	< €50	0	0	1	4
30–45	1.000–2.500	€100–250	1	5	0	0
30–45	1.000–2.500	€50–100	2	9	1	4
30–45	500–1.000	< €50	0	0	1	4
15–30	500–1.000	€50–100	3	14	0	0
3–15	0–500	< €50	2	9	0	0
TOTAL			**22**	**100**	**23**	**100**

care sector, on the contrary, most organizations had many locations with various functions.

In order to answer the research questions, we organized the questionnaire as follows. First, we asked for the function of the respondent in order to be able to value their answers. Further, to indicate the type of organization completing the survey, we asked for characteristics of the organization. Second, we asked for the position of the real estate department within the organization, and what was taken into consideration when selecting the type of project coalition. The third aspect, project coalitions and different types of flexibility, was addressed by asking for the type of project coalition used in one specific project, to be chosen by the respondent, the extent to which flexibility in terms of a real option was considered in the project coalition, and to what extent it had been exercised. The value of a real option was operationalized by asking for the extent to which the economic feasibility of the options was considered and to what extent the economic feasibility was proven. We categorized flexibility types using the real options concept, and the question applied to both the construction and the exploitation phases. Throughout the survey, we asked for explanations of the answers. The operationalization of the questions is shown in the Appendix at the end of this article.

Table 2. Project Coalitions Used

Separated	27	60%
DB	5	11%
DBF	1	2%
DBM	1	2%
DBFM	1	2%
DBFMO	3	7%
Alliance	1	2%
DBM with options for F&O	1	2%
BM for technical infrastructure, separated for construction of building	1	2%
Unknown yet	4	9%
TOTAL	**45**	**100%**

Results

In this section we answer the various research questions, beginning with the results of the research on types of project coalitions chosen, and the rationales used by respondents for those choices. We also discuss how the organization of Corporate Real Estate Management is positioned in the health organizations. This section ends with a discussion of the types of real options that are considered and exercised by health organizations

Types of Project Coalitions Chosen

This section deals with the first research question: what types of project coalitions are chosen in the development, construction, and operation of real estate in both cure and care organizations? Construction and maintenance tasks are outsourced when health organizations are not capable of doing these themselves but the different forms of project coalition determine how much responsibility and risk stays with the client. The project coalition, and the way it is shaped by agreements among the participating parties, also determines the extent to which real estate can be adapted and thus the amount of flexibility. Table 2 shows the project coalitions used by the health organizations in our survey. Most organizations opted for a separated form of project coalition. In the remainder of this article, we therefore combine all the types of integrated project coalition under the same descriptor of integrated project coalitions and then compare results between integrated and separated project coalitions.

The Rationale Behind the Type of Project Coalition Chosen

In this section, we deal with the second major question: what is the rationale behind the type of project coalition chosen? We present the external, internal, and project considerations made by health organizations in outsourcing and in real estate management. Next, we investigate the relation between the position of the CREM department in the health organizations and the types of project coalition selected.

Table 3. Current Position of the Real Estate Department within Health Organizations per Type of Project Coalition

TYPOLOGY OF CREM	POSITION OF CREM IN ORGANIZATION	INTEGRATED	%	SEPARATED	%	UNKNOWN	%
2	Limited Company					1	20
2	Facility services	3	23	6	22	2	40
2	Line service			2	7		
3 or 4	Division/independent staff department	3	23	4	15		
3 or 4	Staff department under board	7	54	10	37	1	20
1 or 3	Project organization under board			2	7	1	20
	Not applicable/unclear			3	11		
	TOTAL	**13**	**100**	**27**	**100**	**5**	**100**

Table 4. Plans to Reorganize Real Estate per Type of Project Coalition

TYPOLOGY OF CREM	POSITION OF CREM IN ORGANIZATION	INTEGRATED	%	SEPARATED	%	UNKNOWN	%
2	Limited Company	1	8	2	8		
3 or 4	Division/independent staff department	3	25	2	8		
3 or 4	Staff department under board			2	8		
1 or 3	Project organization under board	1	8	1	4		
	Yes (no specification)	2	17	2	8		
	No (no specification)	7	50	17	65	5	100
	TOTAL	**14**	**100**	**26**	**100**	**5**	**100**

NOTE:
Percentages are rounded to the nearest whole number.

External and internal considerations in real estate decisions External and internal considerations influence the way CREM is executed. In Tables 3 and 4, we show which external and internal factors, respectively, were considered the most important in making real estate decisions. Organizations in the cure sector were asked to choose the most important consideration from a list of possibilities, whereas care organizations were asked to indicate the importance of each consideration using a 5-point Likert scale. The survey in the cure sector was carried out first and based on the findings we changed the approach for the care organizations so as to gain a more complete overview. The results of the care organization survey were analyzed using a Friedman test and the significance of the results is indicated below each table.

In terms of external considerations, the most important consideration according to organizations in the cure sector was the "market and the availability of parties," while organizations in the care sector identified "law and regulations" as the most important consideration. There is a striking difference between the care and cure sectors, with only 17% of the cure organizations considering the law

and regulations as the most important consideration. A reason for this could be that the requirement to include assets in budgeting was introduced later in the care than in the cure sector.

In the care sector, finance was the most important internal consideration, but not in the cure sector. One reason for its importance in the care sector is the increasing uncertainty surrounding the financing system and obtaining loans from banks. "Knowledge, experience, and capacity" was given as the most important consideration in the cure sector. This was anticipated given current developments regarding the privatization of real estate and the subsequent need for increased knowledge, experience, and capacity of CREM personnel.

Table 5. Internal Considerations in Real Estate Decision Making

	CURE		CARE
INTERNAL CONSIDERATIONS	#	%	MEAN *n*=23
Knowledge, experience, and capacity	6	26	3,8
Finance	5	22	4,3
Organization structure	4	17	3,4
Organization culture	2	9	3,0
Various considerations: finance, merger	2	9	—
Merger	0	0	1,4
No consideration made	3	13	—
Not filled in	1	4	—
TOTAL	**23**	**100**	

NOTE:
The mean ranks differed significantly (χ^2= 3201; *df* = 4; $p < 0.00$).

Table 6. External Considerations in Real Estate Decision Making.

	CURE		CARE
EXTERNAL CONSIDERATIONS	#	%	MEAN *n*=23
Market, availability of parties	8	35	2,7
Trust in cooperating parties	4	17	3,3
Politics and society	4	17	2,8
Law and regulations	1	4	3,4
Various considerations: asbestos clean-up, trust in parties	2	8	—
No consideration made	4	17	—
TOTAL	**23**	**100**	

NOTE:
The mean ranks differed significantly (χ^2= 7920.; *df* = 3; $p < 0.00$).

Project-related considerations Several considerations can be important when making CREM decisions related to a specific project (see Table 5). Money and complexity are the most important project-related considerations in cure projects, whereas money and quality are the most important in care. Finance is an important internal consideration, and logically this has impact on the project. Projects in the cure sector are often larger than care projects and so will almost certainly be more complex. The importance attached to quality might be an indicator of the increasing competitiveness in the healthcare sector.

Respondents were asked to select one project involving their organization and to answer the remaining questions based on this project. Since uncertainties related to financing have been identified elsewhere as obstructing the progress of projects (Plexus en BKB, 2010), Table 6 shows whether finance had been arranged for the projects selected. In fact, in only half of the organizations had finance been structurally arranged. Reasons for not yet having loans in place were:

- Uncertainties over governmental policy; organizations were waiting for clarification.
- Waiting until problems related to balance sheet values had been reduced by governmental arrangements.
- Negotiations ongoing with banks and/or project developers and guarantee fund for healthcare organizations.
- Ongoing consultations with the Dutch "guarantee fund for health" which had recently become the sole guarantor of bank loans.
- Costs exceed budget.
- Waiting to finalize strategic real estate plan before arranging finance.

The position of Corporate Real Estate Management (CREM) In Table 7, we show the position of the CREM department in the health organizations investigated, and their correspondence with the typologies identified by Krumm

Table 7. Project Related Considerations in Real Estate Decision Making

	CURE		CARE
PROJECT RELATED CONSIDERATIONS	#	%	MEAN *n*=23
Money	5	22	4,4
Complexity	5	22	3,8
Quality	4	17	4,3
Risks (risk allocation)	3	13	4,1
No project related consideration made	3	13	—
Influence client on project	2	9	4,0
Time	1	4	3,8
TOTAL	**23**	**100**	

NOTE:
The mean ranks differed significantly (χ^2= 11088.; $df = 5$; $p < = 0.00$).

Table 8. Finance Arranged for Projects among Respondents, in Percentages

	YES	TEMPORARY	NO
Cure	20	7	22
Care	29	9	13
TOTAL	**49**	**16**	**36**

(2001). As can be seen in Table 7, most health organizations manage their real estate in either a decentralized way, shared among various facility services, or centralize them in a staff department under the board. In most cases, they had no plans to change this. Another finding from the survey is that respondents speak of the independence of CREM departments, rather than describing them in centralized or decentralized terms. For example, staff departments are centrally organized, but in some cases become independent staff departments. When analyzing the position of the CREM department in the health organizations and the different types of project coalitions selected there seems to be no relation.

Most health organizations manage their real estate in either a decentralized way shared among various facility services or centralized in a staff department.

Only one organization within our study organized its real estate through an independent entity within a limited liability company, although two more were planning to go down that route (see Table 8). Not many organizations were planning to reorganize their real estate but, when they were, they wanted to make the CREM department more independent, preferably as a division. Conversely, a quarter of the CREM departments were in a dependent position (Line Service or Facility Services), and more than half of these organizations were not planning to change this. Overall, there does not seem to be any obvious trend in terms of positioning CREM services within the organization.

Flexibility and Real Options

This section deals with the third major question: What types of flexibility are considered within separated and integrated project coalitions and to what extent are they actually exercised within these coalitions? Using the real options concept, we consider the types of flexibility considered and exercised, in the cooperation between the parties in the project coalition, in the various phases of a project.

Real options considered and used in project coalitions in the design and construction phases Agreements made within a project coalition create process flexibility in the various phases of a project. In the design and construction phase, real options "on" the project play a large role. When moving to the exploitation phase, the real options "in" the project become more important. Process flexibility creates product flexibility through agreements on adapting the product when necessary. As such, process flexibility is a condition for exercising flexibility in the product or, as phrased in the theoretical framework, so-called real options "in" the real estate.

Table 9. Average Ratings of Options for Separated and Integrated Project Coalitions in the Development and Construction Phase

	REAL OPTIONS	PROJECT COALITIONS	CONSIDERED	EXERCISED	DIFFERENCE
Options "in" the real estate	Switch	Integrated	4.1 (n = 13)	3.3 (n = 11)	–0.8
		Separated	3.3 (n = 23)	2.6 (n = 18)	–0.7
	Grow	Integrated	3.5 (n = 11)	2.4 (n = 9)	–1,1
		Separated	2.8 (n = 21)	2.4 (n = 18)	–0.4
	Shrink	Integrated	3.5 (n = 11)	2.0 (n = 9)	–1.5
		Separated	2.7 (n = 21)	2.2 (n = 18)	–0.6
Options "on" the project	Defer	Integrated	3.6 (n = 11)	1.6 (n = 11)	–2.0
		Separated	2.6 (n = 17)	2.0 (n = 17)	–0.6
	Abandon	Integrated	2.8 (n = 13)	1.7 (n = 9)	–1.2
		Separated	2.8 (n = 22)	1.9 (n = 18)	–0.9
	Accelerate	Integrated	2.8 (n = 12)	2.0 (n = 9)	–0.8
		Separated	2.5 (n = 20)	1.8 (n = 16)	–0.7
	Lengthen	Integrated	2.7 (n = 12)	2.0 (n = 9)	–0.7
		Separated	2.6 (n = 20)	2.2 (n = 16)	–0.3

We asked the participants in our survey to evaluate each option, on a scale of 1 to 5, on the extent to which it was considered in advance in the project coalition, and to what extent the option was exercised. A score of 1 means that it was "not considered/exercised" and 5 indicates that it was "to a large extent considered/exercised." In some instances, respondents only evaluated "consideration," for example because the project had yet to start. In Table 9, the average scores shown reflect only those instances where a "mark" was given. From the table, we observe that, on average, the difference between considered and exercised flexibilities is larger in integrated project coalitions than in separated project coalitions. Most organizations do consider flexibility, but the integrated project coalitions consider on average 91% of all the real options, and the separated project coalitions only 71%. The integrated project coalitions had exercised 73% of the real options, and the separated ones only 45%.

As Table 9 shows, of the real options, changing the design was, by far, the most considered and exercised in both types of project coalitions, and especially applied in the integrated project coalitions. Changing the design is often a reason to lengthen a project, the option showing the least difference between the extent of it being considered and exercised. On this basis, it seems that health organizations have a good insight into the probability of extending the duration of a project.

The options to grow or to shrink were also widely considered, especially in the integrated project coalitions. In our sample, it seems that the probability of needing to grow or to shrink was equally perceived by the organizations. These options were less often exercised, but still more often than the "on" the project real options. One reason that the options had not been exercised could be that these options can be exercised later during the operation phase. Before exercis-

ing the option to change a design, one might expect the option to defer would be equally considered and exercised since changes in the design often lead to deferral of the project. However, this was not the case.

Given the uncertainties affecting healthcare, one would expect the defer option to be seen as important. Indeed, our results show that it is the most considered after the option to change the design. The option to abandon was less often considered. However, the options to defer and to abandon were both more or less equally exercised, albeit infrequently. In three projects with a separated coalition, the option to abandon was exercised to a significant extent (scores of 4 or 5). This is striking since we would expect boards to be very reluctant to abandon a project because these are often once in a lifetime opportunities to which many interests are connected. This reason could also explain why organizations do not defer that often since deferment has similar negative consequences to abandoning. Separated project coalitions consider and exercise the option to accelerate less often than integrated project coalitions. Notably, one respondent claimed not to have considered this option but then to have exercised it to the maximum extent. It is noticeable that integrated project coalitions consider each real option for process flexibility more, but exercise each option less, than the separated project coalitions. In separated project coalitions, the flexibility considered in advance corresponds better to the flexibility ultimately demanded.

In separated project coalitions, the flexibility considered in advance corresponds better to the flexibility ultimately demanded.

Real options considered and exercised in the operation and maintenance phases of project coalitions The grow, scale, and switch options are real options "in" the real estate and are most relevant in the operation and maintenance phase. The scaling up and down, and grow-and-shrink, options create strategic flexibility facilitate the long-term real estate strategy. In order to keep the questionnaire short, we operationalized the grow-and-shrink options but not the scaling option. We did this by asking whether the possibility to expand or shrink the building has been considered and exercised in the project coalition. Further, the switch option can provide flexibility on the tactical and operational levels, and this was operationalized by asking whether spaces could be used for other functions or adapted by means of removable walls for example. We operationalized the value of the real options by asking for the extent to which the economic feasibility of the options was considered and to what extent the economic

Table 10. Average Ratings of Options for Separated and Integrated Project Coalitions in Operation Phase.

REAL OPTIONS AND FEASIBILITY	PROJECT COALITIONS	CONSIDERED	EXERCISED	DIFFERENCE
Option to grow or shrink	Integrated Separated	3.7 ($n = 11$) 3.2 ($n = 22$)	3.0 ($n = 4$) 2.7 (n = 18)	–0.7 –0.5
Option to switch function	Integrated Separated	3.9 ($n = 13$) 3.4 ($n = 22$)	4.2 ($n = 10$) 3.0 ($n = 17$)	+0.3 –0.4
Economic feasibility considered and proven	Integrated Separated	3.9 ($n = 13$) 3.5 ($n = 22$)	3.8 ($n = 5$) 2.5 ($n = 17$)	–0.1 –1.0

feasibility was proven. Questions on the economic feasibility of the switch option provided some interesting findings: while the feasibility of this option appeared to be nearly the same when actually exercised as when considered in advance by the integrated project coalitions, the feasibility was much lower in practice than when considered in advance in the separated project coalitions. Where the economic feasibility appeared to be lower than considered in advance, it can be questioned whether the real option had enough value and therefore should have been invested in. Not all respondents were able to comment on the extent to which an option was exercised or its economic feasibility proven. Organizations that had not yet chosen a project coalition form, or had not completed this part of the questionnaire were excluded from the analysis. The results are shown in Table 10. There is closer agreement between the scores for considering and for exercising the switch option than for the option to grow.

Discussion

Through an exploratory survey we have explored the relation between the types of project coalitions selected by health organizations and the real options considered and exercised in the design and construction phase of a project and the operations and maintenance phase.

Our first question was what types of project coalitions are chosen in the development, construction, and operation of real estate in both the cure and the care sectors. Our study shows that two-thirds of the organizations arranged construction projects in the form of separated project coalitions while one-third opted for integrated project coalitions.

Second, we focused on external, internal, and project aspects considered by health organizations as clients in selecting project coalitions and the potential effect of the position of Corporate Real Estate Management (CREM) within these organizations on this selection decision.

Law and regulations form an important external consideration in the care sector. These are changing, and certain competences are required to deal with this. As such, this might be an important factor in selecting cooperating parties for construction projects. However, most organizations opted for the separated project coalition form where more tasks and responsibilities remain with the client. One reason could be that health organizations recognize that the availability of parties is an important factor and see a lack of competent parties with which they could cooperate.

The health organizations surveyed placed the organizational structure in third place when ranking the most important internal considerations in selecting project coalitions. Here, they perceived knowledge, experience, and capacity and finance as being more important. These internal issues are linked to the consideration of issues outside the organization that are seen as the most important, namely the market and the availability of, and trust in, cooperating parties. One can conclude from this that health organizations outsource tasks related

to real estate management because of a lack of knowledge within their own organization.

Project-related considerations that are viewed as the most important are money, quality, and complexity. Risks and risk allocation, the influence of the client on the project, and time are less important. Therefore, a preference for integrated project coalitions was expected. In result, the high proportion of separate project coalitions is striking given that, with this form, the client in general has more influence and carries more of the risks than in an integrated project coalition.

The different positions of CREM departments as presented by Krumm (2001) are also found in health organizations. Most organizations manage their real estate in a fairly decentralized form. A small trend can be recognized toward CREM departments becoming more independent. This can be achieved in a decentralized way (by creating a limited company) or through centralization (establishing an independent staff department). Nearly one-third of the organizations investigated have their CREM departments decentralized according to the second stage of Krumm (2001). Here, tasks such as design and engineering tasks were outsourced while most services remained in-house. There seems to be no relation between the position of the CREM department within the health organizations and the type of project coalition selected.

Our third question focused on the types of flexibility considered within project coalitions and to what extent they were actually exercised within the various types of project coalitions. Regarding process flexibility in the design and construction phases, it is notable that the integrated project coalitions consider such options more often, but exercise them less, than with separated project coalitions. In other words, in separated project coalitions, the flexibility considered in advance more closely corresponds to the flexibility ultimately demanded. One reason could be that, in integrated contracts, more commitments have to be made, whereas in separated project coalitions the client has the opportunity to reconsider flexibility needs after each phase. It seems that integrated project coalitions, maybe for this reason, pay more attention to flexibility: relatively, they consider and exercise more types of real options than the separated project coalitions. Looking at the extent of the consideration given, the real options "in" the real estate are perceived as more important than the real options "on" the project, especially in integrated project coalitions. This reflects a practice in which design changes often occur, resulting in project deferrals, again one of the most considered options.

The difference between the extent of considered and exercised real options is often more negative in integrated project coalitions than in separated project coalitions, but still the difference in economic feasibility between considered and exercised options is more equivalent while in separated project coalitions the economic feasibility of exercised real options is much more negative evaluated than considered real options. It seems that redundancy in real options considered has less influence on the economic feasibility in integrated project coalitions than in separated project coalitions. This is striking since it is expected that costs increase

as more real options are considered. Logically, the explanation should be found in the agreements made within the two different project coalition forms.

Considering the options in the operations and maintenance phases, we see that the option to switch function within an existing building is the only option that is more exercised than considered. Besides, this option has been considered and exercised most by both separated and integrated project coalitions. Regarding flexibility in the operations and maintenance phases, there is closer agreement between the scores for considering and for exercising the switch option than for the option to grow. It is apparently easier to estimate the need for tactical and operational flexibility than for strategic flexibility. This is logical since strategic flexibility concerns the longer term and has greater implications for the building.

The large difference between the economic feasibility of all real options in both the separated and integrated project coalitions is striking. The integrated project coalitions show a strong correspondence between considered and proven economic feasibility.

Conclusions

The aim of this article has been to explore the impact of the type of project coalition on types of flexibility by analyzing considered and exercised flexibilities in separated and integrated project coalitions in the design and construction phase and the operations and maintenance phase of a healthcare construction project. In examining the real estate strategy within both separate and integrated project coalitions, we focused on the use of different types of flexibility and classified them in terms of real options. The study provided insights into the considerations taken into account by health organizations when selecting the type of coalition. There seems to be no relation between the position of the CREM department within a health organization and the type of coalition preferred.

The results show differences in the use of real options between the two types of project coalitions. The study also shows that real-options thinking is already incorporated in real estate management, although more flexibility is considered in advance of the project than is actually realized during and after construction. Integrated project coalitions pay more attention to flexibility: relatively, they consider and exercise *more types* of real options than the separated project coalitions. In integrated project coalitions each real option for process flexibility is considered more but exercised less than the separated project coalitions. In other words, in separated project coalitions, the flexibility considered in advance more closely corresponds to the flexibility ultimately demanded. Looking at the extent of the consideration given, the real options "in" the real estate are perceived as more important than the real options "on" the project, especially in integrated project coalitions. There is large difference between the economic feasibility of all real options in both the separated and integrated project coalitions. The integrated project coalitions show a strong correspondence between considered and proven economic feasibility.

Although some real options are independent of the form of project coalition, we showed that the choice of a certain type of project coalition enables exercising certain real options. Here, more in-depth research into these project coalitions would be useful in generating further insights into conditions for creating, exercising, and valuing real options. Further research on the use of real options to classify and to value estate options would be useful for generating insight into how a flexible real estate strategy can be created to adapt to future uncertainties. Case-studies on consequences and cost-effectiveness of the various real options should facilitate a more informed decision making on which type of project coalition to choose. Despite the exploratory nature of this study, we believe that the findings are of interest both to health organizations, since they can learn from other organizations on how they deal with flexibility and strategic real estate management, and governmental organizations, since the study provides insight into the effects of current policies. Contractors might also gain from this study from the insights into the considerations leading up to clients' choices for a specific type of project coalition, and their expectations and experiences with flexibility.

Implications for Practice

- An overview of knowledge on current practice of Corporate Real Estate Management of health organizations can generate insights and new ideas among and between the organizations.
- The Dutch example in this study can be used for comparative research among various other countries.
- Governmental organizations can benefit from the study because it provides insight into the effects of current practices.
- The considerations that are part of choosing a certain project coalition can help contractors meet the needs and expectations of health organizations.
- The research provides tools to use in practice, including the classification and valuation of real options.

APPENDIX: OPERATIONALIZATION OF THE QUESTIONS USED IN THE SURVEY		
SUBJECT	OPERATIONALIZATION	TYPE OF ANSWER/SCALE
1 Characteristics of respondents	Size, number of locations, function of respondent, type of care provision, characteristics of building for which answers are provided.	Multiple choice
2 Professionalization of CREM	Position of organization of real estate within organization and plans to change the position.	Description
5 Project coalition	Project coalition chosen in project.	Multiple choice
6 Considerations in choosing project coalition: Internal	Organization structure and culture, finance, merger, knowledge, experience and capacity, no consideration.	Multiple choice
7 Considerations in choosing project coalition: External	Market, availability of parties, trust in cooperating parties, politics and society, law and regulation, no consideration.	Multiple choice
8 Considerations in choosing project coalition: Project	Money, time, quality, influence client on project, complexity, risks (risk allocation), no consideration.	Multiple choice
9 Flexibility considered in the design phase “on” and “in” the project	Option to stop, to adapt the design, to extend, to shrink, to accelerate the project, to slow the project down.	Likert scale 1–5 or N.A.
10 Flexibility used during construction	Extent to which the above mentioned options have been exercised; ask for clarification if 9 and 10 differ.	Likert scale 1–5 or N.A.; description
11 Flexibility considered and exercised during the maintenance and operation phases	Option to extend or shrink the size of the building, change spaces or use spaces differently within the building; ask for clarification if considered and exercised flexibility differs.	Likert scale 1–5 or N.A.; description
12 Options “in” the project for tactical and strategic flexibility	Tactical flexibility: option to switch by suitability of spaces for other functions, e.g., by demountable walls; strategic flexibility: option to shrink or grow. Extent of consideration and exercising options.	Likert scale 1–5 or N.A.
13 Value of real options the project	Difference between considered and actual economic feasibility of real options.	Likert scale 1–5 or N.A.

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When the World Is Closing In: Effects of Perceived Room Brightness and Communicated Threat During Patient-Physician Interaction

Vanessa Okken, MSc; Thomas van Rompay, PhD; and Ad Pruyn, PhD

ABSTRACT

OBJECTIVE: The study proposes that room brightness creates impressions of a more spacious environment and that this perception positively impacts feelings and behaviors during high-threat conversations in particular.

BACKGROUND: To a large extent healthcare providers depend on their patients' willingness to disclose information. In addition to characteristics related to the physician and topic of conversation, research indicates that environmental factors influence patients' affective experiences and self-disclosure.

METHODS: A two-factor between-subjects experimental design was used in which participants (n = 90) were presented with a scenario describing a patient–physician encounter varying in communicated threat. Subsequently, participants were exposed to a picture in which room brightness was manipulated. Next, patient comfort, experienced spaciousness, and self-disclosure intentions were measured.

RESULTS: An effect of brightness was found on affective experiences and self-disclosure intentions. In addition, the predicted interaction was obtained between brightness and communicated threat on these measures. Analyses confirmed that perceived spaciousness mediates the relationship between room brightness and self-disclosure intentions.

CONCLUSIONS: The study confirms that brightness impacts self-disclosure intentions. Additionally, this relationship is influenced by psychological circumstances, with a more pronounced need for spaciousness when in an anxious state of mind. The results suggest that the physical environment can be used as a tool to improve active participation. In addition, the results stress the importance of attending to the patient's state of mind in creating the right atmosphere.

KEYWORDS: Lighting, patients, physicians, satisfaction

AUTHOR AFFILIATIONS: Vanessa Okken is a PhD student in the Department of Corporate and Marketing Communication at the University of Twente in Enschede, the Netherlands. Thomas van Rompay is an Assistant Professor in the Department of Industrial Design Engineering at the University of Twente in Enschede, the Netherlands. Ad Pruyn is a Professor in the Department of Corporate and Marketing Communication at the University of Twente in Enschede, the Netherlands.

CORRESPONDING AUTHOR: Vanessa Okken, University of Twente, Department of Corporate and Marketing Communication, P.O. Box 217, 7500 AE Enschede, The Netherlands; v.s.okken@utwente.nl; 0031 53 489 3287, 0031 53 489 4259 (fax).

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Imagine yourself entering an unfamiliar room for the first time. Whether it is a colleague's apartment, a private physician's practice, or a counseling environment, you can instantly tell whether the room provides you with enough "breathing room" or freedom of movement. Depending on such impressions, you are likely to feel confined, secure, or lost, and you may feel the urge to stay, explore the space, interact with others, or, alternatively, leave as soon as possible. Sometimes, however, the room that was spacious on one occasion may feel less "roomy" on another, or, put differently, the walls that once were at a safe distance now suddenly are "closing in." What this example suggests is that perceptions of spaciousness are not only the result of architecture and interior design, but also vary with the visitor's state of mind.

In line with this example, research shows that spatial aspects of environmental settings play an important part in influencing affective experiences and behaviors. Sundstrom (1975) showed that limited physical space induces crowding perceptions, which in turn may decrease communicative behavior. Okken, van Rompay, and Pruyn (2012) examined the effects of limited space during patient–physician interaction by altering room size and interpersonal distance. Their results showed that participants who felt physically restricted expressed a lowered willingness to self-disclose. From a practical point of view, however, manipulations related to architectural or interior design elements are often troublesome; room size is usually fixed, and factors such as room layout and furniture selection are not always under the control of healthcare providers either. Of particular interest to current undertaking, however, is the finding that atmospheric variables such as color and lighting may also foster perceptions of spaciousness (Stamps, 2011) and related feelings (Akalin-Baskaya & Yildirim, 2007) and behaviors (Baron, Rea, & Daniels, 1992). Examining the effects of such environmental influences in a counseling or healthcare context can possibly provide more easily adaptable and flexible tools to create the "right" atmosphere. In turn, this may improve the diagnostic process by increasing patients' active participation during conversations with their physician. Hence, in current research we addressed the relationship between perceived room brightness (fostering perceptions of a more or less spacious environment) on the one hand and experienced affect and behavioral intentions on the other. More specifically, to extend knowledge about the influence of the physical environment on patient–physician communication, this study investigated effects of perceived brightness on the disclosure of personal information during a simulated patient–physician conversation. In addition, we studied whether effects of perceived brightness are qualified by the patient's state of mind, and more in particular, the extent to which a patient feels threatened or relieved.

Participants who feel physically restricted express a lowered willingness to self-disclose.

Environmental Factors and Spaciousness Perceptions

Research suggests that perceived spaciousness is important to inhabitants across environmental settings because it inspires feelings of freedom. For instance, Meyers-Levy and Zhu (2007) showed that a high, as opposed to a low, ceiling activated feelings of freedom and spaciousness and more creative strategies for problem solving tasks. In a similar fashion, Levav and Zhu (2009) exam-

ined the effects of experienced spaciousness in store environments and showed that narrow aisles activate feelings of confinement, which consumers counteracted by making more varied product choices. These findings suggest (in line with embodiment research; IJzerman & Semin, 2010; Williams & Bargh, 2008) that restraining physical space invokes feelings of limited psychological space. In turn, these negative feelings of restraint may cause reactance, emerging as a refusal to cooperate or comply with behavioral norms or to display expected behavior.

In addition to variations related to tangible or physical parameters, these perceptions of spaciousness may also vary with room atmospherics such as color (Acking & Küller, 1972; Kwallek, 1996; Oberfeld, Hecht, & Gamer, 2010; Yildirim, Akalin-Baskaya, & Hidayetoglu, 2007) and lighting (Durak, Olgonturk, Yener, Guvenc, & Gurcinar, 2007; Flynn, Spencer, Martyniuk, & Hendrick, 1973; Hidayetoglu, Yildirim, & Akalin, 2012; Manav 2007). For instance, Acking and Küller (1972), who repainted dayrooms in a hospital in different colors, found that a white room was judged as more open, compared to a light green room and a dark green room. In line with these findings, Kwallek (1996) revealed that a white wall color received the highest spaciousness scores, in comparison to darker colors such as green and red. Oberfeld, Hecht, and Gamer (2010) showed that not only a brighter wall color, but also a brighter ceiling color increases perceived spaciousness. The relationship between lighting and perceived spaciousness also has received considerable attention. Flynn, Spencer, Martyniuk, and Hendrick (1973) showed that spaciousness judgments differed significantly for rooms with different lighting conditions. More specifically, lighting all four walls (compared with merely lighting the center of the room with overhead lighting) induced greater feelings of spaciousness. Durak et al. (2007) varied room brightness and found that the brighter condition was judged as more spacious. Finally, Manav (2007) investigated lighting conditions in an office setting and showed that brighter lighting conditions received higher scores for comfort and spaciousness compared to more dimmed conditions.

These findings suggest that spaciousness perceptions vary depending on both lighting conditions and color selection. Nevertheless, understanding of how and why atmospherics influence brightness perceptions is still limited. In addition, atmospheric factors such as color and lighting are complex stimuli, making it hard to pinpoint what exactly accounted for the effects observed (*cf.* Valdez & Mehrabian, 1995). Arguably, perceived room brightness is a key variable in explaining effects of room atmospherics, with brighter surroundings conveying the impression of a more spacious environment. The rationale behind this line of reasoning holds that a brighter, as opposed to a darker, environment provides higher levels of perceptual clarity and that increased perceptual clarity makes an environment come across as more spacious (*cf.* Flynn, Spencer, Martyniuk, & Hendrick, 1973). This is in line with findings of Hidayetoglu, Yildirim, and Akalin (2012), showing that a brightly lit environment positively affects perceptual clarity of the environment and facilitates navigation and wayfinding therein. Also, when looking at our own experience we find that we can better survey our environment during daytime, and that we can see more of our surroundings in daylight compared to nighttime.

Perceived Brightness and Self-Disclosure

Previous research indicates that variations in lighting conditions affect self-disclosure (e.g., Gifford, 1988; Miwa & Hanyu, 2006). For instance, Gifford (1988) showed that bright lighting stimulated both general and intimate communication of participants. In this paper it is argued that effects of brightness on self-disclosure are mediated by spaciousness perceptions with brighter surroundings creating the illusion of a more spacious environment. Because physical freedom triggers positive perceptions of psychological freedom, people are more likely to cooperate with requests (*cf.* Meyers-Levy & Zhu, 2007; Levav & Zhu, 2009), and hence may self-disclose more easily. Darker lighting conditions, on the other hand, may cause negative feelings of insufficient space and reduced freedom, in turn increasing reactance and hence lowering the willingness to self-disclose. Hence the first hypothesis:

> **Hypothesis 1:** An increase in perceived brightness induces perceptions of spaciousness (H1a), thereby generating more positive affect (H1b) and enhancing self-disclosure intentions (H1c).

However, as suggested, in some cases darker surroundings may promote self-disclosure, arguably because they create a more intimate environment (Miwa & Hanyu, 2006). In addition, research suggests that feelings of reduced spaciousness may be preferable in terms of affect and behavior when the conversational context is stress free. For instance, Greene (1977) showed that when receiving positive feedback, a smaller distance between conversation partners invoked more positive affect. Furthermore, Schiffenbauer and Schiavo (1976) showed that a smaller interpersonal distance promotes likeability during a positive conversation, whereas during a negative conversation, a larger distance promotes a more positive response. Finally, a study by Dosey and Meisels (1969) showed that participants maintain a larger distance between themselves and an interviewer in high-stress, as opposed to low-stress, situations. In line with these findings, Okken, van Rompay, and Pruyn (2012) demonstrated that during a positive conversation the need for space is less pronounced than during a negative conversation.

A smaller interpersonal distance promotes likeability during a positive conversation, whereas during a negative conversation, a larger distance promotes a more positive response.

At this point, one could wonder whether a non-threatening situation merely reduces spaciousness needs or whether a patient's state of mind influences spaciousness perceptions in the first place. Although this question has not yet been tested explicitly in the context of healthcare services, the idea that the state of mind influences environmental perception is commonly accepted in other, related areas of research. For instance, results of Hui and Bateson (1991) indicate that experiencing more control makes a service environment seem less crowded (*cf.* Baum, Fisher, & Solomon, 1981). Inspired by research indicating that one's state of mind steers environmental perception, here it is argued that:

> **Hypothesis 2:** Effects of perceived brightness on perceived spaciousness (H2a), affective experience (H2b), and intended self-disclosure (H2c) are more pronounced during a threatening conversation, as opposed to a non-threatening conversation.

Finally, research indicates that effects of environmental variables can translate to respondents' judgments of other persons present in the room. For instance, a classic study of Maslow and Mintz (1956) showed that people consider faces more attractive when presented in an aesthetically pleasing, as opposed to an ugly, room. Similar results were found by Teven and Comadena (1996), who studied the effect of the aesthetic quality of a teacher's office on, among others, evaluations of teacher credibility and communication style. Results showed that room aesthetics positively influenced credibility ratings and translated to more positive judgments of communication style. These findings suggest that positive affect inspired by room atmospherics may positively influence person perception. Hence, for explorative purposes we will test the prediction that:

> **Hypothesis 3:** The positive effects induced by room brightness translate to higher ratings of physician likeability.

Method

To test the three hypotheses outlined above, perceived brightness was manipulated using pictures of a consultation room, and the level of communicated threat by constructing two variants of a scenario (i.e., a low threat and a high treat scenario), resulting in a 2 (perceived brightness: bright vs. dark) × 2 (communicated threat: low vs. high) between-subjects design.

Participants and Procedure

A total of 90 participants (33 male, 57 female; mean age 20.94 years, *SD* = 2.25) participated. They were recruited by approaching passers-by on the campus of a Dutch university with the request to participate in a study on their impression of healthcare environments. All participants were students enrolled in various (under)graduate programs at the university. In the introduction, participants were informed that the purpose of the study was to extend knowledge about patients' judgments of consultation rooms of general practitioners and specialists in hospitals. Next, they were presented with one of two possible scenarios varying in communicated threat. The low threat condition presented a conversation with a doctor following a "nothing to worry about" checkup, whereas the high threat condition presented a conversation following a more troublesome checkup. A manipulation check confirmed the intended difference between the scenarios [F (1, 89) = 15.31; $p < 0.001$], displayed below. (*Note*: Manipulations are displayed in bold typeface; wording used in the high threat condition are between brackets.)

> About 8 weeks ago you visited your general practitioner because you experienced skin irritations on your abdomen and back. You were referred to a dermatologist at the local hospital. In the following period, several medical tests took place and the dermatologist provided you with a zinc ointment to rub on the irritated parts of your body. The treatment appears **[not] to work** because you experience **less itching [more itching]** and the irritation **has almost disappeared [seems to increase].** Last week you had a telephone consultation with your dermatologist. He informed you that the test results of the

> latest test are in **and that it appears to be nothing serious [and that the results are inconclusive].** Today you have an appointment with the dermatologist for a discussion of the test results, your experiences and an additional check-up. You feel **relieved [worried]** because **the itching and irritation pose no serious threat [the source of your complaints is unclear],** and **have almost disappeared [that it is hard to assess the seriousness of the health threat involved].**

Next, the participants were presented with a picture of one of two possible consultation rooms and asked to imagine themselves in the situation depicted. In order to manipulate perceived brightness, one template of a consultation room was used, of which the brightness of the back wall was modified. A pilot study was conducted in which 10 participants were shown a series of pictures with different brightness values and asked to indicate what they considered a realistic setting for a patient–physician conversation. Based on these results, one picture was selected for the bright condition and one picture for the dark condition. The difference in brightness value was 60% (RGB values dark vs. bright: 137, 133, 129 vs. 189, 185, 180). In order to control for a possible confound of aesthetic impression, participants of the pilot study were also asked to judge the aesthetics of the pictures. Results showed that the selected pictures do *not* differ in this regard ($F < 1$, *ns*).

Next, the questionnaire was presented, comprising the dependent variables perceived spaciousness, affective experience and intended self-disclosure. Upon completion of the questionnaire, participants were thanked for their cooperation and dismissed.

Measures

Responses to all scales were recorded on 7-point rating scales.

Perceived Spaciousness

Perceived spaciousness was measured using the items: "I would feel constricted inside this room" (reverse coded), "I would feel confined inside this room" (reverse coded), "I would have sufficient freedom of movement inside this room," and "I would easily feel suffocated inside this room" (reverse coded) ($\alpha = 0.68$).

Affective Experience

To measure affective experience, a measure was used comprising the items: "Inside this room I would feel at ease," "Inside this room I would feel unhappy" (reverse coded), "I would feel uncomfortable inside this room" (reverse coded) and "This room would give me a pleasant feeling" ($\alpha = 0.73$).

Intended Self-Disclosure

Intended self-disclosure was measured using the items: "I would feel inhibited from speaking inside this room" (reverse coded), "Inside this room I would feel

able to speak freely," "I would feel uncomfortable in sharing personal information inside this room" (reverse coded) and "It would be hard for me to talk about myself inside this room" (reverse coded) ($\alpha = 0.82$).

Liking

To measure the patient's judgment of the physician in terms of liking, a measure was used comprising the items: "This physician is unkind" (reverse coded), "This physician is involved," "This physician is empathetic," and "This physician is unfriendly" (reverse coded) ($\alpha = 0.77$).

Results

Analyses of variance (ANOVA) were conducted with perceived brightness and communicated threat as the independent variables and perceived spaciousness, affective experience and intended self-disclosure as the dependent variables. Results were analyzed for gender and age using ANOVA, but because none proved significant there will be no further discussion of these variables ($p > 0.10$ for all measures).

Perceived Spaciousness

No main effect was found for perceived brightness [F (1, 88) 1.14, $p = 0.289$, partial $\eta^2 = 0.01$]. Communicated threat, on the other hand, was found to have a significant effect on perceived spaciousness [F (1, 88) = 4.52, $p = 0.036$, partial $\eta^2 = 0.05$], indicating that the low threat condition triggered more perceived spaciousness than the high threat condition (Table 1).

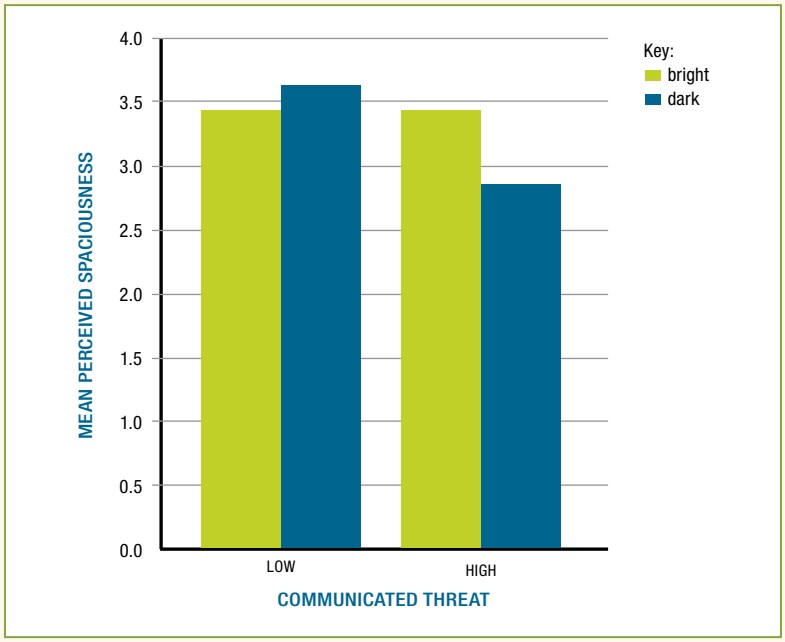
Interestingly, and in line with expectations (H2a), an interaction was obtained between communicated threat and perceived brightness [F (1, 86) = 4.43, $p = 0.038$, partial $\eta^2 = 0.05$] (Figure 1). For the high threat condition, the difference in mean scores for perceived brightness was significant, with participants

Table 1. Means and Standard Deviation (in parentheses) for All Variables

	COMMUNICATED THREAT		PERCEIVED BRIGHTNESS		BRIGHTNESS X COMMUNICATED THREAT INTERACTION			
					Low threat		High threat	
	Low threat	High threat	Brighter room	Darker room	Brighter room	Darker room	Brighter room	Darker room
Perceived spaciousness	3.53* (0.13)	3.14* (0.14)	3.44 (0.14)	3.24 (0.14)	3.44 (0.17)	3.64 (0.20)	3.44* (0.20)	2.83* (0.20)
Affective experience	2.86* (1.00)	2.49* (0.92)	2.79 (0.14)	2.57 (0.15)	2.73 (0.18)	3.04 (0.20)	2.87** (0.20)	2.11** (0.20)
Intended self-disclosure	3.73 (0.17)	3.61 (0.18)	3.75 (0.16)	3.60 (0.18)	3.57 (0.22)	3.95 (0.25)	3.98* (0.25)	3.25* (0.25)
Liking	4.13 (0.15)	4.16 (0.16)	4.17 (0.15)	4.11 (0.16)	3.94 (0.19)	4.37 (0.22)	4.48* (0.22)	3.85* (0.22)

NOTES:
* $p < 0.05$
** $p < 0.01$

Figure 1. The interaction between brightness and communicated threat for perceived spaciousness scores.



judging the brighter room as more spacious than the darker room [F (1,86) = 4.75, p = 0.032, partial η^2 = 0.05]. For the low threat condition, this difference was not significant (F < 1, *ns*). Hence, perceived brightness only affected spaciousness perceptions (in the predicted direction) in the high threat condition.

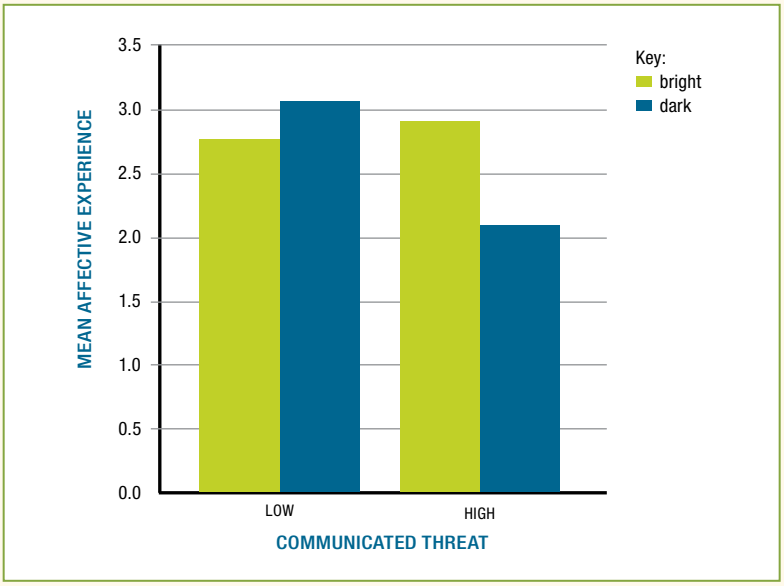
Affective Experience

Again, no main effect was found for perceived brightness (H1b) [F (1, 88) = 1.35, p = 0.249, partial η^2 = 0.01]. Communicated threat, again, had a significant effect on the affective experience [F (1, 88) = 4.02, p = 0.048, partial η^2 = 0.05], indicating that the low threat condition generated more positive affect compared to the high threat condition.

Similar to the results for perceived spaciousness, an interaction was obtained between communicated threat and perceived brightness [F (1, 86) = 7.30, p = 0.008, partial η^2 = 0.08] (see Figure 2). For the high threat condition, the difference in mean affective experience scores for perceived brightness was significant, with participants experiencing more positive affect in the brighter room [F (1,86) = 7.04, p = 0.009, partial η^2 = 0.08]. For the low threat condition, the difference in mean affective experience scores for perceived brightness was not significant [F (1, 86) = 1.26, p = 0.264, partial η^2 = 0.01].

To test whether spaciousness perceptions can account for the latter interaction, analyses of covariance (ANCOVA) were conducted. Following the procedure of Baron and Kenny (1986) these analyses should show (in addition to yielding

Figure 2. The interaction between brightness and communicated threat for affective experience scores.



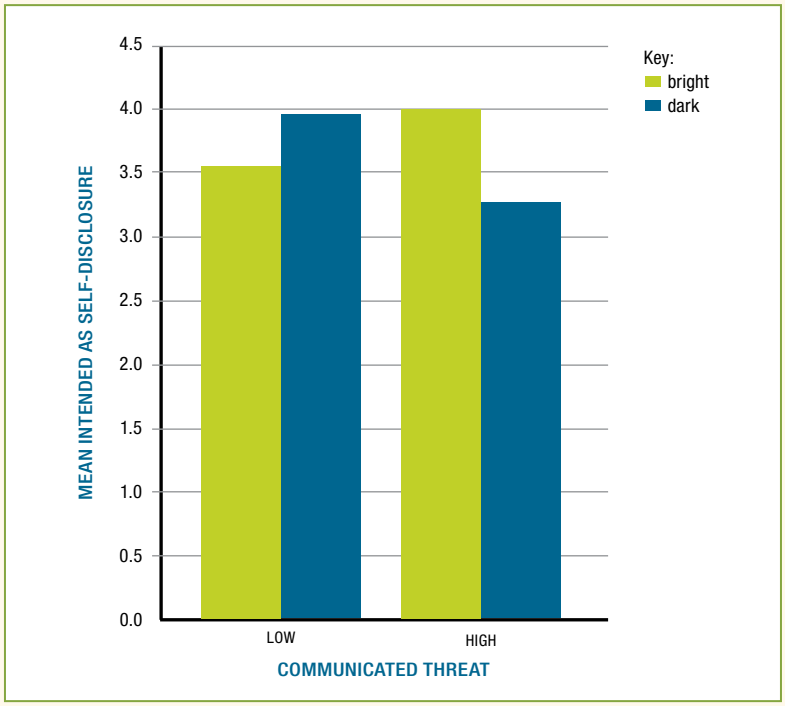
the effects described above) that the interaction effect between the two independent variables (perceived brightness and communicated threat) on the dependent variable (affective experience) should weaken when the mediator (perceived spaciousness) is included as a covariate in an ANCOVA. In addition, the effect of the mediator on the dependent variable should be significant. Analyses following these outlines show that the effect of the perceived brightness × communicated threat interaction indeed becomes non-significant [F (1, 85) = 3.53, p = 0.064, partial η^2 = 0.04], while the influence of perceived spaciousness is significant [F (1, 85) = 24.37, p < 0.001, partial η^2 = 0.22]. In other words, in the high threat condition, the brighter room generated more positive affect *because* participants experience it as being more spacious.

Intended Self-Disclosure

No main effects were obtained for either room perceived brightness (F < 1, ns) or communicated threat (F <1, *ns*). However, the interaction between communicated threat and perceived brightness was significant [F (1, 86) = 5.45, p = 0.022, partial η^2 = 0.06) (Figure 3). Similar to the interactions above, in the high threat condition, the difference in mean scores for perceived brightness was significant, with participants having a higher intention to self-disclose in the brighter room [F (1, 86) = 4.37, p = 0.039, partial η^2 = 0.05]. For the low threat condition, this difference was not significant [F (1, 86) = 1.40, p = 0.240, partial η^2 = 0.02].

Again, we tested whether spaciousness perceptions underlie the obtained interaction between perceived brightness and communicated threat. When perceived spaciousness was included in the model, the influence of the perceived bright-

Figure 3. The interaction between brightness and communicated threat for intended self-disclosure scores.



ness x communicated threat interaction became non-significant [F (1, 85) = 2.76; p = 0.100, partial η^2 = 0.03], while the influence of perceived spaciousness was significant [F (1, 85) = 11.45; p = 0.001, partial η^2 = 0.12]. In other words, in the high threat condition, participants disclose more information in the brighter room because they experience more spaciousness.

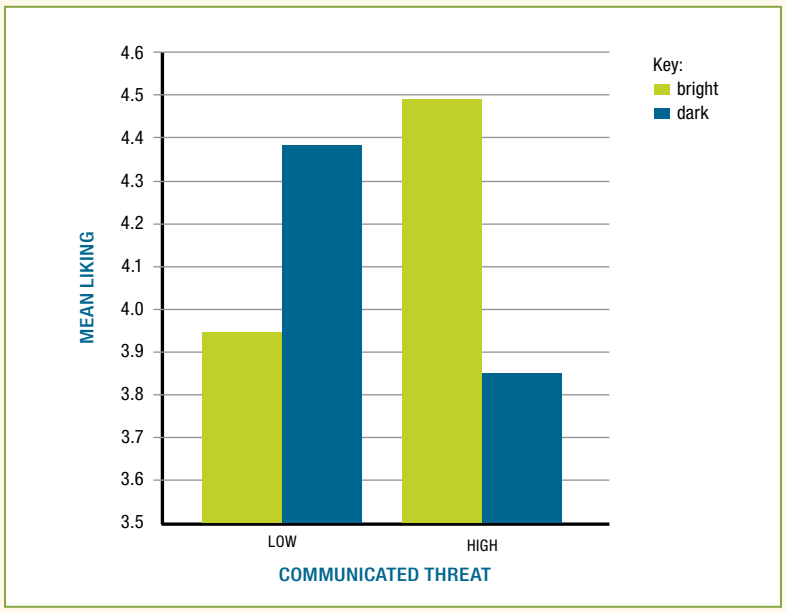
Similar analyses were conducted to test whether the relationship between the perceived brightness × communicated threat interaction and intended self-disclosure was mediated by affective experience. However, the mediating effect of this variable was non-significant (p = 0.335).

Liking

No main effects were found for brightness (F < 1, *ns*) and communicated threat (F < 1, *ns*). An interaction was obtained between communicated threat and brightness [F (1, 86) = 6.42, p = 0.013, partial η^2 = 0.07] (Figure 4). For the high threat condition, the difference in mean scores for brightness was significant. With participants judging the physician more positively in the brighter room [F (1, 86) = 4.26, p = 0.042, partial η^2 = 0.05]. For the low threat condition, this difference was not significant [F (1, 86) = 2.26, p = 0.136, partial η^2 = 0.03].

This time however, the effect of the brightness × communicated threat interaction remained significant [F (1, 85) = 4.56; p = 0.036, partial η^2 = 0.05] when

Figure 4. The interaction between brightness and communicated threat for liking scores.



inserting perceived spaciousness as a covariate, and the influence of perceived spaciousness was non-significant [F (1, 85) = 2.62; p = 0.110, partial η^2 = 0.03]. This indicates that the relationship between the room brightness × communicated threat interaction and physician judgment is *not* mediated by perceived spaciousness.

Whether the affective experience mediated the brightness × communicated threat interaction was examined. Insertion of the affective experience as a covariate revealed a significant effect of this mediator [F (1, 85) = 6.19; p = 0.015, partial η^2 = 0.07]. In addition, the brightness x communicated threat interaction became non-significant [F (1, 85) = 3.27; p = 0.074, partial η^2 = 0.04], indicating that the relationship between room brightness × communicated threat and physician judgment is mediated by positive affect. In other words, in the high threat condition, participants judged the physician more positively in the brighter room because they experienced more positive affect.

Discussion

The results presented first and foremost show that effects of room atmospherics in the healthcare context vary depending on the patient's state of mind; no main effects were obtained for perceived brightness. However, when taking into account communicated threat, a relationship surfaced between perceived brightness and the outcome measures; in a threatening conversation, perceived brightness positively influenced perceptions of freedom, generated more positive affect, and a higher willingness to self-disclose. In a worry-free conversation, participants were unaffected by the brightness manipulation. These combined find-

Effects of room atmospherics in the healthcare context vary depending on the patient's state of mind.

ings are in line with previous research indicating that people value more space particularly when they perceive the situation as threatening (Albas & Albas, 1989; Dosey & Meisels, 1969; Greene, 1977). In line with this emphasis on people's need for space, results further showed that the interactive effects of perceived brightness and communicated threat on both the affective experience and intended self-disclosure are mediated by perceived spaciousness.

In addition, the results revealed a significant main effect of communicated threat on perceived spaciousness. This finding provides strong evidence for the claim that environmental perception (and related affective and behavioral measures) is very much shaped by psychological circumstances; participants in the high threat condition actually perceived the room as less spacious compared to participants in the low threat condition. This finding suggests that depending on one's mindset, walls that appear at a safe and comforting distance in a joyous, relaxed situation may indeed seem to be "closing in" when threat comes to the fore and anxiety takes over.

In line with reactance theory (e.g., Levav & Zhu, 2009), our results show that a room that comes across as less spacious not only invokes less positive judgments, but also decreases self-disclose intentions. Hence, displaying a lower self-disclose intention can be seen as a form of reactance to a "space invasion." This is in line with results of Albert and Dabbs (1970), who studied the effect of interpersonal distance on attitude change. Their results show that when interpersonal distance decreases, the amount of reactance increases, transpiring in a lowered willingness to accept persuasive messages. Generally, reactance can be expected to surface in a refusal to comply with (implicit) requests, in our study the physician's "request" to self-disclose information that allows for an accurate diagnosis and a fitting treatment or procedure.

Additionally, our results show that room brightness may also steer physician perceptions, a finding in line with previous research (e.g., Campbell, 1979; Maslow & Mintz, 1956; Schiffenbauer & Schiavo, 1976; Teven & Comadena, 1996; Van Rompay & Tanja-Dijkstra, 2010). Specifically, our results show that a brighter room makes the physician come across as more likeable. This relationship was not mediated by perceived spaciousness, but rather by the affective experience. It should be noted however that the mediation analyses presented across the variables by no means rule out additional mediators (especially when taking into account that the interaction terms remained marginally significant after insertion of the mediator as a covariate). For instance, earlier research suggests that prototypicality plays an important role in determining likeability-outcomes, with physicians displayed in more prototypical offices coming across as more positive (Swan, Richardson, & Hutton, 2003; Ward, Bitner, & Barnes, 1992). Alternatively, brightness may induce competence perceptions, perhaps generating more trust and hence more self-disclosure.

A room that comes across as less spacious not only invokes less positive judgments, but also decreases self-disclosure intentions.

Limitations

The main limitation of the current study is that visual displays were used to represent the environments and that participants were not physically "submerged" in an actual setting. However, the use of photographic material in environmental research has been shown to accurately simulate real environments (Bateson & Hui, 1992; Hendrick, Martyniuk, Spencer, & Flynn, 1977; Stamps, 1990). A meta-analysis of research using both measurements obtained in actual environments and measurements obtained through photographic material revealed a 0.86 correlation (Stamps, 1990). Likewise, Okken, van Rompay, and Pruyn (2012, 2013) showed that reactions to limited space did not differ across simulated settings (i.e., photographic material) and actual environments. Of course, in order to enhance applicability of our findings and to allow recommendations on specific brightness levels (i.e., absolute values as opposed to relative differences in brightness levels), follow-up studies are required.

Another point of attention is that in the current study no actual patients participated. Although one can safely assume that the students in our study have experiences visiting a general practitioner or specialist (and can draw on these encounters to imagine themselves in the scenarios described in our study), field studies examining actual behaviors of patients with actual (situation-specific) fears and worries in real environments are needed to further increase knowledge about the influence of environmental factors. Furthermore, although analyses did not reveal age and gender-related differences, it should be noted that participants in our study were all students similar in age, cultural background and education. Hence, our findings do not rule out that differences related to these factors play a role with different, or less homogeneous, target groups. For instance, concerning cultural background, Hofstede and colleagues have extensively documented differences across cultures with respect to variables such as power distance (i.e., the degree to which less powerful members of a society accept and expect that power is distributed unequally) and masculinity–femininity (e.g., Hofstede, Hofstede, & Minkov, 2010). For instance, the masculinity side of the latter dimension represents a preference in society for achievement, and assertiveness and thus reflects the extent to which society at large is competitive. Its opposite, femininity, stands for a preference for cooperation and caring, and this reflects a more consensus-oriented society. Arguably, self-disclosure comes more natural and easy in the latter type of society, similar to how, on an individual level, self-disclosure is sometimes said to come easier for women (Dindia & Allen, 1992).

Furthermore, although the results presented in this paper indicate that relatively small differences in perceived brightness influence both affective experiences and behavioral intentions, no conclusions can be drawn about specific brightness settings (apart from the obvious prediction that extreme values are likely to induce negative effects).

Conclusions

Our findings show that altering the atmospherics can be used as a tool to improve the affective quality of the environment. In small environments in particular, perceived spaciousness can be increased by increasing room brightness (as our findings suggest). In addition to room brightness, previous research showed that lighting likewise may affect self-disclosure intentions (although the line of reasoning proposed in this paper has not been tested in relation to lighting) (Gifford, 1988). In addition to such atmospheric (non-tangible) variables, research suggests that material aspects of built environments may also affect spaciousness perceptions and can thus be used to improve the spatial ambiance of the environment. For instance, Stamps and Krishan (2006) investigated the influence of wall texture or roughness on perceived spaciousness and showed that spaciousness perceptions differed across (otherwise identical) rooms varying in wall texture. Finally, environmental features such as furniture selection and positioning (i.e., layout) within the room can also affect spaciousness perceptions (e.g., with a greater interpersonal distance as the result of furniture layout enhancing spaciousness impressions and hence self-disclosure intentions).

Altering the atmospherics can be used as a tool to improve the affective quality of the environment.

Regardless of the environmental factor under discussion, however, it is most important to realize that such effects are very much dependent on the patient's state of mind. It could even be argued that as familiarity and intimacy with a physician increase in the course of a treatment, a more intimate setting might even generate positive effects, as also suggested by research showing that dim lighting may increase self-disclosure (Miwa & Hanyu, 2006). And although effects of perceived brightness were non-significant in the low-threat conversation, the results across the dependent variables (see Figures 1–4) tentatively suggest that patients may prefer a less spacious setting when emotions such as relieve and happiness, rather than anxiety and fear, take over. Arguably then, physicians might benefit from means that allow for flexible adaptation of room atmospherics. For instance, usage of a dimmer switch in consultation rooms could enable the physician to adjust lighting conditions to the type of conversation at hand, using brighter lighting when high anxiety or stress levels can be expected (i.e., first visits, discussing results of medical tests, etc.) and dimmed lighting for low-stress situations.

Based on the observation that such adjustments are particularly called for when patients face worries and anxiety, and that such a state of mind is common in many healthcare environments (e.g., visits to one's physician are usually not stress-free), our findings are particularly relevant in the healthcare context. Their importance is further stressed by research demonstrating that more active participation of patients during interactions with physicians (implying more self-disclosure) improves the effectiveness of medical consultations (Zandbelt, Smet, Oort, Godfried, & Haes, 2007), and that patient satisfaction, adherence and medical outcomes fare well by increased self-disclosure (Harrington, Noble, & Newman, 2004). These combined findings underline the importance of attending to patients' affective needs and creating a soothing environment. Additionally, this type of knowledge can also be put to use in other types of services in

relation to which creating a pleasant (service) environment is considered important. This also follows from research examining effects of spatial density and experienced spaciousness in retail environments, showing that creating open spaces (Haytko & Baker, 2004; van Rompay, Galetzka, Pruyn, & Moreno-Garcia, 2008) may boost shopping satisfaction.

Awaiting future research addressing these and related issues, the findings presented are a first step towards unraveling how environmental and psychological variables conjointly influence affective experiences and related behaviors.

Implications for Practice

- The content of this paper and its results can help designers of healthcare environments become more cognizant of the effects of environmental stimuli on both affective and behavioral responses of patients.
- Based on the observation that fostering spaciousness preceptions is called for especially when patients face worries and anxiety, and that such a state of mind is common when discussing health-related issues, our findings are particularly relevant in the healthcare context.
- The results underline the importance of attending to patients' affective needs and creating a soothing environment.
- The findings presented indicate that—in addition to the physical or architectural dimensions of health settings—relatively subtle and easy-to-incorporate adjustments in atmospheric variables may also impact spaciousness perceptions and hence increase self-disclosure.

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Design Decision Making and ICU Life Support Systems

D. Kirk Hamilton, FAIA, FACHA, EDAC

D. Kirk Hamilton, FAIA, FACHA, EDAC

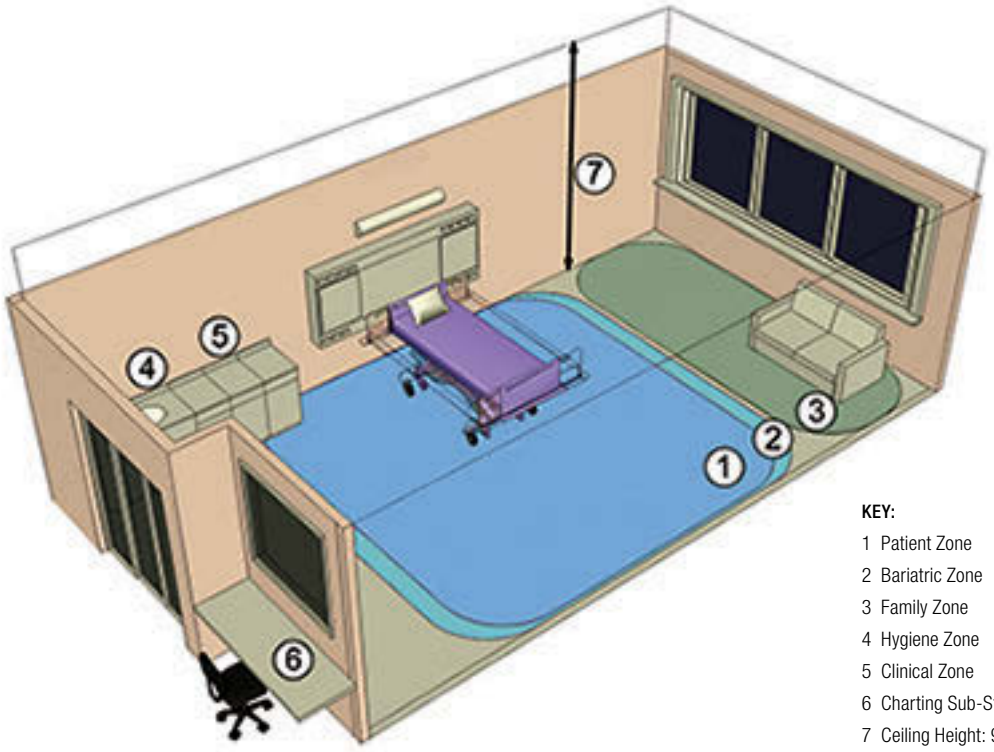
What kind of evidence would help a design team confirm an important decision, such as the choice of a life support system for an intensive care unit? How can a research-informed or evidence-based design process assist in making such a decision? (Hamilton & Shepley, 2010)

The design of a hospital intensive care unit (ICU) patient room, where critical care is provided to seriously ill patients by specialist physicians and nurses, is significantly influenced by the type of life support system chosen for the design, such as a headwall, power column, or overhead boom configuration (Hamilton, 1999; Hamilton & Ulrich, 2008). Why do designers and their clients choose one system over another? The decision often seems to be made based on familiarity with one system or another, or purely on cost. What evidence could be used in making this decision as part of a design project?

The headwall model, in which the utilities and physiological monitors are located on the wall behind the head of the bed (see Figure 1), is the most common choice. Familiarity with this model may influence its use; it has been the principal system in ICUs since their beginning, when the ICU was an adaptation of the surgical recovery room model. Clinicians who have experienced only this model may understandably favor it. Another factor is that a headwall configuration can be the most economical choice. In the case of a crisis, or "code blue" situation, the bed must be pulled off the headwall to allow someone to stand behind the head to ensure that the patient's airway remains open. Difficulties for staff associated with stepping over lines and cords, and potentially disconnecting something important, is an inconvenience at best and a problem with serious health consequences at worst.

The power column system is the second most common choice (see Figure 2). The power column is a vertical system, standing floor to ceiling, typically located

Figure 1. Manufactured rail life support system.



KEY:

1 Patient Zone
2 Bariatric Zone
3 Family Zone
4 Hygiene Zone
5 Clinical Zone
6 Charting Sub-Station
7 Ceiling Height: 9' to 11' (2.7 m to 3.3 m)

Image courtesy Elizabeth Viets Schmitz.

diagonally off the head of the bed. It has connections for medical gasses, outlets for electricity, and uninterrupted power. A power column has a bracket on which to mount the physiologic monitor, and usually includes baskets or shelves for necessary items. It often has an attached sphygmomanometer.

More recently, ceiling-mounted boom systems have been introduced, with overhead swiveling pendants to support the monitor, gasses, electrical connections, and other utilities (see Figure 3). The overhead boom life support model is similar to a power column, except that it is not attached to the floor, and can be moved to different positions. The ceiling-mounted boom system can include a pair of booms, and thus a pair of pendants with utilities and other features.

Because these different systems to deliver life support technologies perform in different ways, they influence staff activity and behaviors (Gallant, 2001), although comparisons are possible (Pati et al., 2008). Flexibility and adaptability increases as one moves from headwall to power column to overhead booms. The power column obviates the need to move the bed and the risk of umbilical disruption. The overhead boom in turn allows greater movement of the bed and multiple possible positioning options, as well as the ability to swing it out of the way when desired.

Figure 2. Power column life support system.

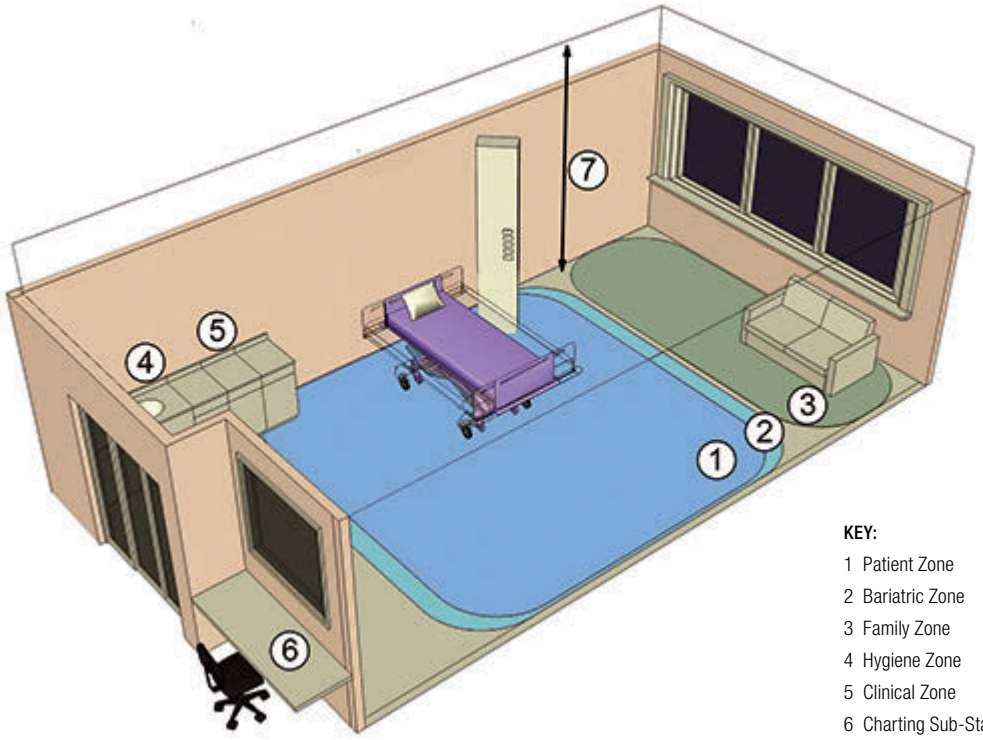


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Image courtesy Elizabeth Viets Schmitz.

If I were still in practice as a hospital architect, or in a consulting role for an organization involved in the design of a new critical care unit, I would consider the choice of a life support system to be a key design decision requiring serious attention. Sometimes the program of space requirements will include a specific square footage that may restrict the choice, but design of the patient room cannot be completed without this decision.

I have suggested that identifying the key design issue and turning it into a researchable question is an early step in an evidence-based process. To do this we would need definitions of life support systems, identification of the various choices available, and an understanding of the uses to which such systems may be put. Scholarly research literature would be searched for relevant articles, using combinations of keywords that would include, for example, ICU, critical care, life support system, headwall, power column, medical gasses, physiologic monitor, code blue, resuscitation, and so forth.

The clinician users of a new unit need to be involved in the decision on the life support system. This can be considered part of collaborating with an educated client. The first data gathered would be historical. What is the current volume of service for the ICU being replaced? What type of life support system is currently

Figure 3. Ceiling-mounted pendant life support system.

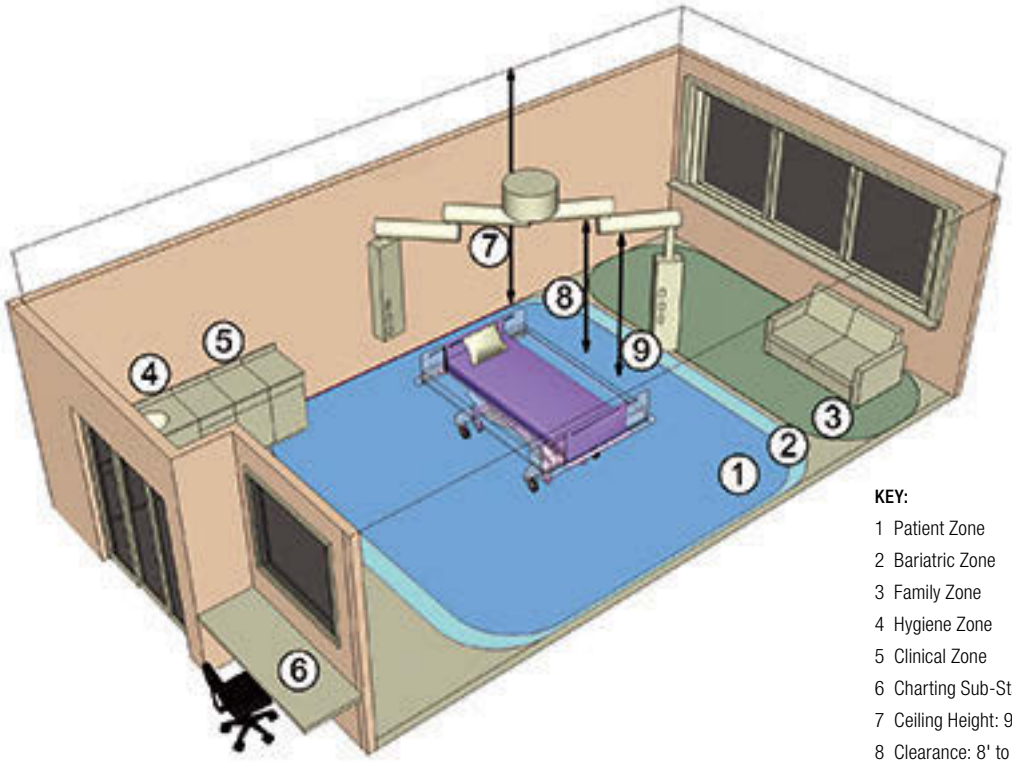

Image courtesy Elizabeth Viets Schmitz.

KEY:

1 Patient Zone
2 Bariatric Zone
3 Family Zone
4 Hygiene Zone
5 Clinical Zone
6 Charting Sub-Station
7 Ceiling Height: 9' to 11' (2.7 m to 3.3 m)
8 Clearance: 8' to 10' (2.4m to 3.0m)
9 Clearance: 7' to 9' (2.1m to 2.7m)

in use? What percentage of patients in the ICU experience one or more "code blue" crises? What are the nurses' and physicians' experiences with different systems? There is information available about ICU design and best practice examples (Rashid, 2006); the users can assist in the search for relevant information.

One way to educate users about the choices would be to have them tour facilities that use each type of life support system. Arrangements could be made for physicians to shadow physicians, and nurses to shadow nurses, in order to see the various life support systems in everyday use. The idea would be to pick exemplars where the users are pleased with their system. As a decision is close to being made, realistic, full-scale mock-ups could be built in which users can "try on" the likely system choice and make decisions to refine the design before it is built. University Medical Center Princeton built real rooms prior to its construction project, and used them for both comparison studies with staff and admission of real patients.

As information is collected, the design team and the users should be prepared to interpret the impact of what is found on their unique and individual project. These interpretations will lead to development of the design concepts for the patient room and its life support system. Alternative concepts can be compared

and tested (Brown & Gallant, 2006). Ultimately, the design team and the users will be prepared to make a selection and to have a concept of how it will be used in the patient room.

This is the time to record a design hypothesis and anticipate a measurement to determine whether the hypothesis has been supported. For a unit changing from a headwall to a power column, a hypothesis might be something like this:

> There will be no need to move the bed during a code blue situation as there will always be direct access to the patient's head and airway.

Such a hypothesis can be measured by observing whether access to the airway is immediate and the bed is not repositioned during codes. For a unit planning to adopt an overhead boom configuration, the hypothesis could be similar to the previous one, or could be something like this:

> The movable pendant-mounted boom with suspended life support elements will permit multiple orientations of the bed within the room and provide appropriate support for procedures performed in the patient room.

The measurement in this case would be observations of how often the bed orientation was changed, and how well the system served during line insertions and other procedures performed in the patient room.

Once a decision as serious as the life support system has been made, it would be helpful if the team prepared a report documenting the process, the collected data, and the literature reviewed. When the project is completed and has been in use for some time, measurements can be taken to confirm the design hypotheses. Other organizations considering similar decisions would benefit from the information in the report, even if their investigation leads to a different choice. They then would need to make their own report, adding to the available material.

An alternative for considering future decisions is to imagine a regional tier system similar to that for emergency departments that have a Level 1, Level 2, or Level 3 designation based on capabilities and resources. Emergency centers, for example, have requirements for what types of specialized surgeons must be available within 20 minutes for each designation. The Maryland Institute for Emergency Medical Services (MIEMS) is an example of a facility for the highest level of trauma acuity.

To develop such a system for critical care, different acuities among ICU patients would need to be organized into the hierarchy of levels. Perhaps Level 3 could be normal for a community hospital with ICU patients with a moderate level of acuity and a basic set of available physician and nurse personnel and resources. It is conceivable that a headwall design might serve such a facility well because the acuity does not require frequent pulling of the bed off the wall in a code situation.

Level 2 might be applied to tertiary facilities that deal with higher levels of acuity and complications, while having access to more specialized personnel and greater

resources, including intensivist coverage. Such a level of acuity could suggest a need for a bed position off the wall with constant access to the patient's head, as in the case of the power column.

Finally, a Level 1 critical care center or unit would be located at a quaternary care teaching hospital with the greatest access to specially qualified, intensivist-led staff and the full multi-disciplinary capability of a major medical center. These types of units might wish to have the extreme flexibility afforded by the overhead boom life support system.

The choice of life support systems in critical care is a decision fundamental to all other decisions about the design of the patient room. I consider the decision to be an example of a key design issue for an ICU unit, and worthy of the application of an evidence-based or research-informed design process. A rational process to match the implications of the collected research material and the unique requirements of the project should produce a reliable decision. Design practitioners and their clients would be well advised to use a thorough and rigorous process in making their decision.

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Senior Living Environments: Evidence-Based Lighting Design Strategies

Michael D. White, EDAC, LC, LEED AP; Sonia Ancoli-Israel, PhD; and Richard R. Wilson, MD

ABSTRACT

OBJECTIVE: To review from an architectural lighting perspective the effects of indoor lighting on the health and well-being of people in senior living environments.

BACKGROUND: The role of circadian rhythms in people with chronic disorders continues to be a focus of laboratory research and clinical trials. Beneficial, evidence-based indoor lighting design strategies are being considered for senior living environments, particularly for residents who have limited access to natural bright light.

METHODS: Articles published 2002–2012 reporting the results of prospective, randomized, controlled clinical trials (RCTs) were accessed using the U.S. National Library of Medicine PubMed site using the following search terms: "light, sleep, circadian, randomized, controlled, nursing home" and "light, sleep, circadian, randomized, controlled, elderly."

RESULTS: The search resulted in 48 citations, of which 18 meet our pre-search criteria. Data from these RCTs indicate options such as programmable, 24-hour lighting algorithms that may involve light intensity, lighting duration, spectra (wavelength) and lighting timing sequences

CONCLUSIONS: Valid and actionable data are available about circadian rhythms, sleep, and human health and well-being that can inform the design of lighting for long-term care. Evidence-based architectural design of a 24-hour light/dark environment for residents may mitigate symptoms of circadian disruption; evidence-based management of darkness is as important as evidence-based management of light. Further research is needed into the long-term circadian health needs of night staff members in order to understand the effects of shift work while, at the same time providing the highest level of care.

KEYWORDS: Design process, elderly, evidence-based design, lighting, literature review

AUTHOR AFFILIATIONS: Michael White is a senior lighting designer at Schuler Shook in Minneapolis, MN. Sonia Ancoli-Israel is a Professor Emerita of Psychiatry and Medicine at the University of California, San Diego, in La Jolla, CA, and is supported in part by Department of Veterans Affairs San Diego Center of Excellence for Stress and Mental Health (CESAMH). Richard Wilson is the founder of Health Research, LLC, in Arden Hills, MN, and is an adjunct faculty member at the University of Chicago Graham School of Continuing Liberal and Professional Studies, Chicago, IL.

CORRESPONDING AUTHOR: Michael D. White, mwhite@schulershook.com; (612) 339-5958.

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About 10,000 years ago, when a more formalized approach to agriculture demanded that the nomadic lifestyle be abandoned in exchange for a stable food supply, people began building permanent shelters. This relatively recent development arguably led to the development of architecture as civilization developed. Given that *Homo sapiens* emerged some 200,000 years ago, the progression from nomad to villager to couch potato happened comparatively quickly, with the greatest lifestyle changes occurring in the last 100 years. The advent of electric lighting in the early 20th century, along with elevators and air conditioning, allowed buildings tall and deep with little natural light to be built. A species previously adapted to hunting and gathering outdoors in bright sunlight now spends most of its time indoors under relatively dim lighting conditions. Scientists studying the effect of light on human health suggest profound effects on our species as a result of this change in lifestyle.

All plants and animals display regular patterns of behavior and physiology that repeat on daily schedule, often called *circadian rhythms.* Humans, for example, are typically awake during the day and asleep at night. Hormones such as melatonin and cortisol are synthesized and suppressed over the course of the 24-hour day and help drive the sleep/wake rhythm. These and other daily rhythms are orchestrated by the suprachiasmatic nuclei (SCN), which is located deep in the brain in the hypothalamus. Commonly referred to as the "human pacemaker," the SCN regulates multiple processes on a schedule that runs close to, but not exactly, 24 hours. The natural light/dark pattern generated by the rotation of the earth resets the pacemaker each day, which keeps us in sync with the natural world as the light/dark pattern changes across the seasons.

When circadian rhythms slide out of sync, serious conditions can result. A short-term example of this occurs when we fly across multiple time zones and the light/dark cycle suddenly changes, throwing our rhythms out of sync with our surroundings. A more serious condition is seasonal affective disorder (SAD), which causes depression, among other symptoms, in those that suffer from it. The lighting environment in many long-term care facilities fails to provide sufficient light and darkness to maintain a stable circadian rhythm. Indoor light levels are typically low, and most residents have little access to bright natural light needed to entrain the pacemaker to the natural light/dark cycle. Lights are often on at night in patient bedrooms and bathrooms, which interfere with vital dark-induced functions such as melatonin secretion. Lacking bright light during the day, and denied darkness at night, circadian disruption can result. Symptoms of disrupted rhythms include:

- Depression
- Napping during the day, wakefulness during the night
- No clear pattern to the wake/sleep cycle day to day
- Experiencing hunger at odd times
- Loss of cognitive ability

Actionable evidence indicates that environmental light and darkness can mediate these symptoms. In order to achieve reliable and robust results, however, it

is necessary to understand how the controllable properties of light affect human physiology. The quantity and spectra of light, together with the duration of exposure and the timing of that exposure all play a role in the effect on humans. Using these controllable properties of light as the framework, we report on a body of evidence from the literature that can be used to inform lighting design. Armed with this knowledge designers can create lighted environments that contribute to the health and well-being of residents and staff.

Circadian rhythm sleep disorders and other chronic insomnia disorders pose both challenges and opportunities in healthcare. Increased light exposure has been shown to improve both circadian rhythms and sleep. Evidence-based indoor lighting design strategies are being considered in a number of settings. The focus of this article is to examine research articles that report on the effect of increased light exposure on sleep and rhythms in senior living environments, in particular residents of long-term care facilities who have limited mobility due to physical and/or cognitive limitations and therefore have limited access to outdoor activities where they would be exposed to natural bright light.

The role of circadian rhythm in healthy individuals and in individuals with a spectrum of chronic clinical disorders possibly associated with altered circadian rhythm physiology continues to be an area of both laboratory investigation and clinical research. Beneficial, non-pharmacological interventions through evidence-based interior lighting design have been identified for treatment of chronic sleep disorders in elderly residents of senior living and long-term care facilities. In this review, the crucial relationship between lighting interventions and clinical responses includes analyses of dose as follows: dose = (intensity + spectrum) × duration. In addition, we examine the effect of prior light exposure on response to a given intervention (photic history).

Methods

The U.S. National Library of Medicine PubMed website (http://www.ncbi.nlm.nih.gov/pubmed) was used to identify relevant, prospective, randomized, controlled, clinical trials published in peer-reviewed journals from 2002 through 2012 (listed as of December 31, 2012). The following search terms were used:

- Light, sleep, circadian, randomized, controlled, nursing home; *and*
- Light, sleep, circadian, randomized, controlled, elderly.

Inclusion criteria included prospective randomized controlled trials (RCTs) that were properly designed, conducted, analyzed, and reported. Exclusion criteria included studies that did not include control groups, or did not randomize participants into study and control groups. We also excluded trials that reported on age groups aged younger than 60. We excluded one study that was terminated early on the basis of interim data analysis that appeared inconclusive.

RCTs may be considered to be the gold standard for evaluating health care interventions because they offer the opportunity to compare two or more healthcare interventions while reducing or eliminating "intervention bias" and "regression

to the mean," both of significant concern when the only control data available for comparative analysis of the health outcomes are limited to baseline data.

For these reasons, this article focuses on how RCTs of indoor lighting algorithms being evaluated as therapeutic interventions can be used to inform the design of architectural lighting. The goal is to create a lighted environment that delivers the needed lighting stimulus as a part of the normal daily routine.

We systematically examined the reported components of the lighting interventions and the reported clinical responses. Specifically, we examined the properties of light intervention (dose, timing, and spectrum) using a chart populated with data from the published articles. The results obtained and the conclusions drawn using similar and contrasting intervention designs were compared. We also considered the knowledge base available at the time of publication.

Results

Forty-eight citations were available with these two searches. Of these, 27 articles did not meet our pre-set criteria (prospective, randomized, controlled studies in elderly populations), and two articles were duplicated (cited in both searches). One article reported on a study that was terminated early, and was excluded from the review. This resulted in 18 articles for evaluation (see Table 1).

Dose

Determination of the dose (intensity and duration) needed to achieve a given clinical outcome requires consideration of multiple factors and is therefore complex. Guidance to successful lighting designs can be found in both the successes and failures of well-planned, validly designed, rigorously executed clinical studies.

Dose *can be defined as light intensity plus light spectra multiplied by duration of light exposure.*

Dose can be defined as light intensity plus light spectra multiplied by duration of light exposure. The human response to light is dose-dependent, meaning that as the dose increases, the response increases as well. The durations and the intensities of the interventions varied widely in the published articles reviewed here. Brief exposures of 30 to 120 minutes predominated, with intensities of 2500 to 10,000 lux. Studies that employed longer durations often used lower intensities of 250 to 1000 lux. However, exceptions included one study that used just 400 lux of blue light from an LED source (Royer et al., 2012), while another used just 210 lux from a halogen source (Gasio et al., 2003).

Many of these published articles tried various combinations of intensity and duration in an attempt to find a more practical application under the rationale that a brief intervention is more likely to achieve improved compliance. Caregivers may have had insufficient time to devote to new tasks such as supervising subjects in a lighting study. The practical limitations of any intervention in an institutional environment were evident in all of the studies.

TABLE 1. REPORTED SOURCE, INTENSITY, AND DURATION FROM RCTs PUBLISHED 2002–2012

SOURCE (chronological order)	OBJECTIVE	LIGHT SOURCE	INTENSITY (LUX)	DURATION IN MINUTES	TIME OF DAY	NUMBER OF DAYS
1 Ancoli-Israel, S., Martin, J. L., Kripke, D. F., Marler, M., & Klauber, M. R. (2002). Effect of light treatment on sleep and circadian rhythms in demented nursing home patients. *Journal of the American Geriatrics Society, 50*(2), 282–289.	To determine whether fragmented sleep in nursing home patients would improve with increased exposure to bright light.	Brite-Lite box from Apollo Light Systems, Orem, Utah—cool white, full spectrum fluorescent lamps	2500	120	Morning: 9:30–11:00 a.m.	10
		Brite-Lite box from Apollo Light Systems	2500	120	Evening: 5:30–7:30 p.m.	10
2 Fontana Gasio, P., Kräuchi, K., Cajochen, C., Someren, E., Amrhein, I., Pache, M., … Wirz-Justice, A. (2003). Dawn-dusk simulation light therapy of disturbed circadian rest-activity cycles in demented elderly. *Experimental Gerontology, 38*(1), 207–216.	We investigated whether low intensity dawn-dusk simulation (DDS), a "naturalistic" form of light therapy designed to embed sleep in its accustomed phase, could improve the disturbed circadian rest-activity cycle, nocturnal sleep and and/or cognitive functions in dementia.	Halogen lamp	c210	840	Dawn to Dusk	21
3 Ancoli-Israel, S., Gehrman, P., Martin, J. L., Shochat, T., Marler, M., Corey-Bloom, J., & Levi, L. (2003). Increased light exposure consolidates sleep and strengthens circadian rhythms in severe Alzheimer's disease patients. *Behavioral Sleep Medicine, 1*(1), 22–36.	This study examined the effect of light on sleep and circadian activity rhythms in patients with probable or possible Alzheimer's disease.	Brite-Lite box from Apollo Light Systems	2500	120	Morning: 9:30–11:00 a.m.	10
		Brite-Lite box from Apollo Light Systems	2500	120	Evening: 5:30–7:30 p.m.	10
4 Palmer, C. R., Kripke, D. F., Savage Jr., H. C., Cindrich, L. A., Loving, R. T., & Elliott, J. A. (2003). Efficacy of enhanced evening light for advanced sleep phase syndrome. *Behavioral Sleep Medicine, 1*(4), 213–226.	This study tested whether a newly designed enhanced evening light therapy was well tolerated and effective in relieving symptoms of Advanced Sleep Phase Syndrome (ASPS).	Senior's Luminaire™ lighting device, Apollo Light Systems, Orem, Utah. Philips Hi-Vision F32T8/TL841	265	Light on: 120–180; average exposure 145 from actigraphy	Evening	28
5 Pallesen, S., Nordhus, I. H., Skelton, S. H., Bjorvatn, B., & Skjerve, A. (2005). Bright light treatment has limited effect in subjects over 55 years with mild early morning awakening. *Perceptual and Motor Skills, 101*(3), 759–770.	[A]n experimental study to be conducted in a clinical outpatient setting to investigate the effect of 30 min. daily evening exposure to bright white light of 10,000 lux (as against less light for longer duration).	ML-10000 manufactured by Miljclys, Norway. (Philips, Ecotone, PL-L, RA-index = 80, light temperature 4000 K	10,000	30–60	Evening	21

continues…

TABLE 1. REPORTED SOURCE, INTENSITY, AND DURATION FROM RCTs PUBLISHED 2002–2012 *(continued)*

SOURCE (chronological order)	OBJECTIVE	LIGHT SOURCE	INTENSITY (LUX)	DURATION IN MINUTES	TIME OF DAY	NUMBER OF DAYS
6 Alessi, C. A., Martin, J. L., Webber, A. P., Cynthia Kim, E., Harker, J. O., & Josephson, K. R. (2005). Randomized, controlled trial of a nonpharmacological intervention to improve abnormal sleep/wake patterns in nursing home residents. *Journal of the American Geriatrics Society, 53*(5), 803–810.	The objective of this study was to test a multidimensional, nonpharmacological intervention to improve abnormal sleep/wake patterns in nursing home residents.	Sunlight or Apollo Brite-Lite IV	10,000	30	"generally in the morning"	5 consecutive days
7 Dowling, G. A., Mastick, J., Hubbard, E. M., Luxenberg, J. S., & Burr, R. L. (2005). Effect of timed bright light treatment for rest-activity disruption in institutionalized patients with Alzheimer's disease. *International Journal of Geriatric Psychiatry, 20*(8), 738–743.	The purpose of this randomized clinical trial was to test the effectiveness of timed bright light therapy in reducing rest-activity (circadian) disruption in institutionalized patients with AD.	Sunlight or Apollo Brite-Lite IV	2500	60	Morning: 9:30–10:30 a.m.	50 out of 70 (M–F, 10 weeks)
		Sunlight or Apollo Brite-Lite IV	2500	60	Afternoon: 3:30–4:30 p.m.	50 out of 70 (M–F, 10 weeks)
8 Martin, J. L., Marler, M. R., Harker, J. O., Josephson, K. R., & Alessi, C. A. (2007). A Multicomponent nonpharmacological intervention improves activity rhythms among nursing home residents with disrupted sleep/wake patterns. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 62*(1), 67–72.	We examined the impact of a multicomponent nonpharmacological intervention on 24-hour rest/activity rhythms among long-stay NH residents.		This article is based on data from Alessi et al., 2005.			
9 Hickman, S. E., Barrick, A. L., Williams, C. S., Zimmerman, S., Connell, B. R., Preisser, J. S., … Sloane, P. D. (2007). The effect of ambient bright light therapy on depressive symptoms in persons with dementia. *Journal of the American Geriatrics Society, 55*(11), 1817–1824.	To assess the effect of ambient bright light therapy on depressive symptoms in persons with dementia.	GE F54T5HO 6500K noted at NC and assumed for Oregon site. Skylights at Oregon only.	2500	150–180	Morning: 7–11 a.m.	Multiple 3-week periods
			2500	150–180	Evening: 4–8 p.m.	Multiple 3-week periods
			2500	504	All day: 7 a.m.–8 p.m.	Multiple 3-week periods
			2500	504	All day: 7 a.m.–8 p.m.	Multiple 3-week periods

continues…

TABLE 1. REPORTED SOURCE, INTENSITY, AND DURATION FROM RCTs PUBLISHED 2002–2012 *(continued)*

SOURCE (chronological order)	OBJECTIVE	LIGHT SOURCE	INTENSITY (LUX)	DURATION IN MINUTES	TIME OF DAY	NUMBER OF DAYS
10 Sloane, P. D., Williams, C. S., Mitchell, C. M., Preisser, J. S., Wood, W., Barrick, A. L., … Zimmerman, S. (2007). High-intensity environmental light in dementia: Effect on sleep and activity. Journal of the *American Geriatrics Society, 55*(10), 1524–1533.	To determine whether high-intensity ambient light in public areas of long-term care facilities will improve sleeping patterns and circadian rhythms of persons with dementia.	GE F54T5HO 6500K noted at NC and assumed for Oregon site. Skylights at Oregon only.	2500	150-180	Morning: 7–11 a.m.	Multiple 3-week periods
			2500	150–180	Evening: 4–8 p.m.	Multiple 3-week periods
			2500	504	All day: 7 a.m.–8 p.m.	Multiple 3-week periods
			2500	504	All day: 7 a.m.–8 p.m.	Multiple 3-week periods
11 Dowling, G. A., Burr, R. L., Van Someren, E. J. W., Hubbard, E. M., Luxenberg, J. S., Mastick, J., & Cooper, B. A. (2008). Melatonin and bright-light treatment for rest-activity disruption in institutionalized patients with Alzheimer's disease. *Journal of the American Geriatrics Society, 56*(2), 239–246.	Sleeping patterns and circadian rhythms of persons with dementia.	Sunlight outdoors, or indoors though windows or Apollo Brite-Lite IV when sunlight not available	Light Box produced 2,500 lux. Median exposure was 6204 +/– 2,668 lux	60	Morning: 9:30–10:30 a.m.	50 out of 70 (M–F, 10 weeks)
				60	Morning: 9:30–10:30 a.m.	50 out of 70 (M–F, 10 weeks)
12 Riemersma-van der Lek, R. F., Swaab, D. F., Twisk, J., Hol, E. M., Hoogendijk, W. J. G., & Van Someren, E. J. W. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities. *Journal of the American Medical Association, 299*(22), 2642–2655.	To determine whether the progression of cognitive and noncognitive symptoms may be ameliorated by individual or combined long-term application of the 2 major synchronizers of the circadian timing system: bright light and melatonin.	Philips fluorescent lamps: TLD840 and TLD940	1000	540	All day: 9 a.m.–6 p.m.	Mean 450 (mean 15 months; max 3.5 yrs)
13 Friedman, L., Spira, A. P., Hernandez, B., Mather, C., Sheikh, J., Ancoli-Israel, S., … Zeitzer, J. M. (2012). Brief morning light treatment for sleep/wake disturbances in older memory-impaired individuals and their caregivers. *Sleep Medicine, 13*(5), 546–549.	To determine whether bright light can improve sleep in older individuals with insomnia.	"SADelite Lamps" Northern Light Technologies, Montreal, Canada, device calibrated to produce 10,000 lux "full-spectrum"	2000 lux or more	45	Starting 15 min. after wake time	84
			2000 lux or more	45	Starting 1 hour before scheduled bedtime	84

continues…

TABLE 1. REPORTED SOURCE, INTENSITY, AND DURATION FROM RCTs PUBLISHED 2002–2012 *(continued)*

SOURCE (chronological order)	OBJECTIVE	LIGHT SOURCE	INTENSITY (LUX)	DURATION IN MINUTES	TIME OF DAY	NUMBER OF DAYS
14 Barrick, A. L., Sloane, P. D., Williams, C. S., Mitchell, C. M., Connell, B. R., Wood, W., … Zimmerman, S. (2010). Impact of ambient bright light on agitation in dementia. *International Journal of Geriatric Psychiatry, 25*(10), 1013–1021.	To evaluate the effect of ambient bright light therapy (BLT) on agitation among institutionalized persons with dementia.		Common intervention with Hickman, 2007; and Sloane, 2007.			
15 Lieverse, R., Van Someren, E. J. W., Nielen, M., Uitdehaag, B. M. J., Smit, J. H., & Hoogendijk, W. J. G. (2011). Bright light treatment in elderly patients with nonseasonal major depressive disorder: A randomized placebo-controlled trial. *Archives of General Psychiatry, 68*(1), 61.	To determine the efficacy of Bright Light Treatment in elderly patients with MDD.	Philips Bright Light Energy HF 3304, with gel filter Model 061; Lee Filters	7500	6	Early morning	21
16 Zeitzer, J. M., Friedman, L., & Yesavage, J. A. (2011). Effectiveness of evening phototherapy for insomnia is reduced by bright daytime light exposure. *Sleep Medicine, 12*(8), 805–807.	To examine the effect of ambulatory daytime light exposure on phase delays and on the advances produced by timed exposure to bright evening or morning light.		This article is based on data from Friedman et al., 2009.			
17 Royer, M., Ballentine, N. H., Eslinger, P. J., Houser, K., Mistrick, R., Behr, R., & Rakos, K. (2012). Light therapy for seniors in long term care. *Journal of the American Medical Directors Association, 13*(2), 100–102.	To investigate the effects of light therapy on cognition, depression, sleep, and circadian rhythms in a general, nonselected population of seniors living in a long-term care facility.	Color Kinetics "Colorgraze" Powercore tuned to 464nm	400	30	30 min. within 9:30 a.m.–10:30 p.m.	20 out of 28 (M–F)
18 Friedman, L., Spira, A. P., Hernandez, B., Mather, C., Sheikh, J., Ancoli-Israel, S., … Zeitzer, J. M. (2012). Brief morning light treatment for sleep/wake disturbances in older memory-impaired individuals and their caregivers. *Sleep Medicine, 13*(5), 546–549.	This study examined the effectiveness of a "user-friendly" phototherapy protocol that would be readily usable in the home environment to treat sleep disruption in older individuals.	Sunbox company, Gaithersburg, Maryland	4200	30	Starting within 30 minutes of rise time.	14

Improvements to the rest/activity rhythm and entrainment of residents in long-term care to a more normal circadian time schedule may benefit both resident and caregiver. The ideal result would be residents that sleep better at night and are more alert and able to participate in life activities during the day. An added benefit to better-entrained residents is that staff can manage their time more effectively and potentially deliver a higher level of care.

Ancoli-Israel et al. (2003) studied the effect of light on residents of a long-term care facility with Alzheimer's disease (AD) in a study design that included a morning bright light group and an evening bright light group. The dose for both groups was 2500 lux for 2 hours delivered from a light box. They reported that both morning bright light and evening bright light consolidated sleep. They also found increased quality of the circadian activity rhythm in the evening group. Using the same dose in an earlier study, the same investigators found that morning light made the circadian rhythm more robust, and delayed the acrophase of the activity rhythm (Ancoli-Israel, Martin, Kripke, Marler, & Klauber, 2002).

Another study using the same commercial treatment device for only an hour, found that the stability of the rest–activity rhythm was improved, but did not find improved sleep (Dowling, Mastick, Hubbard, Luxenberg, & Burr, 2005).

In contrast, a study that included a multidimensional intervention used sunlight or just 30 minutes of artificial light at 10,000 lux, and found a significant decrease in daytime sleeping and that the social and physical activity of the subject increased (Alessi, Martin, Webber, Cynthia Kim, Harker, & Josephson, 2005).

To further define the dose–response relationship, it is important to understand the interaction between light exposure and hormone expression. Both play a role in the synchronization of the circadian system. Two studies used combinations of these treatments to explore potential interactions. Dowling et al. (2008) treated patients with AD using sunlight, or a light-box device that produced 2500 lux when sunlight was not available. The median exposure was measured as 6204 lux +/- 2668 lux. They found that light treatment alone did not result in improvement, but that in combination with melatonin, subject's activity levels and wake time increased and that the rest-activity rhythm was strengthened.

In a long-term study, residents were exposed to 1000 lux from 9:00 a.m. to 6:00 p.m. for as long as 3.5 years (mean 15 months) (Riemersma-van der Lek, Swaab, Twisk, Hol, Hoogendijk, & Van Someren, 2008). Interventions varied across several study groups and included light treatment, the hormone melatonin, or a combination of light and melatonin. They found that all day exposure to bright light improved cognition, mood, behavior, functional abilities and sleep. When used in combination with melatonin further improvements were found, and they increased over time. The design of this study included all day exposure and continued for an extended period, which is far closer to the natural light/dark cycle than many studies.

In a study of patients with non-seasonal major depressive disorder (MDD), researchers used 7500 lux of white light that was applied for an hour in the early morning (Lieverse, Van Someren, Nielen, Uitdehaag, Smit, & Hoogendijk, 2011). They found improvements to mood and sleep, as well as improvements to hormonal activity.

To ensure consistency of the light interventions under study, three articles reported results of an architectural approach to lighting (Hickman et al., 2007; Sloane et al., 2007; Barrick et al., 2010). The studies shared the same intervention at the same locations, which included extensive renovation of the lighting architecture in two facilities. They reported using 2500 lux as the intervention intensity that was delivered as environmental light from an architectural lighting system rather than a treatment device. Treatment groups included morning bright light, evening bright light, and all day bright light. A programmable lighting control system allowed for multiple 3-week interventions at two sites over the course of a 20-month experiment.

Outcome measures reported in three articles included effects on depression, sleep and circadian rhythms, and agitation in elderly patients with dementia. Sloane et al. (2007) found decreased depression in some persons but increased depression in others. Hickman et al. (2007) found a modest improvement in sleep measures. And Barrick et al. (2010) found that agitation was not reduced by light exposure, and that in some persons agitation increased. Given the well-crafted intervention and the promising results of previous studies, the results in this group of articles were somewhat surprising. Analysis of the limitations of these studies provides important clues as to the difficulties encountered in demonstrating results when variables cannot be fully controlled.

When the newly completed installation was commissioned for use, light levels were measured to ensure compliance with the study protocol (Sloane et al., 2005). When the lighting system was adjusted to produce 2500 lux of vertical illuminance (the desired state) staff complained that the lighting was too bright. In response, the meter was held in a horizontal position (parallel to the floor), and the lighting was dimmed to achieve 2500 lux of horizontal illuminance. The quoted light quantities may therefore be overstated. Measurements reported during commissioning suggest that the actual light levels at the eye were on the order of 1250 lux. Furthermore, the reported lighting level of 500 lux selected for the control group was based on industry design standards rather than existing conditions (Sloane et al., 2005). In comparison, a study of lighting conditions in long-term care facilities in California found the mean level to be 54 lux (Shochat, Martin, Marler, & Ancoli-Israel, 2000).

These limitations illustrate the need for fully understanding measurement of light exposure when establishing a dose that reliably results in the desired clinical outcome.

One of the most recently published articles combined an architectural strategy to enhance compliance with a programmable light source to deliver light centered in the action spectrum. Royer et al. (2012) used a unique light source capable of

producing light with programmable spectral content. Using the action spectrum as a guide, a lighting fixture with an LED source was programmed to deliver narrow band colored light—464 nm (blue) as intervention and 628 nm (red) as control. Because the light from the source was targeted near the peak response of the circadian system, the intensity of the intervention was a relatively low 400 lux for a brief period of 30 minutes. They found improved mood and improvements in cognition. This approach may permit a clinically effective dose without some of the issues associated with bright white light, such as excessive brightness, added heat and energy cost.

Timing

It is well understood that the response of the healthy circadian system differs depending on the timing of the stimulus (Lewy et al., 1998). For example, light before body temperature nadir will delay the phase; light after nadir will advance the phase. The optimal time for delivering a lighting intervention depends upon an individual's circadian cycle and relation to a model rhythm that is in sync with the natural light/dark cycle.

The design of most of the articles in this review included a scheduled intervention period of 30 minutes to 3 hours of light in the morning and/or evening. One study used all day bright light (Riemersma-van der Lek et al., 2008). The three studies discussed above that shared a study design had morning, evening, and all-day treatment groups.

Results were quite varied, depending on baseline conditions and study objectives. It should be noted that the terms morning and evening relate to clock time, which may or may not relate to the circadian phase of a given subject. None of the studies assessed the subject's endogenous circadian phase.

Several studies compared the effect of timing on the intervention. The most common effect of time of day was the advance or delay of the acrophase. In a pair of studies examining the effect of bright light on nursing home patients with AD, some differences were found with morning versus evening exposure (Ancoli-Israel et al., 2002, 2003). In the 2002 study, morning light delayed the acrophase and improved activity rhythmicity. In the 2003 study, both morning and evening light resulted in more consolidated sleep at night; and evening light increased the quality of the circadian rhythm. It is important to note that in the morning group of the 2002 study the treatment delayed the phase of every subject. In normal subjects it would be expected that morning light would advance the phase and evening light would delay the phase, based on Lewy's theory of the phase response curve (PRC) (Lewy et al., 1998). (A phase response curve illustrates the time variation in response to a stimulus.) The rhythms of older adults have been shown to be phase advanced relative to younger subjects (Nicolau et al., 1985), which would also shift the timing of the PRC to an earlier timeframe. Although it was morning, the intervention may have occurred during the time when subjects were within the phase delay portion of the PRC.

These results suggest that while scheduled brief exposure to bright light can be a beneficial part of a treatment regimen, it may not be appropriate as part of an architectural approach to lighting design in a facility because results can vary widely depending upon individual rhythms. All-day light exposure may be the preferred design parameter because it most closely resembles the natural light/dark pattern.

One article reported on the effect of morning light or afternoon light in institutionalized patients with AD (Dowling et al., 2005). Differences between treatment groups were not found, but the stability of the rest-activity rhythm improved in both groups compared to the control group.

All-day light exposure may be the preferred design parameter because it most closely resembles the natural light/dark pattern.

Variation was found in morning versus evening versus all day exposures in the three studies mentioned above that shared a common study design (Hickman et al., 2007; Sloane et al., 2007; Barrick et al., 2010). Hickman et al. (2007) assessed the effect of bright light on depressive symptoms and found that morning light benefited some persons, but that others had negative results. Sloane et al. (2007) studied the effect of bright light on sleep and found that morning or all-day light resulted in a modest benefit for nighttime sleep. Barrick et al. (2010) found that agitation was higher in most treatment groups with some variation by site. Agitation was not significantly lower in any treatment group.

Spectrum

It is well-established that the circadian system responds to a relatively narrow range of light and is maximally responsive to light at 480 nm (blue) (Brainard et al., 2001; Thappan, Arendt, & Skene, 2001). This is a function of the intrinsically photosensitive retinal ganglion cell (ipRGC) receptors that respond to light in this range and are connected anatomically to the circadian pacemaker in the brain. A light source must contain significant intensity within the action spectrum to be effective. Recent work has established that the classic receptors (rods and cones) involved in vision also play a limited role in circadian response (Gooley et al., 2010), which is discussed in a later section.

Much of the research into light and circadian rhythms over the last 10 years has referenced the action spectrum in determining the spectra of intervention sources. One study used a unique approach.

Royer et al. (2012), as discussed above, used a unique light source capable of producing light with programmable spectral content. Using the action spectrum as a guide, a lighting fixture with an LED source was programmed to deliver narrow band colored light—464 nm (blue) as intervention and 628 nm (red) as control. This allowed the intensity of the intervention to be a relatively low 400 lux, while providing significant light within the action spectrum. The authors concluded that "Blue light treatment led to significant cognitive improvements compared with placebo red light and may be a promising environmental intervention to reduce cognitive symptoms in elderly, long-term care residents" (p. 100).

Using artificial light to supplement or replace the natural light/dark cycle can be difficult given the enormous intensity of sunlight, and the changing spectral content. The above study demonstrated that the circadian system can be targeted with light in a narrow band width, thus reducing the cost of energy and avoiding unwanted heat from a comparable white light system.

Most light treatment devices reference the established action spectrum in the specification of the fluorescent tubes provided. However, some devices are not as well designed. Palmer et al. (2003) conducted a study of a specific device intended for use in treatment of Advanced Sleep Phase Syndrome (ASPS). Although the light treatment devices were well received by the participants, the results were equivocal. The published spectral power density chart for the lamps used in the device indicates that little light is produced within the action spectrum. The study did not find any significant difference between treatment and control groups.

Gasio et al. (2003) found a response in a study of a dawn-to-dusk simulation (DDS) despite the fact that the chosen light source was halogen, which contains little light in the action spectrum. The study began before the action spectrum was identified, so the investigators could not have known that the spectrum of light was critical to elicit response from the ipRGC receptors. The authors also acknowledged that the intensity of the intervention may have been too low to achieve a clinical response. Despite the limitations they did have "promising" results that included trends towards longer sleep duration and improved rest-activity rhythms. Given the limitations it is perhaps surprising that any improvement was measured over placebo light. It may be that classic photoreceptors are responsible for the results demonstrated in this study.

This means that short duration interventions using white light can elicit response from both ipRGC and cone receptors.

Recently published research in healthy subjects has determined that classic photoreceptors (rods and cones) can play a role in melatonin suppression and circadian phase resetting (Gooley et al., 2010). These data indicate that the cone receptors that stimulate the visual cortex can also affect circadian response and melatonin suppression during the first 90 minutes of light exposure, after which the response declines exponentially. It was also found that the mid-range cone receptors (green) provide circadian stimulus in low light conditions. This means that short duration interventions using white light can elicit response from both ipRGC and cone receptors. It is possible that the results found in Gasio et al. (2003) may have been due to response from the cone receptors during the dawn portion of the dawn-to-dusk simulation.

If this line of reasoning explains the findings in Gasio et al. (2003), why didn't Palmer et al. (2003) achieve clinical results, given that their device also produced white light that would stimulate the cone receptors? The intent of Palmer et al. (2003) was to delay the phase using evening exposure to light, so the intervention took place at the end of the day. Because the cones are involved for a relatively short duration, whatever response the subjects may have had from classic receptors had occurred long before the intervention began. Given that the device did

not produce light in the relevant portion of the spectrum, the ipRGC receptors were not engaged either and results were equivocal.

Photic History

An additional layer of complexity to the lighting algorithm is that photic history, that is, prior light exposure, appears to play a significant role. Two of the articles in the review reported on separate analyses of the same study database. In the first article, Friedman et al. (2009) no difference was found between bright light treatment and placebo dim light. These results appeared to be inconsistent with other previous studies. However, a subsequent analysis of the same data (Zeitzer, Friedman, & Yeasavage, 2011) demonstrated that the results were likely due to an uncontrolled variable. The study design included "sleep hygiene," including daily walks outdoors during the day, which was given to all participants. Two years later Zeitser et al. (2011) reviewed a subset of the same data and found that exposure to daylight (which often exceeds 50,000 lux and can be as much as 100,000 lux) diminished the effect of the evening treatment light of 2000 lux. The effect was not found for morning light. It appears that the circadian pacemaker responds to a range of values, rather than a threshold. Other studies have confirmed that the pacemaker is sensitized by dim light and desensitized by bright light, meaning that recent history of light exposure will affect response (Hebert, Martin, Lee, & Eastman, 2002; Smith, Schoen, & Czeiler, 2004; Chang, Scheer & Czeiler, 2011).

It appears that the circadian pacemaker responds to a range of values, rather than a threshold.

The implications for residents of long-term care facilities that are typically dimly lit are profound. It may be that if your circadian system is sensitized to dim light, it is then subject to phase resetting from ordinary room light, such as an exam light over the bed that is switched on during the night by caregivers. It may be that if this effect is repeated throughout the day the circadian rhythm of the resident is disrupted. This is consistent with observed behavior in long-term care facilities where residents may nap, or be awake and active at any time day or night.

The study by Zietzer and colleagues illustrates two important points:

1. Variables outside the intervention may confound the outcome.
2. Photic history is one such variable.

When the baseline included exposure to daylight during a noontime walk (reported as max 90,650 lux), the effect of 4000 lux of treatment light administered a few hours later was significantly diminished. That the results of Friedman et al. (2009) were confounded by this intervention argues for at least monitoring light exposure across the 24-hour day to ensure that when an intervention is planned prior history is considered.

Discussion

Light entrains the human circadian rhythm, can suppress or stimulate synthesis of hormones and neurotransmitters, and has been shown to reduce stress and relieve depression. Given the extensive amount of time that people in our society spend indoors, it is imperative that we examine our use of light in the built environment to ensure that the lighting environment supports the health and well-being of the occupants. The focus in this article is on the application of evidence from studies of elderly residents in long-term care who are typically not exposed to bright light during the normal course of the day. We considered it important to view these relevant prospective, randomized, controlled clinical trials published in the last 10 years in context. What was known at the time the study was conceived would have affected the study design and the conclusions reached. What we know now allows us to review the previous work from a perspective unavailable at the time the studies were conceived and implemented. It is now possible to incorporate these results into a better understanding of why certain interventions achieved clinical outcomes and others did not.

Given the extensive amount of time that people in our society spend indoors, it is imperative that we examine our use of light in the built environment to ensure that the lighting environment supports the health and well-being of the occupants.

Beginning with the discoveries of the action spectrum and the ipRGC, the direction of research evolved from an investigation of the visual system to a broader understanding that human anatomy and physiology includes a separate circadian system with dedicated light receptors. These ipRGC project directly to the circadian pacemaker, which triggers a cascade of hormones and neurotransmitters that affects and entrains multiple systems in the brain and body.

The articles in this review, along with well-established prior work, suggest a set of lighting parameters that could be called the lighting algorithm. Humans respond differentially to these parameters in ways that are, to an extent, predictable and repeatable. An understanding of this algorithm is fundamental to creating an architectural lighting environment that addresses biological needs in addition to classic requirements for aesthetics and vision.

Design considerations for circadian light include intensity, spectrum, duration, time of day (clock time as well as individual circadian time), and photic history. The effect of these parameters on human biology can be better understood through evaluation of the relevant literature. And the evidence from these studies of light treatment can inform the design of architectural lighting.

Most of the 18 articles reviewed here reported on therapeutic light interventions delivered via a treatment device commonly called a light box. In those studies, the device was typically placed near the subject, who was encouraged to sit in place at a scheduled time of day to receive the desired dose of light. Compliance may have been an issue since study participants required supervision, and therefore the assigned treatments needed to fit within the caregivers existing schedule. The interaction with staff may also have had an effect on the subjects, potentially confounding results. Furthermore, maintaining such a regimen on a long-term basis can become challenging, if not impossible.

However, in the five remaining articles, architectural lighting systems were integrated with the interior environment of the residential facilities (Hickman et al., 2007; Sloane et al., 2007; Barrick et al., 2010; Riemersma-van der Lek et al., 2008; Royer et al., 2012). Under this approach the schedule and light level was programmed into the control system, and all in attendance receive the treatment regardless of diagnosis. This architectural approach ensured both subject compliance and delivery of assigned light therapy. Given that residents of nursing homes will vary within a given population and over time, systems design should be flexible to accommodate changing needs. Moreover, because our understanding of dose (intensity times duration) is imperfect the lighting system should be programmable to allow for tuning the lighting as required to meet changing need and/or revised conditions.

Beginning with the discoveries of the action spectrum and the ipRGC, the direction of research evolved from an investigation of the visual system to a broader understanding that human anatomy and physiology includes a separate circadian system with dedicated light receptors.

In a truly architectural approach, it may make sense to abandon the concept of treatment entirely. Rather than delivering a dose of light at a specific time, we propose that an architectural lighting environment be created that supports the health of the occupants over the 24-hour day. The scope of the designed environment will need to include bedrooms and bathrooms, and all areas that residents and staff spend appreciable time in. The lighted environment would be programmed using the algorithm described above based on criteria such as occupant needs, season of the year and clinical objectives. For each hour of the day, each parameter in the algorithm would be programmed to deliver optimal exposure.

A host of other lighting requirements must be met to support both residents and staff, which will not here be discussed in detail since it is beyond the scope of this article. Of equal importance to designing a 24-hour lighting environment is designing darkness to support occupant's needs at night. Melatonin is key to maintaining entrainment and plays an important role in sleep, healing and other processes. Because this important hormone is only released at night and in darkness, the lighting environment for residents during evening and nighttime hours must be controlled carefully. The lighting algorithm should generally follow the natural light/dark pattern, with reduced light levels during evening hours and, to the extent possible, darkness at night.

The operational requirements of residents and staff demand illumination at night, and those needs do not always align. The nighttime lighted environment should avoid disrupting resident's circadian rhythms while providing illumination for safety.

In a truly architectural approach, it may make sense to abandon the concept of treatment entirely.

The lighting environment should also address staff requirements for nighttime lighting. In order to provide care for residents, staff members must be able to see the resident clearly, which may be in conflict with the resident needs for darkness. Staff members that work at night or on a rotating shift schedule also have health issues related to circadian disruption that will be difficult to address.

Some individuals may also need treatment, which could be delivered with standard or novel means.

Conclusions

Based on this analysis, we concluded that (1) valid and actionable data are available about circadian rhythms, sleep and human health and well-being that can inform the design of lighting for long-term care; (2) evidence-based architectural design of a 24-hour light/dark environment for residents may mitigate symptoms of circadian disruption; (3) evidence-based management of darkness is as important as evidence-based management of light; and (4) further research is needed into the long-term circadian health needs of night staff in order to understand the effects of shift work while, at the same time providing the highest level of care.

Implications for Practice

- Residents in long-term care often suffer from symptoms of circadian disruption including depression, difficulty sleeping, frequent daytime napping, and loss of cognitive ability. Evidence from randomized controlled trials indicates that a regular pattern of light and darkness can mitigate these symptoms by restoring a stable circadian rhythm.
- The authors propose an architectural approach to providing the needed light and darkness, which will require cooperation between administrators, medical directors and facility managers. In order to reach consensus, all must share an understanding of the science, physiology and practical application.

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Data-Driven Performance Improvement in Designing Healthcare Spaces

Wendy M. Novicoff, PhD

Measuring performance and defining good quality is a relatively recent phenomenon in healthcare. Starting in the 1980s, when the publication of report cards and information about outcomes of practice, healthcare has steadily improved its skill with using data to understand performance with the intention of making improvements in clinical care as well as in financial performance. Throughout the last 30 years, there have been several methodologies that have been introduced to assist organizations in improving quality, including Total Quality Management (TQM), Clinical Quality Improvement (CQI), and Value Stream Management (VSM). While the rest of this article will concentrate on Lean Six Sigma and how it was used to execute a hospital design project, it is vital to understand that these methodologies and their associated tools are all part of a larger "toolbox," and can be integrated with other tools or methodologies based on the needs of a particular improvement project.

In order for improvement to take root and flourish in an organization, an intense commitment on the part of senior management is required to support improvement activities through training, monitoring, and continued improvement activities after initial implementation. In addition to the need for management support for improvement projects, all employees must embrace some basic prin-

AUTHOR AFFILIATIONS: Wendy M. Novicoff is an Associate Partner with Creative Healthcare, Inc., in Solana Beach, California, a company that specializes in helping healthcare organizations use Lean and Six Sigma tools to improve patient care.

CORRESPONDING AUTHOR: Wendy M. Novicoff, PhD, wmn@creative-healthcare.com

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ciples of quality and performance improvement. Good quality and productive work can't be accomplished without well-defined processes and metrics that are monitored over time. It is also impossible to have good quality without understanding the needs of customers, both internal and external. Finally, it is vital for everyone to remember that the main source of quality defects is within the process itself or the system that is being used, not with the people who are involved in the process. It is far too easy to blame particular people or departments for poor quality, when it is often the system that is fundamentally flawed.

Increasing performance can only be achieved in two ways: increase capacity or reduce variation. If the concentration is (and should be) on making the system better, the concept of variation becomes paramount. Understanding variability is the key to improving a process or a system so that goods or services produced meet the needs of customers. Variation can be described as deviation from a standard process. Variation is ubiquitous, additive, and in most systems that involve humans, can't be completely eliminated. Traditional approaches seek to mitigate the effects of variation in process, sometimes putting a "quick-fix" into place that ends up not only not fixing the problem at hand, but often also making the entire system work less effectively and efficiently.

But in discussing the best way to approach quality improvement, there are some other basic principles to consider. Poor quality leads to incremental cost to the business, for example, in terms of rework, dealing with customer complaints, loss of market share, among others. In some processes, up to half of the work done is "non-value-added," that is, work that does not contribute to either the bottom line or to satisfying customers. An organization can't improve everything at once, so it should concentrate on the processes or systems that are most vital to core business objectives. Decisions should be made based on data that have been analyzed using sound scientific and statistical thinking. Improvement needs to be embraced at every level of the organization, or it will not be sustained.

What Is Lean Six Sigma?

In very broad terms, Six Sigma is a statistically based approach to process improvement. Lean is a methodology that focuses on eliminating waste—doing more with less—and has its origins in the Toyota Production System that was introduced in Japan. Lean Six Sigma combines the toolboxes of the separate methodologies of Lean and Six Sigma to provide a hybrid approach to process improvement. Because many of the tools in each methodology are similar or overlap, this combined approach is common.

The basic goals of Lean Six Sigma are as follows:

- Identify and eliminate non-value-added activity, that is, any activity that doesn't contribute directly to producing what customers need and want.
- Identify and reduce variation.
- Understand and optimize the parts of the process so that it always yields consistent results that customers expect.

There are two primary approaches in traditional Six Sigma: DMAIC and DMADV.

DMAIC

DMAIC stands for Define, Measure, Analyze, Improve, and Control, and is used to improve existing processes.

Define

In this step, the concentration is on getting the "Voice of the Customer" (identifying customer needs and requirements) and defining what the goals of the project will be. Helping to define what success will look like will keep stakeholders from having varying expectations of what will be solved, how, when, by whom and so on.

Measure

Defining and measuring the "as-is" state is vitally important. A group needs to determine which metrics are most important to measure so that resources can be best spent collecting meaningful data that will be useful to the team. For example, is the goal to reduce overall cycle time or is to reduce the total space requirements for a particular task? Having precise and objective operational definitions and good data collection will help the team decide on project goals, how much improvement is necessary and/or feasible, and even if performance is, in fact, adequate so no improvements are necessary.

Analyze

This phase allows the team to use the data collected in the Measure phase to examine trends or patterns in the current process performance. Only by taking time to understand—systematically and conclusively—what drives process behavior, can the correct root causes for performance be discovered.

Improve

This is the stage where the team selects solutions to the root causes identified in the Analyze step. By taking this step in order (as opposed to skipping to solutions without systematic data collection and analysis), the team has a much better chance of fixing the correct problem with the correct solution that will lead to improved performance. This is also the time when new solutions can be piloted before large-scale improvement is attempted.

Control

The Control phase helps to finalize project solutions and cement their continued use. The Control Plan sets up who will continue to monitor the improved process, how often it will be monitored, and what the triggers should be if performance starts to slide.

DMADV

The other approach is DMADV, which represents the five phases of Design for Six Sigma (DFSS)—Define, Measure, Analyze, Design, and Verify—and is used to design new processes to meet customer requirements. The first three phases are exactly the same as in DMAIC. Defining, measuring, and analyzing without too many preconceived notions about whether there will be improvement to an existing process or designing a new one are essential to a project. Let the data and the team decide which path to take.

- **Define** Define the project opportunity and goals; get customer requirements to define specifications.
- **Measure** Assess needs and specifications.
- **Analyze** Statistically examine options to meet specifications.
- **Design** Develop the process/product to meet specifications.
- **Verify** Check the design to ensure specifications are being met.

Lean Principles

There are five basic principles in Lean: vaue, value stream, flow, pull, and perfection. All processes should be evaluated against these principles, and any part of a process that does not meet the requirements for being value-added should be improved.

Value

Value can only be defined by the customer, and only then can the producer create what is needed. Asking the customer is vital to understanding what they want—assume nothing!

Value Stream

There must be a fundamental understanding of how an entire process works together, or does *not* work together, before improvement can begin. There is no point in improving one part of a process if it ends up adversely affecting another part of the process. Only by examining the entire process can "value" be assigned to various steps based on customer needs and requirements.

Flow

Processes should be designed to minimize interruptions, handoffs, waiting, and other stoppages. Flow is the opposite of "batching"—doing several like items before moving onto the next task—and is the predominant method for the way many organizations work today.

Pull

No part of the process should produce anything until the next step in the process is ready for it. Flow and Pull are necessarily interlinked—a good process will flow well, but not produce more than is needed until it is actually needed.

Perfection

Perfection represents the ideal state where all waste is eliminated and all steps in the value stream create value for the customer. This concept, while rarely achieved, should be a goal to strive for. If you are able to remove all of the waste possible in your process, then you can move into using strategies like Six Sigma to strive for even better results.

Using Lean Six Sigma requires a disciplined approach to following all of the steps of the methodology—no steps can be skipped, or there is the very real risk of missing important root causes for why processes are not performing adequately, rushing to an incorrect solution, or choosing an approach that does not have enough support from the organization to lead to lasting change. There are multiple ways that an organization can measure and communicate process performance to ensure continued commitment, including the use of control charts or other graphs, doing regular audits, disseminating information about the process to all employees, and using a tool that can bring multiple methods together to enhance continued interest in the project. One such method to "bring it all together" is the A3 report, which puts all of the information about a project—from background to baseline measures to analysis to implementation to follow-up—on one piece of paper, giving a visual representation of the entirety of the work that has been done to date.

Lean Six Sigma in the Design Process

Evidence-based design has been rapidly gaining support in design of healthcare spaces over the last decade. Using evidence from multiple disciplines, such as engineering, psychology, and social sciences, combined with clinical expertise to help either to design new spaces or to redesign existing spaces leads to spaces that can truly harmonize the needs of employees, patients, and patient families. Systematic integration of research done on healthcare environments can result in better outcomes in terms of patient and employee safety as well as clinical care.

By using the Lean Six Sigma approach to design, the goals of the space, whether new or redesigned, can be investigated from multiple customer points of view. Patients and employees can both be consulted to determine the requirements for the new area, and these requirements are necessarily going to change based on the type of care offered (such as inpatient vs. outpatient care) and type of patient served (such as family care, women, elderly care, pediatrics, etc.).

Another important consideration is the need for safe, efficient, and effective care that still meets productivity standards. This is where Lean principles become most important—all processes in an area need to work together, which requires an examination of how people will actually use the space, how they move

through a space, where items (and patients) are located in the space, and so on. Lean Six Sigma also requires the intense participation of employees in all levels of the organization, including front-line caregivers, helping to ensure consensus and commitment for the resulting design.

Designing spaces using this approach can be somewhat more time-consuming than using a more traditional design approach because it requires careful consideration of multiple viewpoints as well as defining guiding principles for design that go beyond the aesthetics of a space into the realm of improving patient outcomes. But the rewards can be great, including a resulting space that is well-utilized, staff who are happy with the new space, and a space that doesn't require redesign or major adjustments.

Implications for Practice

- Using the basic goals and tenets of Lean Six Sigma during healthcare building design or redesign can help reduce non–value-added activities, reduce variation, and improve consistency of customer results, including improvements in patient outcomes.
- Examination of multiple, often disparate, stakeholder viewpoints (including those of regulatory bodies, caregivers, and patients and their families) is imperative in designing healthcare spaces. The needs of one group of end-users might differ significantly from those of another group.
- Healthcare facility design should make use of the best available evidence from multiple disciplines, including research from engineering, psychology, and other social sciences. Case studies of what has worked—and not worked—in healthcare design should be referenced wherever possible.

Fall Prevention for Inpatient Oncology Using Lean and Rapid Improvement Event Techniques

Laurie Wolf, MS, CPE, ASQ-CSSBB; Eileen Costantinou, MSN, RN-BC; Cathie Limbaugh, MSN, CNS-BC, OCN; Kathy Rensing, MSN, ANP-BC, CRNI; Phyllis Gabbart, MSN, APRN-BC; and Pat Matt, RN, MSN, CIC, ASQ-CSSBB

ABSTRACT

OBJECTIVE: The objective of this project was to reduce patient falls and falls with injury on three oncology divisions at a large urban teaching hospital. By standardizing assessment, intervention, and post-fall investigation processes the goal was to decrease patient falls and falls with injury rate by 50% and 30%, respectively.

BACKGROUND: Preventing patients from being injured due to a fall during their hospitalization has been a concern in healthcare for many years. Organizations around the world such as Institute of Medicine, The Joint Commission, National Institute for Health and Clinical Excellence, National Australian Patient Safety Foundation, and the World Health Organization have been conducting research and publishing guidelines to identify evidence based interventions for fall prevention (Ulrich et al., 2008, Di Pilla, 2010). Falls are the most common cause of non-fatal injury and hospital admission for trauma. Death rates due to falls have risen sharply over the past decade due to aging of the population.

METHODS: A Rapid Improvement Event (RIE) technique was selected to implement the fall prevention initiative because it aligned with the hospital's lean transformation initiative. There was coordination with other departmental staff (physical and occupational therapy, pharmacy, physicians, information systems, low bed equipment vendor, and clinical operations) to achieve multidisciplinary input.

RESULTS: A 22% decrease in total fall rate and a 37% decrease in falls with injury rate were achieved in the 16-month post-intervention period. Although a 22% decrease in total falls did not meet the goal of 50% decrease, the total falls with injury decrease of 37% did exceed the goal of 30%.

CONCLUSIONS: Falls are a multi-faceted, complex problem that needs constant vigilance and continuous improvement to sustain patient safety. Anticipating physiologic changes in patients' conditions and implementing interventions before the fall is critical to fall prevention. While well-validated screening tools performed thoroughly and accurately can help hospital staff identify patient specific fall risk factors, risk assessment alone does not prevent falls. If the prevention of patient falls is identified as important by leadership and staff at the division level and all are invested in achieving established goals, success can be achieved and sustained.

KEYWORDS: Case study, falls, hospital, human factors, organizational transformation, patients

AUTHOR AFFILIATIONS: Laurie Wolf is a Performance Improvement Engineer at Barnes-Jewish Hospital in St. Louis, Missouri. Eileen Costantinou is a Senior Coordinator Practice Specialist and Cathie Limbaugh, Kathy Rensing, and Phyllis Gabbart are Advance Practice Nurses also at Barnes-Jewish Hospital in St. Louis, Missouri. Pat Matt is a Senior Quality Patient Care Consultant with BJC Center for Clinical Excellence in St. Louis, Missouri.

CORRESPONDING AUTHOR: Laurie Wolf, One Barnes-Jewish Hospital Plaza, Mail stop 90-71-435, St. Louis, MO 63110; lwolf@bjc.org; (314) 747-5711.

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Introduction

Preventing patients from being injured due to a fall during their hospitalization has been a concern in healthcare for many years. Organizations around the world such as Institute of Medicine (IOM), The Joint Commission, National Institute for Health and Clinical Excellence, Australian Patient Safety Foundation (APSF), and the World Health Organization (WHO) have been conducting research and publishing guidelines to identify evidence-based interventions for fall prevention (Ulrich et al., 2008, Di Pilla, 2010). Patient falls continue to be the most frequently reported adverse event in hospitals and the leading cause of injury and death in adults 65 years and older. Falls in the adult inpatient setting range from 0.86 to 9.2 falls per 1,000 patient bed days; with geriatric areas as high as 10.7 (Hignett, Sands, Youde, & Griffiths, 2010). Falls are the most common cause of non-fatal injury and hospital admission for trauma. The consequence of a fall can include injuries such as laceration, fracture, or head injury. A serious injury can result in an extended hospitalization or even death. Hip fractures in the elderly often result in decreased mobility, fear of falling, and increased likelihood of nursing home placement. Death rates due to falls have risen sharply over the past decade due to aging of the population (Centers for Disease Control, 2013).

In 2002, the National Quality Forum labeled hospital falls resulting in death or serious injury as a serious reportable event. In 2008, the Centers for Medicare and Medicaid Services (CMS) identified these serious events as hospital-acquired conditions (HACs), subject to nonpayment. As part of the Patient Protection and Affordable Care Act of 2010, beginning in fiscal year 2015, hospitals in the worst performing quartile for HAC rates will receive a reduction in Medicare payments across the board for all discharges (Center for Medicare & Medicaid Services, 2013).

Oncology Patients' Risk for Falling

Oncology patients receive a variety of medications that have the potential to increase the risk for fall, such as benzodiazepines and sedatives/hypnotics. Because of these medications, the oncology patient may be at risk for dizziness or weakness. There is often a learning curve on the part of patients in understanding how the effects of medications they are receiving impact the real risk for fall and injury. Some medications or disease-associated pathology can cause altered elimination (frequent urination or diarrhea). Most falls in oncology involve patients who do not call for help (even when instructed to do so) and who get up for some toileting-related activity without assistance.

Oncology Patients' Risk for Injury When a Fall Occurs

The two main factors that impact an oncology patient's risk for injury are coagulopathies and bone issues. Some diseases and many treatments can cause blood platelet counts (important for clotting) to drop precipitously. As long as these patients do not hurt themselves, they usually don't encounter problems. For this reason, they are taught preventive measures, such as not to shave with a straight

razor, but to use an electric razor instead, and not to engage in contact sports. When these patients fall, they are at risk for serious injury associated with uncontrolled bleeding. If a patient bumps his head, he is at high risk for cerebral bleed and death. Bone issues are also problematic. These are seen in patients on long-term steroids or with diagnoses that decrease the strength of the bone, such as Multiple Myeloma or bony disease, be it metastatic or primary disease. These patients are at high risk for fracture, which certainly impacts the trajectory of their recovery. If they happen to also have a low platelet count, they are often not even a candidate for reparative surgery.

Objective

The objective of this project was to reduce patient falls and falls with injury on three oncology divisions at a large urban teaching hospital. This academic medical center is part of a 13-hospital system and is affiliated with a medical school. Utilizing Lean methodology, a gap analysis between current and future state identified that patient assessment of gait and mental status were not being conducted in a consistent manner. It also revealed that if a fall risk assessment indicated a specific intervention (such as a bed alarm or low bed), that the intervention may not be implemented until after the patient had fallen. By standardizing assessment, intervention, and post-fall investigation processes the goal was to decrease patient falls and falls with injury rate by 50% and 30%, respectively.

A Rapid Improvement Event (RIE) technique was selected to implement the fall prevention initiative because the technique aligned with the hospital's lean transformation initiative.

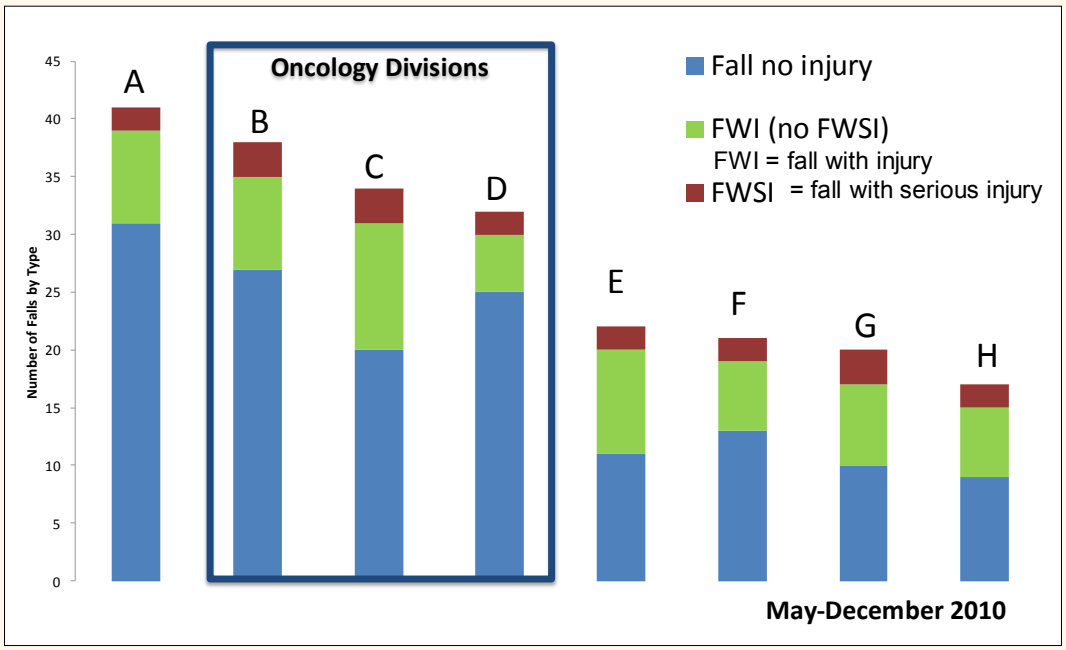
Background

A Rapid Improvement Event (RIE) technique was selected to implement the fall prevention initiative because technique aligned with the hospital's Lean transformation initiative. Lean transformation is a journey toward improving efficiency and quality by eliminating wasted motion and promoting consistent processes. Leadership support for this project was obtained from the Clinical Nurse Executive and Director of Oncology at the hospital level as well as unit level management. Leadership supported the allocation of resources, which allowed front-line nursing staff to attend the 3-day Rapid Improvement Event. In addition, they coordinated with other departmental staff (physical and occupational therapy, pharmacy, physicians, information systems, low bed equipment vendor, and clinical operations) to achieve multidisciplinary input. Leadership attended the event and enabled meeting and project work preparation activities. The oncology director also demonstrated support for this project by requesting to be on-call 24/7, to be notified whenever a patient fell.

Preparation for Rapid Improvement Event

The graph in Figure 1 supports the focus of this project and the reason for selecting the three oncology divisions to participate in the RIE. Figure 1 illustrates the number of fall by type in eight divisions across five hospitals from May 2010 to December 2010. Three of the four divisions with the highest number of falls

Figure 1. Hospital system divisions with the highest number of falls and injuries.

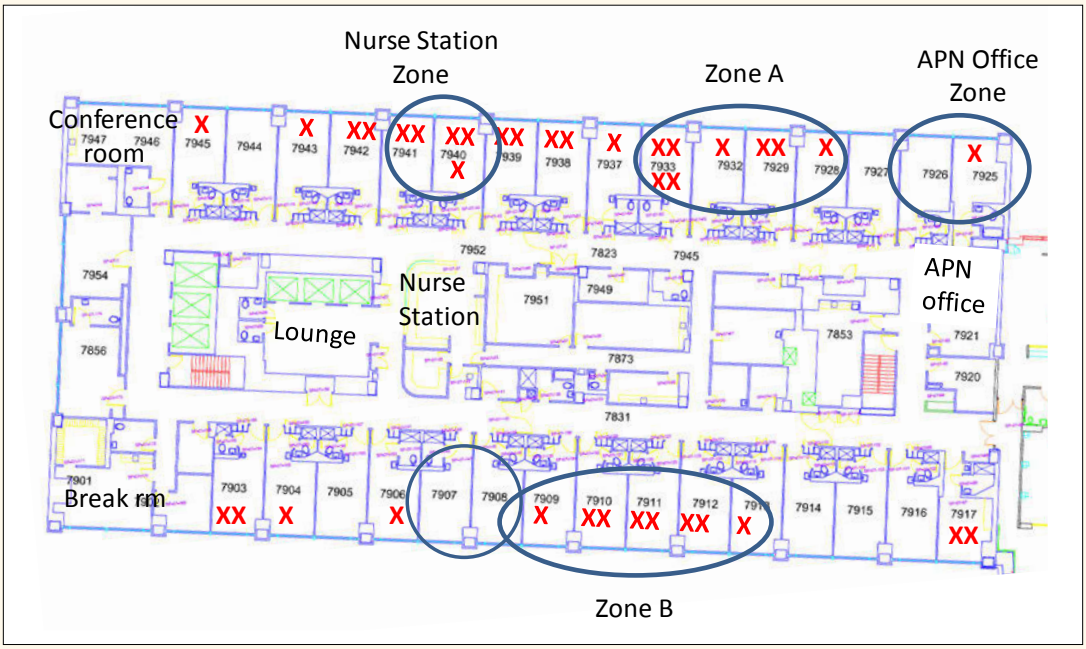


with injury (FWI) in the healthcare system are oncology divisions within the same academic medical center. The majority of falls occur when the patient gets up for toileting activity without using the call light to ask for assistance and the fall typically occurs near the bedside. Patients often overestimate their ability and then suddenly experience weakness.

Although each oncology division has a slightly different layout, they all have long hallways with very few rooms within sight of the nurses' station. Figure 2 is a floor plan of one oncology division ("Division B" in Figure 1). Each "X" represents the location of a fall that occurred in 2011. Rooms that are closest to the nurses' station ("Nurse Station Zone") have a high number of falls but this may be due to the tendency to relocate high fall risk patients near the nurses' station for easier access. Rooms in Zones A and B in Division B also have falls because of the distance to the rooms and awkward access from the nurses' station. The two rooms within 10 feet of the Advanced Practice Nurse's office had only one fall in 2011 because the Advanced Practice Nurse (APN) was able to reach patients very quickly from her office.

The room layout typically has the bathrooms on the headwall side but there are various obstacles, including a sink, in the pathway. Semi-private rooms can be very cramped with equipment, chairs, and computers that create additional obstacles. All patient rooms have vinyl composite tile over concrete, with tile in the bathroom and shower area. Night-lights are built in under most bed frames. Wall-mounted night-lights are also in each room and are located approximately 2 feet above the floor near the bathroom.

Figure 2. Floor plan for Division B, with "X" indicating location of falls in 2011.



The majority of rooms in Divisions B and C are single patient rooms or single occupied due to bone marrow transplant isolation issues. For the three divisions discussed here, the breakdown of rooms and beds is as follows:

- Division B = 38 beds (26 single rooms)
- Division C = 34 beds (all single rooms)
- Division D = 25 beds (11 single rooms)

For the remainder of this article, Divisions B, C, and D from Figure 1 will be collectively referred to as "oncology divisions."

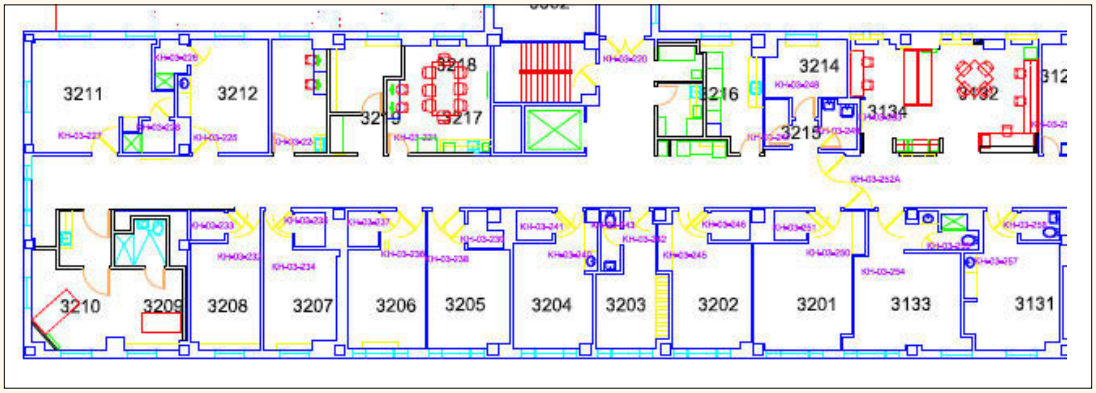
As part of a system-wide Preventable Harm Initiative, a consortium of fall prevention experts and front-line staff from multiple hospitals was assembled to develop a package of fall prevention standards. The package reflects best practice and evidence-based methods to assess patients and to select appropriate interventions. The fall prevention package had three components:

1. Assessment
2. Interventions
3. Data transparency

In preparation for the consortium, a system level team reviewed data and conducted a literature review to understand these three components and best practice interventions.

Figure 3. Floor plan for Division C.

Figure 4. Floor plan for Division D.



A review of patient falls, combined with observation of current processes and feedback from front-line nursing staff, indicated that improvement was needed in assessment of patient gait and mental status. For the gait assessment component, the consortium evaluated several gait assessment tests against selected criteria and selected the Get Up and Go (GUG) test. The first part of the GUG test evaluates the ability to stand up from a seated position. If the patient passes, then they walk for approximately 10 feet and the nurse scores their ability to ambulate. The GUG tool was selected because it was quick to administer and did not require the nurse to have any extra tools such as a stop watch. For the mental status assessment, the Short Portable Mental Status Questionnaire (SPMSQ) was selected. The SPMSQ is a validated 10-item questionnaire used to screen older adults for cognitive impairment. It tests orientation, memory, and the ability to

count backwards by threes. This screening test was later eliminated by the oncology divisions because of problems during repetitive administration that were encountered by both patients and staff. It was replaced with a set of standard questions asking the patients their name, current location, date of birth, and current year. Additional questions were included as part of the fall risk assessment to determine whether the patients overestimate or forget their limitations and/or lack understanding of their physical and cognitive limitations (Erkinjuntti, Sulkava, Wikström, & Autio, 1987).

Method

A system-level consortium for the Preventable Harm Team established the fall and injury rate outcomes for the project. The National Database of Nursing Quality Indicators (NDNQI) was used to benchmark fall and fall with injury rates and to help set goals for the program. Once the consortium determined the standards for fall prevention and goals for the project, the hospital prepared to conduct the RIE to determine how these assessments, interventions, and post-fall investigations would be incorporated into their daily workflow process.

Hospital leadership used a Supplier/Input/Process/Output/Customer (SIPOC) chart to select which roles would be represented in the RIE (George, Rowlands, Price & Maxey, 2005). Specific team members selected for those roles were chosen according to availability and expertise. A key stakeholder assessment was conducted initially to identify potential areas of support and resistance. Key stakeholders identified were front-line RNs, division leadership, and the director of oncology.

Once members of the RIE team were identified, in an effort to understand best practice programs, they participated in a telephone interview with a representative from a similar size collaborative hospital to discuss their successful Fall Prevention Program. They also read fall-related research studies conducted a few years earlier at the hospital in collaboration with the medical school and utilized other nationally recognized journal articles addressing best practices in fall and fall injury prevention.

Rapid Improvement Event (RIE)

A systematic, data-driven process was used with Lean methodology to provide structure for this project. In order to implement the fall prevention package, a 3-day RIE was held to establish how the package would be implemented on the oncology divisions. Breakout groups were established to develop standard work related to GUG gait assessment, the SPMSQ assessment, intervention selection, and the post-fall investigation process. Traditional Lean methodology was used throughout the event to resolve issues such as fist to five, silent voting, and affinity diagramming. Round-robin techniques of brainstorming were used to ensure input from all team members. Traditional Lean and Performance Improvement tools were used to conduct the RIE and follow-up meetings (Benbow & Kubiak, 2005).

Current state and future state were documented in process maps. The remaining activities performed during the RIE addressed the gap between current and the desired future state: assessment, interventions, and data transparency (post-fall activities).

Current State

Current state was documented in a process map with swim lanes for each of the three oncology divisions (Benbow & Kubiak, 2005). Nursing process maps were verified by direct observation on all three oncology divisions. Multidisciplinary input from key stakeholders was represented in each swim lane; solicitation of input and feedback continued throughout the project during frequent reunion meetings following the RIE.

Future State

A future state map was developed with the following goals:

- Fall Risk Assessment completed every shift (and when patient condition changes) that reflects clinical assessment of gait (GUG) and mental status (SPMSQ).
- Appropriate fall prevention interventions selected and implemented based on the results of the fall risk assessment.
- Thorough systematic process to collect information within 60 minutes during the post-fall huddle followed by a more detailed investigation by the unit Advanced Practice Nurse (APN) (four-page post-fall huddle form).
- Transparent information on fall data available to all staff—fall tracking board developed to display information collected during the post-fall huddle and APN investigation.
- Outcomes for the falls and falls with injury were established at the system level and adopted by the hospital oncology teams as part of the future state:

  —Goal for reduction in falls rate was 50%.

  —Goal for reduction in falls with injury rate was 30%.

Assessment

Because a new fall risk assessment was being developed at the time of the RIE, the team decided to enhance the current inpatient fall risk assessment. The group developed a standard work document for use of the GUG (Currie, 2008) and SPMSQ on the oncology divisions. A laminated reminder card was developed to highlight steps involved with the nursing assessments. Standard work was also developed for how to easily document results of the assessments in the electronic medical record (EMR).

Intervention

Another subgroup worked on developing an algorithm to ensure the appropriate interventions were selected and implemented by the nurse based on assessment and clinical expertise. This algorithm shown, in Figure 5, was based on deficits identified during the patient assessment in an attempt to mitigate risk associated with individual risk factors and common combination of risk factors. Algorithm guidelines are based on best-practices interventions according to fall prevention literature (ECRI Institute, 2009).

The box in the upper left corner of Figure 5 illustrates that if a patient had an "altered gait" (i.e., failed the GUG test), then the recommended interventions would be to use a low bed and floor mat with a bedside commode and gait belt and to request an order for physical and occupational therapy. If the same patient also had altered elimination (required frequent toileting), no additional intervention would be required because the patient already had a bedside commode. If this same patient also became confused (e.g., missed three or more questions on the SPMSQ test), because a low bed and floor mat were already in place, the patient's lab results would also need to be reviewed. Because the patient has all three risk factors (altered gait, altered elimination, and confusion) simultaneously, the algorithm also would recommend a bed and chair alarm.

Data Transparency (Post-Fall Activities)

The third subgroup established the processes that would be required after a patient fell. Each division was already conducting a post-fall huddle but was using slightly different processes. All divisions agreed on using one form with investigative questions, some of which were required to be completed within 60 minutes of the fall during the staff-led post-fall huddle and the remainder within 48 hours by the division's Advance Practice Nurse. Data gathered from this investigation were then entered in to a secure database managed by the system level Preventable Harm Team. The data were then aggregated and progress reports were provided post-implementation. Another process developed to make information visible was the posting of a fall tracker board (Figure 6). The board displayed information such as the reason for getting up when the fall occurred, contributing factors (medications, clutter, wet floor, and lighting), scoring on assessments, and types of interventions that were in place and follow up that occurred after the fall. The information helped leadership and staff develop action plans to resolve issues as they were discovered. The fall board is discussed with new staff to quickly make them aware that the majority of falls that occur are related to toileting and patients not calling for assistance.

The fall board is discussed with new staff to quickly make them aware that the majority of falls that occur are related to toileting and patients not calling for assistance.

Executive reviews were held at the end of each of the 3 days of the RIE to engage leadership and key stakeholders in assisting the team with setting goals and outcomes for the project. If ad hoc team members were unable to attend during the event they were encouraged to join the discussions at the end of the day to understand activities and decisions that were completed.

Figure 5. Algorithm for linking fall risk assessment to an appropriate intervention.

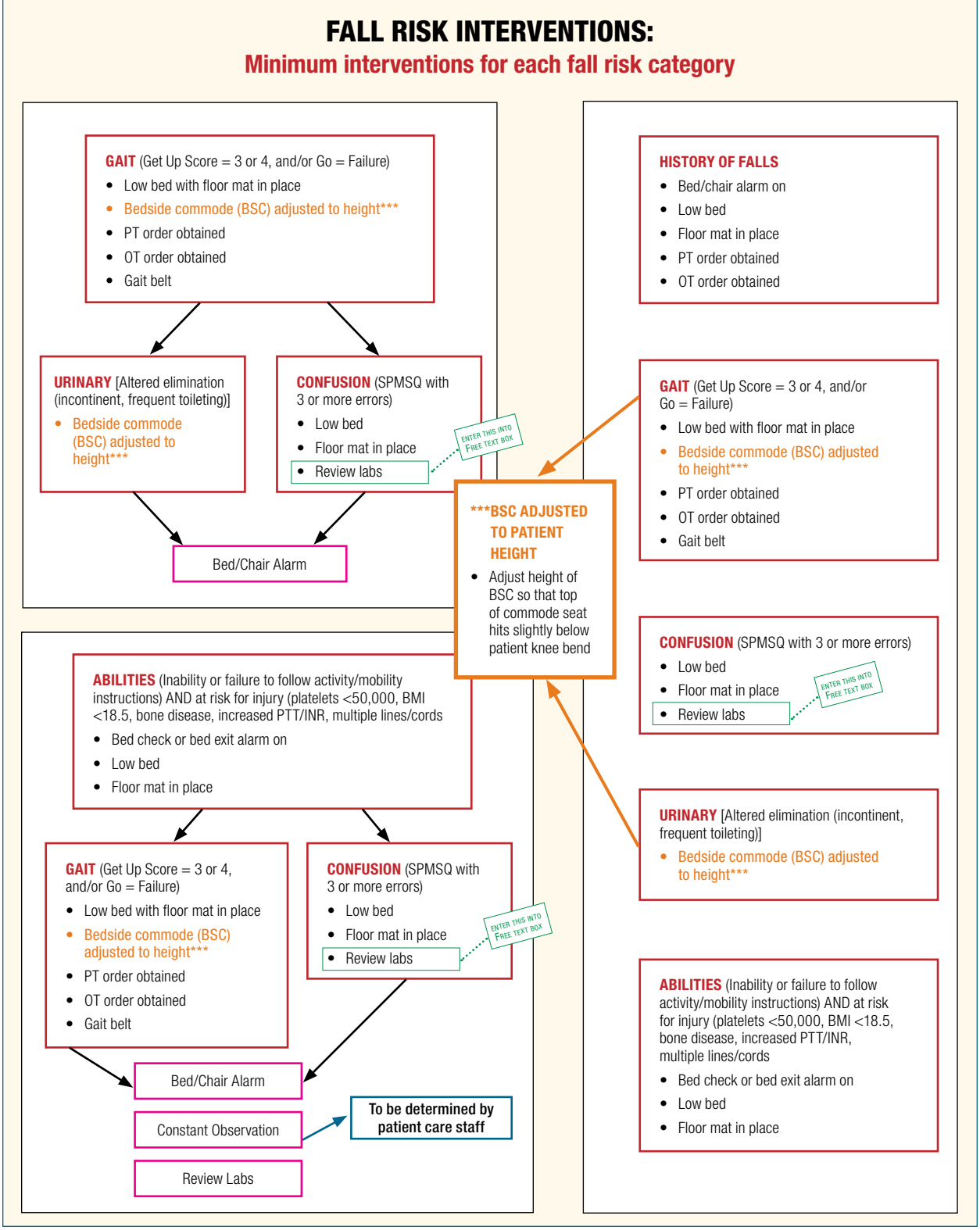
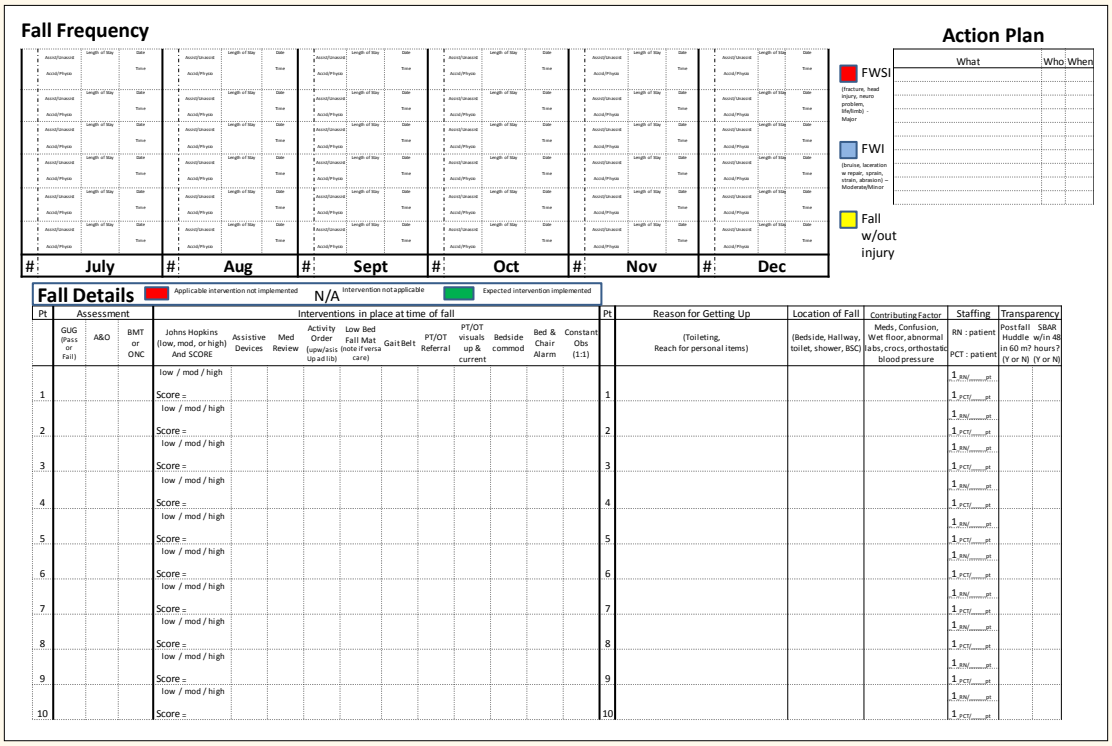


Figure 6. Fall tracker board for posting information after a fall occurred.



Activities after the RIE

Setting a go-live date established the deadline for achieving all activities that needed to be completed after the RIE (such as training and staff demonstration of competencies). Action item lists from the RIE structured the schedule for all the preparation activities for implementation. Approximately 4 weeks were required to finalize preparation materials. For example, photographs and standard work processes had to be completed before the educational materials could be developed for the training sessions. Weekly meetings were held by a core team to monitor progress of action items. Additional work sessions were required to integrate standard work from the assessment and intervention subgroups. Another 4 weeks were needed to allow time for nurse training and communication to all multidisciplinary partners.

All of the members of the multidisciplinary team committed to changes in their work to achieve project outcomes. For example, physical and occupational therapy staff posted an activity communication form in each patient room. Heightened awareness of medications and their link to falls was addressed by pharmacy staff during daily rounds with physicians. Risk management staff incorporated the post-fall investigation documents in their fall event files. Issues with availability and quality of low beds were identified and resolved; this impacted all of the hospital's inpatient units. Multiple ideas for enhancements to the EMRs were generated during the project. Some of these have been implemented, such

as the Fall Note and GUG parameter, and some are still in progress. Tip sheets, developed by the hospital Fall Team, were utilized for ancillary departments to elicit their help in making fall prevention the responsibility of every hospital staff member. Physicians are more engaged than prior to the RIE in knowing the patient fall risk level and what orders are needed. For example, if an activity order "up with assistance only" is required, the physician ensures that orders for both physical therapy and occupational therapy have been written.

Standard Work

Standard work was used to establish a uniform method for fall risk assessment and selection of appropriate interventions. Nurse Managers and an Advanced Practice Nurse educated every nurse utilizing the "Oncology Heroes Preventing Falls Competency and Skills Validation Checklist." A return demonstration was required to ensure understanding was achieved. Approximately 150 nurses received individual education and signed the competency checklist affirming their commitment. Training for other disciplines was achieved in staff meetings and individual communication. Representatives from bed alarm and low bed manufacturers provided education during staff meetings and skills day training sessions to ensure consistency.

Standard work was used to establish a uniform method for fall risk assessment and selection of appropriate interventions.

Action Items

Action plan techniques were used after the RIE to develop work plans to keep activities on track. Each action plan was complied with the W-W-W methodology (WHAT action is needed–WHEN must it be completed–WHO is responsible).

Overcoming Barriers

Various problems and barriers were encountered as improvements were implemented across all three divisions. The following list describes how some of the barriers were resolved:

1. It was difficult to educate so many nurses (approximately 250 in one month) in a short amount of time. This challenge was overcome by the Joint Oncology Unit Practice Committee identifying nurse champions to assist with training.
2. Results of a staff survey conducted post-implementation identified problems with staff acceptance of the cognitive assessment (SPMSQ). Nurses said that their patients thought the questionnaire was redundant and staff members were dissatisfied with the amount of time required to complete the assessment. Based on this feedback, the SPMSQ was eliminated and education was conducted on a standardized version of the current mental status assessment questions.
3. Lack of utilization of low beds was overcome by consistent education and coaching by the APN with the staff. A collaboration with the low bed vendor also improved availability of low beds, which decreased time from

order to delivery. A true culture change was achieved that resulted in a 50% increase in low bed usage post-implementation and 56% increase in low bed days (May, June, July vs. August, September, October).

4. No parameter existed to document results of the gait and cognitive assessment (GUG and SPMSQ) in the electronic medical record. Nurses were trained to document these assessments according to a standard method. Nurses were trained to add the GUG and SPMSQ by adding a comment in the fall risk assessment.
5. Lack of knowledge and consistent utilization of existing bed alarms was addressed by having the vendor participate in skills day sessions.

Results

A 22% decrease in total fall rate and a 37% decrease in falls with injury rate were achieved in the 16-month post-intervention period. Although a 22% decrease in total falls did not meet the goal of 50% decrease, the total falls with injury decrease of 37% did exceed the goal of 30%. Differences in rates were assessed for statistical significance. For all falls, the difference from baseline to post-RIE (5.93/1,000 patient days versus 4.61/1,000 patient days, respectively) was statistically significant ($p < 0.05$). For falls with a minor injury, the difference from baseline to post-RIE (2.01/1,000 patients versus 1.26/1,000 patients, respectively) was also statistically significant ($p < 0.05$).

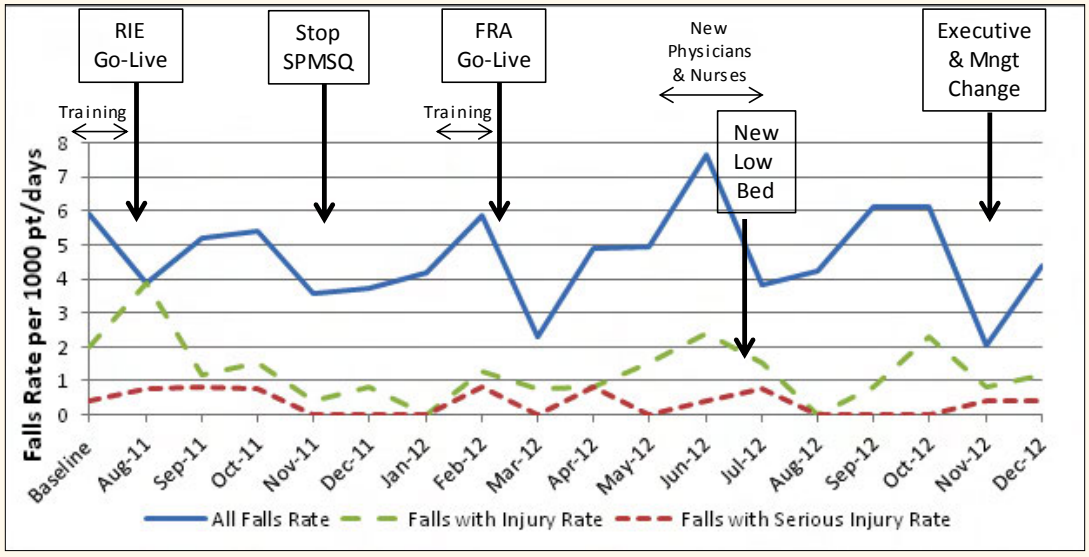
A 22% decrease in total fall rate and a 37% decrease in falls with injury rate were achieved in the 16-month post-intervention period.

The literature states that the average cost of an injury sustained by a patient from a fall in the hospital is $13,316 (Wong, Recktenwald, Jones, Waterman, Bollini, & Dunagan, 2011). Because the number of falls with injury was reduced from 77 (baseline) to 54 (post-intervention), for a total of 23 fewer falls in a similar 16-month time interval, a cost avoidance of $306,268 was achieved (23 ×

Table 1. Three Oncology Divisions: Combined Results

	Jan 2010–April 2011 (Baseline = 1 yr., 4 mo.)	Aug 2011–Dec 2012 (Post-RIE = 1 yr., 4 mo.)	% Improvement Goal	% Improvement Actual	Significance Level Z Distribution
All Falls	227	197			
Falls with Minor Injury (FWI)	62	39			
Falls with Serious Injury (FWSI)	15	15			
Total Falls with Injury = (FWI) + (FWSI)	77	54			
Patient days	38,296	42,771			
All Falls Rate (all falls/1,000 patient days)	**5.93**	**4.61**	50%	22.3%	***p* <0.05**
Falls with Total Injury Rate [(FWI+FWSI)/1,000 patient days]	**2.01**	**1.26**	30%	37.3%	***p* <0.05**
Falls with Serious Injury Rate (FWSI/1,000 patient days)	0.39	0.35		10.3%	Not significant

Figure 7. Monthly fall rates and project milestones.



$13,316 = $306,268). To understand a financial return on investment, this must be balanced by the estimated cost of conducting the project. The 3-day RIE was 7.5 hours with 25 people attending (562.5 hours), plus three reunion meetings lasting 2 hours with 20 people attending (120 hours), plus training time of 30 minutes for 150 nurses and 30 minutes for the trainers (150 hours), for a total of 832.5 hours. This time estimate multiplied by $35.00 per hour as an average salary brings the cost of manpower for the project to approximately $30,000. The cost avoidance of just over $300,000 in addition to the patient benefit from reducing falls makes this project a valuable improvement.

The Figure 7 illustrates major project milestones with the corresponding fall rates by month. There is a large variation in fall rates from one month to the next. All rates are calculated with the denominator of 1,000 patient days so a comparison can be made each month regardless of how many patients were involved. The top line represents the rate of total falls that occurred in the oncology divisions. The bottom line represents falls with serious injury, which includes death, major injuries (fractures, subdural hematomas), and moderate injuries (sutures, steri-strips, muscle strain). The middle line represents falls with serious injury plus falls with minor injuries, such as a bruise or abrasion or pain requiring a limb to be elevated.

As shown in Figure 7, falls with injury (FWI) and falls with serious injury (FWSI) trends improved the first 6 months after the RIE. Then a rise in rates occurred in February 2012 during training for the new fall risk assessment that was incorporated into the electronic medical record. Other peaks were seen in April and July. While increased rates in the summer could be explained by new physician and nursing staff, the peak in April is puzzling. The increase in falls

in April 2012 shows how much one or two falls with serious injury can impact the trend since it is typically such a rare occurrence. One of the falls in April that resulted in death occurred with a patient that was terminally ill and had numerous co-morbidities before the fall. Another fall in July occurred caused by the patient's fatal heart attack and subsequent fall. There was also a large staff and executive turnover with all management (Clinical Nurse Manager and Lead Charge Nurses) gone by end of 2012. By fall of 2012, one division only had one original team member remaining (the Advanced Practice Nurse).

As with any applied research, the issue of confounding impact from different interventions is a concern with this project. It is difficult to pull out the impact of one specific factor when interventions are implemented at different times and so many variables are uncontrolled. Outside contributing factors that we observed during our project included management changes, staff turnover, new fall risk assessment dictated by the hospital system, construction projects, new staff arrivals and mentor training, executive leadership changes bringing new direction and focus. However iterative improvement changes will continue to be made to strive for improved fall rates. If falls are not a priority, prevention opportunities will be missed. Staff will not make falls a priority unless management demonstrates the importance (Weinberg et al., 2011).

Sustainment

Fall prevention issues were integrated into existing leadership frameworks to modify interventions as needed and sustain success. For example, progress and results were discussed as a regular agenda item at oncology leadership and unit staff meetings. These meetings provided a forum for discussing issues and providing answers to questions. Progress was shared during Executive Out-briefs. Guidance was provided during 1:1 meetings between the oncology director and Advanced Practice Nurses. The joint Unit Practice Committee (UPC) met bimonthly to discuss implementation of the processes. Adjustments were made as needed during "reunion" meetings that were held monthly to identify barriers and revise interventions. Original team members from the RIE were invited to attend the reunion meetings to achieve coherence and sustainability. Each reunion meeting had to be scheduled 4 weeks prior to the meeting to ensure all members could attend.

The Advanced Practice Nurses wrote articles for practice updates and newsletters, sharing case studies and best practices related to fall prevention. Various posters and bulletin boards are maintained for staff, patients and families. The Practice Specialist brought fall prevention findings and results to monthly Fall Team meetings, and as needed to the Clinical Practice Council and Patient Care Leadership.

In addition to the Fall Tracker board, reports were accessible from the EMRs, providing the Advanced Practice Nurses and unit leadership with a real-time display of fall risk assessment and intervention documentation for each patient. The Advanced Practice Nurse and Unit Management ownership of the project is critical to sustaining the momentum.

Based on the heightened engagement that was experienced during and after the RIE, one of the divisions was selected to participate in a collaborative project with the Joint Commission's Center for Transforming Healthcare (CTH). This Lean Six Sigma project began in January 2012, and was completed in February 2013. The next phase of process improvement began in February 2013: a Six Sigma method to develop a Patient Partnering intervention. The interventions from the Rapid Improvement Event continue to present day.

Conclusions

Falls are a multifaceted, complex problem that needs constant vigilance and continuous improvement to sustain patient safety. Any patient's risk for fall is subject to change at any time. Anticipating this risk is part of the puzzle. Anticipating physiologic changes in a patient's condition and implementing interventions is critical to fall prevention. Throughout the hospital stay, a patient often experiences information overload, nevertheless communication with patients every shift by all staff members is critical. The importance of fall prevention cannot be over emphasized. Patients often view falling down as a sign of disability or clumsiness, therefore they often don't want to accept the fact that they are at risk and may not cooperate or agree to the interventions needed to mitigate their risk. Each patient is unique with different life experiences and beliefs. This requires an individualized approach to keeping them safe from harm. While well-validated screening tools performed thoroughly and accurately can help hospital staff identify patient-specific fall risk factors, risk assessment alone does not prevent falls. Effective interventions must be tailored to each patient's specific risk factors and implemented proactively, including the patient and the patient's family as active partners in the patient's care. If the prevention of patient falls is identified as important by leadership and staff at the division level and all are invested in achieving established goals, success can be achieved and sustained.

Falls are a multifaceted, complex problem that needs constant vigilance and continuous improvement to sustain patient safety.

Implications for Practice

- The Lean methodology used in a Rapid Improvement Event format achieved a suitable pace of change for this project. The event was done in 3 days with 1 month of action items and team training before the intervention could go live. The drawback to this methodology is that it may not address the entire root of the problem.
- Although the standard work for assessing patients and developing interventions for patient fall prevention was an improvement in total falls and falls with minor injuries, falls still occurred that resulted in moderate and major injuries. Continuous improvement is needed.
- Short-term improvements that are continually revised are easier to manage in a fast-paced, ever-changing environment.

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Environmental Design in Acute Care Settings: A Case Study of a Neurological Rehabilitation Unit

Lindsay J. McCunn, MSc, and Robert Gifford, PhD

ABSTRACT

OBJECTIVE: The purpose of this case study was to examine environmental variables that lead to staff error in acute care settings: noise; lighting; ergonomics, furniture, and equipment; and patient room design and unit layout.

BACKGROUND: Chaudhury, Mahmood, and Valente (2009) reviewed a number of design considerations related to reducing errors by nursing staff in acute care settings. The Neurological Rehabilitation Unit (NRU) at one hospital served to further examine the design recommendations outlined by Chaudhury et al. (2009).

METHODS: Based on photographs, a site tour, interviews with the NRU manager and with the son of a patient of 5 months, comparisons were made between the NRU and the acute care setting design considerations reviewed by Chaudhury et al. (2009).

RESULTS: The NRU appeared to comply with many recommendations: enforced noise reduction was facilitated through limiting both the number of patients per room and the number of patients admitted to the unit. Distinct rooms were used for various tasks that helped to contain activity-based noise. A combination of daylighting and artificial lighting was in place, but efforts to control glare and thermal comfort were not integrated into the design. The ergonomic needs of employees were incorporated in the design of the NRU, and the layouts of patient rooms and the layout of the NRU in general also were compatible with the design recommendations reviewed by Chaudhury et al. (2009).

CONCLUSIONS: Many of the design attributes advocated by Chaudhury et al. (2009) were included in the NRU. Supplemental research should be undertaken, however, to objectively measure nursing error, efficiency, and staff satisfaction with respect to the comparisons and assumptions presented in this study.

KEYWORDS: Case study, evidence-based design, hospital, lighting, noise, satisfaction

AUTHOR AFFILIATIONS: Lindsay J. McCunn, MSc, is a PhD Candidate, and Robert Gifford is a Professor, both in the Psychology Department of the University of Victoria in Victoria, British Columbia, Canada.

CORRESPONDING AUTHOR: Lindsay McCunn, Department of Psychology, University of Victoria, P.O. Box 3050 STN CSC, Victoria, BC V8W 3P5; lindsayjmccunn@gmail.com; (250) 893-0603.

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The physical environment of any workplace can influence how employees think, feel, and behave. However, flaws in design can strongly affect the attitudes and behaviors of those who work in healthcare settings. Certainly, the way in which the physical environment is organized in hospitals can impact decisions, reaction times, and the emotional well-being of medical professionals and patients (Rollins, 2004; Simmons, 2003; Spreckelmeyer, 2004). Therefore, research to develop optimal design models for hospitals and other healthcare settings is important.

A recent review summarized the effects of environmental design on nursing error and efficiency in acute care settings (Chaudhury, Mahmood, & Valente, 2009). It outlined four design attributes that the authors believe contribute most to employee error:

- Noise
- Lighting
- Ergonomics/furniture/equipment
- Patient room design and unit layout

The investigation discussed in this case study article examined the role of these attributes in one hospital's acute care unit.

The 20-bed Neurological Rehabilitation Unit (NRU) serves adult patients (17 years or older) who have suffered a stroke, head injury, or other neurological affliction. After being assigned to the NRU, patients work with a rehabilitation team to optimize their recovery for a safe and timely discharge (Vancouver Island Health Authority, 2010).

Comparisons between design attributes of the NRU and those oulined in the Chaudhury et al. (2009) review were based on two data collection methods: a guided tour of the unit, and interviews with the NRU manager and with the son of a patient with 5 months of daily experience in the setting. The tour allowed the researcher to observe the design of the unit in the attendance of a staff member with access to all areas in the NRU. Interviews also afforded the researcher informal accounts of the NRU's functionality from the perspective of both a staff member and a visitor.

How the NRU Works

Like other rehabilitation units, the NRU serves patients who suffer from single-incident neurological events, such as a head injury, stroke, subarachnoid hemorrhage, or other form of diffuse brain damage. Those who are permanently vegetative or minimally aware are typically not admitted to the NRU, and patients with tracheotomies are only admitted under exceptional circumstances (Victoria General Hospital, 2010).

The function of the NRU is to provide comprehensive, interdisciplinary rehabilitation services to patients and their families. The goal for patients is to reach

a level of independence that will enable a return to their community. To accomplish this, the unit offers a combination of rehabilitation techniques, physiotherapy, occupational therapy, speech and language pathology, social work, nutrition, and neuropsychology (Vancouver Island Health Authority, 2009).

Although certain physical and cognitive requirements for entry into a rehabilitation program must be met (e.g., stable vital signs, ability to understand and carry out instructions), the NRU also sets out rehabilitation-potential criteria, including a willingness to learn and improve (Victoria General Hospital, 2010). Once admitted, patients are expected to be alert for daily group therapy sessions and dressed for meals in the NRU dining room (Victoria General Hospital, 2010). Much emphasis is placed on practicing familiar activities (e.g., doing laundry, using a day-pass to shop at a nearby grocery store). After a regime of speech and physical therapy, and regular memory rehabilitation using computers and flashcards, patients must successfully cook a meal in the NRU kitchen in order to be discharged.

The NRU Renovation

In 2005, the fifth floor of the hospital was redesigned for the express use of the NRU. Before the renovation took place, consultations occurred between the architect and NRU employees. During an informal interview, the manager of the NRU noted that employees found the input process to be very positive and successful.

The basic structure of the floor space was not altered during the renovation (i.e., plumbing placement was not changed and walls were not moved). However, an electrician with experience working in hospitals designed lighting and electrical elements specific to the needs of the unit. In addition, an interior designer chose paint colors and other materials intended to be calming for both staff and patients.

Because the original structure of the floor was not altered, and because it had several walls on acute angles, wayfinding strategies were integrated into the unit. Distinct paint colors for different departments were chosen for hallway walls and doorframes. For example, taupe walls denote treatment space and blue walls signify patient rooms and leisure areas. Doorframe colors let patients and staff members know what was occurring in each room (e.g., yellow for physiotherapy, orange for attention process training, green for speech therapy, etc.). A listing of the colors and corresponding functions is posted near the nursing station, and is included in an orientation binder given to every patient upon arrival. This strategy not only helps with wayfinding, but also diminishes employee stress by reducing the number of direction-related questions and interruptions.

Design Attributes of the NRU

A number of design variables can help or hinder the health, safety, and job performance of staff members in a healthcare facility. This section examines the

influence of noise; lighting; and ergonomics, furniture, and equipment, as well as patient room design and unit layout on hospital employees.

Noise

Sounds can interfere with a variety of activities in any environment. They can increase stress (Donnerstein & Wilson, 1976) and decrease concentration (Cohen et al., 1991; Glass & Singer, 1972; Smith, 1989). Chaudhury et al. (2009) pointed out that although most research on noise in healthcare settings is carried out from the patient's perspective, telephone sounds, voices, moving gurneys, and paging systems can also have unproductive affects on hospital staff (Ulrich et al., 2004). Noise can also reduce the ability of staff members to communicate and concentrate during surgery (Hodge & Thompson, 1990), and the effects of high noise levels can include stress and burnout (Topf & Dillon, 1988). Such outcomes can be exacerbated when noise levels in hospitals exceed guidelines recommended by the World Health Organization (Blomkvist et al., 2005).

Chaudhury et al. (2009) suggested that sound-attenuating surfaces, such as ceiling tiles, may help combat noise in hospital settings. When traditional lightweight ceiling tiles (usually used in suspended ceilings made from wood or mineral fibers) in patient rooms are replaced with sound-absorbing tiles, patients sleep better, report lower levels of stress, and report that they receive better care from nursing staff (Blomkvist et al., 2005). However, traditional ceiling tiles and conventional laminate flooring (durable, inexpensive flooring made with a backing layer, a print layer, and a laminate wear layer on top) are present in this NRU.

Photographs (see Figures 1–8) show that the layout of the NRU is not open-plan. The various therapeutic areas are separate from each other, and some rooms have doors for further enclosure. For example, patient rooms are some distance away from the occupational therapy room, which is also separate from the dining room and kitchen. Thus, sound from activities taking place in each room is not likely to carry into other areas. This is optimal for nurses' well-being at work and for patients' privacy concerns. Figures 1 and 2 illustrate the separation between rooms in the unit.

Figure 3 shows a wide hallway linking the different areas within the NRU. Noise caused by traffic and discussions in this hallway is likely to penetrate into other areas of the unit. Although Chaudhury et al. (2009) noted that installing carpet in hallways can minimize noise (Neumann & Ruga, 1995), carpeting is not a design feature used anywhere in the NRU.

In their review, Chaudhury et al. (2009) found that reducing the number of beds per room also reduces noise levels (Hilton, 1985; Joseph & Ulrich, 2007; Ulrich et al., 2004). Accomplishing this is not always possible, given the demand for beds versus the supply of space. However, acute care units often restrict the number of patients receiving treatment in the ward at one time. According to the NRU manager, the unit limits enrollment to 20 patients (and two extra patients if necessary) at a given time, and can accommodate up to three patients per room. Compared to other units in the hospital that permit four to six patients

Figure 1. Room N518, Exercise room—note color denotation of room separation.

Figure 2. Room N517, Occupational Therapy—note color denotation of room separation.

per room, each with audible monitoring equipment and the potential for visitors and discussions with staff, the small number of beds in the NRU probably decreases excessive noise within the unit.

The only observable design element for reducing noise in the NRU is the Quiet Treatment room (used by one patient at a time, when one becomes over stimulated and needs a calm, private environment). Nevertheless, the design of the NRU appears to mitigate noise, although whether this was an intentional aspect of the unit's design or not is unclear. The lack of noise-related complaints, according to the NRU manager, is likely attributable to the combination of the layout (distinct rooms for specific tasks) and the small number of beds per room. This inference is supported by the account of the son of a NRU patient, who stated that noise was not a concern for his mother or for himself as a frequent visitor.

Lighting

Illumination affects the health, safety, and job performance of employees who work in hospital settings. Chaudhury et al. (2009) noted that as exposure to daylight increases, nurses are less likely to experience stress and dissatisfaction with their jobs (Alimoglu & Donmez, 2005), and, in contrast, artificial light can contribute to decreased energy levels for nurses and lead to less effective functioning

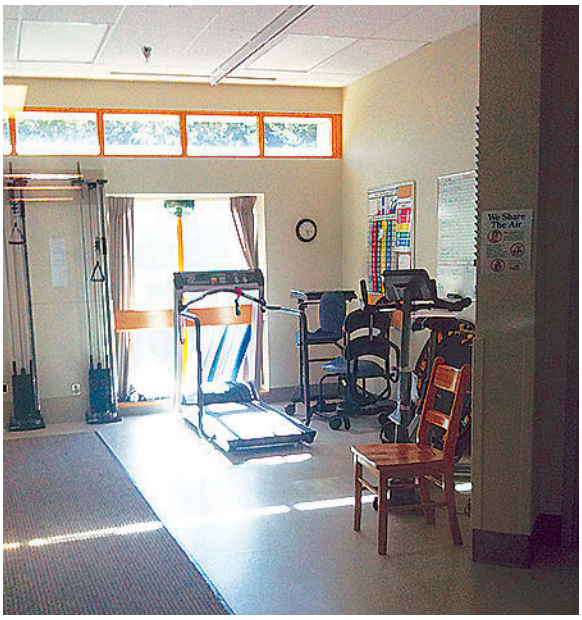
(Scott, 2004). However, it is difficult to implement an optimal combination of artificial light sources and daylighting in an environment that requires various tasks to be performed with a high degree of accuracy.

With respect to daylighting, although none of the windows in the NRU span from floor to ceiling, most are large enough for patients to see the outdoors while in bed or receiving therapy. All of the rooms along the exterior wall of the hospital building have small- to medium-sized windows. These rooms also have a row of small rectangular windows that line the top of one wall (e.g., patient rooms, the exercise room, and the kitchen/dining room—see Figures 4 and 5). Rooms with this high window arrangement that do not have other windows are equipped with more task lighting. Some rooms with this type of window structure have larger windows built into the same wall. The kitchen/dining room is an example of this type of lighting arrangement. In it, tables are situated near the larger windows to afford a view of the outdoors. However, a wooden beam is placed across these windows to signify that outdoor access is not possible. It can also serve as a safety feature, similar to a handrail. This window arrangement is common to all areas of the hospital; it is not specific to the NRU.

Figure 3. Main hallway, illustrating unit layout and distance between rooms.

Figure 4. Dining room and kitchen—note window structure.

Figure 5. Exercise room—note the window structure.



The recreation room is another example of an area in the NRU with a high row of windows near the ceiling and larger windows in the same wall (see Figures 6 and 7). This room, like the kitchen/dining room, has hanging bar light fixtures spaced evenly along the ceiling. The entire NRU uses this type of indirect, artificial lighting.

Chaudhury et al. (2009) suggested that glare-reducing surfaces should be used. The NRU has not applied glare-reducing window film, shades, tinting, or installed solar shading to permit the maximum amount of daylight into each room without the annoyance of glare or excess heat. However, larger windows have curtains for controlling the amount of light coming into the room (and any subsequent glare). The windows along the ceiling perimeter probably do not produce much glare or excess heat, given their smaller, rectangular size and height (neither variable was noted during the walk-through of the unit). This is because high windows distribute light more evenly, control for thermal load, and allow light to penetrate large buildings (Binggeli, 2010).

As is common in many hospital wards, wall-mounted fluorescent light fixtures are above each patient bed to assist nurses with medication administration and

Figure 6. Recreation room—example of window structure.

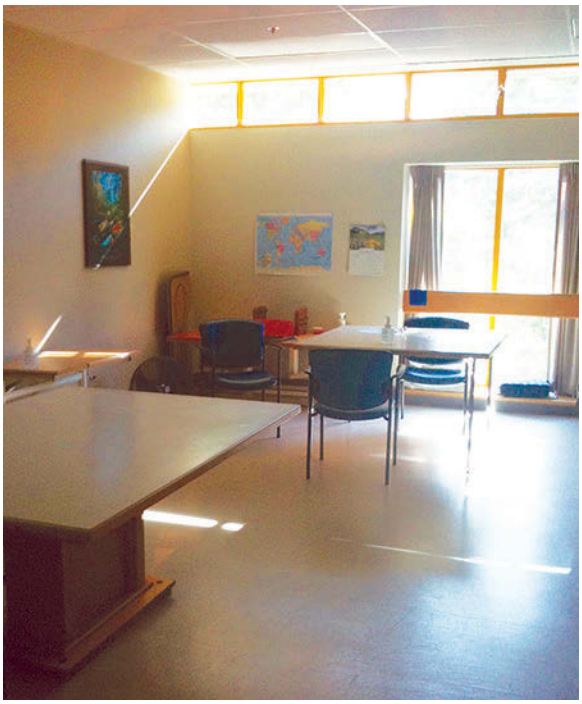


Figure 7. Recreation room—example of window structure.

instrument reading. Figure 8 illustrates how the wall-mounted lighting fixtures allow patients to turn the bottom portion on or off at their convenience (a pull-chain hangs down near the head of the bed). The top portion of the lighting fixture is controlled by nursing staff via a main switch that also controls the ceiling fixtures. Thus, patients have some degree of control over their lighting. Also, during night hours, overhead fixtures are turned off and decorative wall sconces in hallways are dimmed to signify a time for rest.

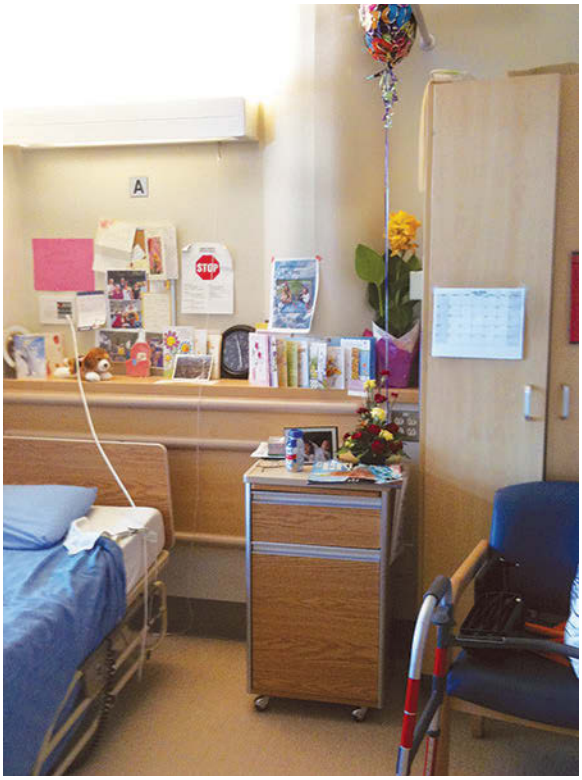
As noted by Chaudhury et al. (2009), the average age of nurses is increasing. Thus, bright illumination levels at workstations (ranging from 1500 to 2000 lux) are becoming more necessary for error reduction and employee comfort (Ulrich & Barach, 2006). Appropriate task lighting has been made available at the central nursing station via three lamps hanging over the workspace, and light fixtures have been installed under the cupboards in the charting room. Although these fixtures likely help to reduce nurse errors, none have especially high illumination levels.

Ergonomics, Furniture, and Equipment

The goals of ergonomic design are to enhance interactions between individuals and the physical elements of the workplace, and to optimize the health and productivity of people at work (Dul & Weerdmeester, 2008). Thus, ergonomic design is an important consideration when creating functional working conditions for employees in any environment. Healthcare settings often adopt ergonomic design principles to improve employee absenteeism and prevent long-term disability caused by repetitive physical stressors and lengthy time periods spent standing. In hospitals, poor ergonomics can result in nursing errors and higher absenteeism (Janowitz et al., 2006).

With respect to nurses' immediate work environments, Chaudhury et al. (2009) stated that nursing stations ought to be ergonomically designed to meet the job requirements of employees (e.g., significant amounts of standing time). Sufficient space should be provided for nurses' feet to enable movement close to counters at nursing stations (Kroemer & Kroemer, 2001). In addition, Chaudhury et al. asserted that in order to enhance working environments for nurses and other hospital employees, ergonomic nursing stations and patient rooms equipped with mechanical (i.e., easily moveable and height adjustable) furniture and equipment should be standard in acute care settings. This would, for example, allow a patient to remain in bed for an x-ray, rather than requring transfer to a different table (Chaudhury et al., 2009)

Figure 8. Patient room—denotation of patient controllability of overhead lighting.



The ergonomic needs of employees have been accounted for in the design of the NRU. The central nursing station has a sufficient number of seats for several staff to sit down and write, talk on the telephone, or work at the computer between rounds. All chairs in the unit are of ergonomic design, following the hospital's recent mandate to reduce physical stress on staff (e.g., all chairs are adjustable in height, and offer lumbar support).

Chaudhury et al. (2009) pointed out that to minimize the need for physical strength of employees, mechanized devices ought to be used, such as beds that do not require patients to be moved for various procedures. The NRU does not use beds that are appropriate for different procedures (e.g., x-rays); however, ceiling lifts with waist belts to assist employees with moving individuals in and out of bed are installed in some patient rooms (not all patient rooms have ceiling lifts because part of the NRU's purpose is to ensure patients become able to enter and exit their beds without mechanical assistance).

Patient Room Design and Unit Layout

Chaudhury et al. (2009) stated that patient room design and acute care unit layout ought to be convenient and accessible to both patients and staff. With respect to patient room design, single-occupancy rooms have been associated with better communication among staff, fewer medication errors, and decreased infection rates (Chaudhury et al., 2009).

The layout of patient rooms in the NRU is standardized in terms of where beds, cabinets, chairs, and privacy curtains are stationed. Thus, nurses who move from room to room are not at a disadvantage with respect to efficiency. The layout of the patient rooms is standardized in part because of the wall-mounted computer fixtures between beds and the size of the rooms.

In addition, Chaudhury et al. (2009) noted the positive role en suite bathrooms play in a successful acute care unit (focus group participants stated that close proximity between bathroom and bed is optimal for reasons of comfort and safety). Patient rooms in the NRU are equipped with en suite bathrooms in close proximity to beds. Each room also affords seating for visitors, controllability of privacy by way of curtains separating each bed, and controllability of temperature by way of access to extra blankets or an electric fan upon verbal request.

The NRU utilizes two supply rooms and one centralized medication room. Members of the focus groups in the review by Chaudhury et al. (2009) stated that decentralized supply rooms are more efficient than a single supply storage area. Another important aspect of the layout of an acute care unit is clear lines of sight between nursing stations and patient rooms. This design goal is difficult to execute in units with several types of rooms, like the NRU. The NRU affords limited visibility of patients by staff because the central nurses' station has sight lines to only a few patient rooms, not to all beds or patients.

Patient rooms in the NRU are also designed to enable patients to receive numerous forms of acute care in one room, regardless of acuity level. Acuity-adaptable

rooms accommodate patients and family members, as well as nurses and staff, by providing ease of use and increased storage for equipment (Chaudhury et al., 2009). Fewer medication errors, patient falls, and procedural errors, as well as shorter lengths of stay, all occur in acuity-adaptable rooms (Hill-Rom, 2002). The combination of acuity-adaptable rooms and decentralized nursing stations has resulted in improved operational and cost efficiency, and satisfaction for patients and staff (Hendrich, Fay, & Sorrells, 2004). Future studies of the NRU should measure whether the unit's combination of a centralized nursing station and acuity-adaptable rooms have a similar positive influence on employee satisfaction levels and procedural errors.

Conclusion

This case study was based on the review by Chaudhury et al. (2009) of the physical aspects of acute care settings that can lead to reductions in nursing staff error. Evidence suggests that nursing staff efficiency and engagement can suffer from common workplace stressors such as distractions due to noise, artificial lighting, poor ergonomics, and disorienting layouts. The NRU at the hospital serves as an appropriate setting for examining the design goals concerning noise, lighting, ergonomics, and unit layout presented in Chaudhury et al. (2009).

Based on a site tour and photographs of the unit, an interview with the NRU manager, and the account of the son of a patient of 5 months, informative comparisons were made between the NRU's design and the acute care setting design guidelines outlined by Chaudhury et al. (2009). In terms of noise, no formal (i.e., structural) attempts to reduce excess sound have been integrated into the design of the NRU. However, the layout of the unit and the limitation on the number of beds per room provide natural barriers to noise. The NRU uses a combination of artificial and natural light in each room, along with task lighting at the nursing station and in the charting room. In addition, the unit uses specialized seats at the nursing station and affords adequate foot space for nurses to comfortably stand at the station for lengthy periods. Ceiling lifts in some patient rooms also decrease physical requirements for nurses. Finally, all patient rooms have a standard layout. The NRU's centralized nursing station, decentralized supply rooms, and acuity-adaptable patient rooms creates a satisfactory working environment for staff.

The NRU includes many of the design attributes advocated by Chaudhury et al. (2009). However, supplemental research should be undertaken to objectively measure nursing error, efficiency, and staff satisfaction with respect to the comparisons and assumptions presented in this study.

Implications for Practice

- No formal attempts to attenuate excess sound were integrated into the NRU's design. However, the layout of the unit and the limitation on the number of beds per room provided natural barriers to noise.

- The NRU used a combination of artificial and natural light in each room, along with task lighting at the nursing station and in the charting room.
- The unit accounted for ergonomics by using specialized seats at the nursing station and afforded adequate foot space for nurses to comfortably stand at the station for lengthy periods. Ceiling lifts in some patient rooms also decreased physical requirements for nurses.
- All patient rooms had a standard layout. The NRU's centralized nursing station, decentralized supply rooms, and acuity-adaptable patient rooms created an apparently satisfactory working environment for staff.

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CASE STUDY FALL 2013 • VOL. 7 NO. 1, pp. 114–123

Risk Assessment as Standard Work in Design

Patricia W. Morrill, PMP, EDAC

ABSTRACT

OBJECTIVE: This case study article examines a formal risk assessment as part of the decision making process for design solutions in high risk areas. The overview of the Failure Modes and Effects Analysis (FMEA) tool with examples of its application in hospital building projects will demonstrate the benefit of those structured conversations.

BACKGROUND: This article illustrates how two hospitals used FMEA when integrating operational processes with building projects: (1) adjacency decision for Intensive Care Unit (ICU); and (2) distance concern for handling of specimens from Surgery to Lab.

METHODS: Both case studies involved interviews that exposed facility solution concerns. Just-in-time studies using the FMEA followed the same risk assessment process with the same workshop facilitator involving structured conversations in analyzing risks.

RESULTS: In both cases, participants uncovered key areas of risk enabling them to take the necessary next steps. While the focus of this article is not the actual design solution, it is apparent that the risk assessment brought clarity to the situations resulting in prompt decision making about facility solutions.

CONCLUSIONS: Hospitals are inherently risky environments; therefore, use of the formal risk assessment process, FMEA, is an opportunity for design professionals to apply more rigor to design decision making when facility solutions impact operations in high risk areas.

KEYWORDS: Case study, decision making, hospital, infection control, strategy, work environment

AUTHOR AFFILIATIONS: Patricia W. Morrill is the President of PM Healthcare Consulting, LLC, in Caledonia, Wisconsin.

CORRESPONDING AUTHOR: Patricia W. Morrill, President of PM Healthcare Consulting, LLC, P.O. Box 287, Caledonia, WI 53108; pmorrill@pmhcconsulting.com; (262) 639-6700.

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Healthcare environments are ironically and yet inherently laden with risk. Staff must be diligent in disposing of needles, solutions and biohazardous waste in appropriate receptacles. The high rate of hospital-acquired infections (HAIs) has increased the exposure of patients and healthcare staff to noxious cleaning solutions and chemically treated surfaces. These are well-known, day-to-day potential hazards that patients and staff encounter. Healthcare facility designers must stay abreast of new products on the market to alleviate the spread of infection from surface materials. This article examines the benefits of addressing potential physical environment risks as standard work in design projects.

Standard work is defined as a step-by-step description of the actions and tools needed to complete a task (Touissant & Gerard, 2010). For the purposes of this article, "task" involves the facility planning process. Standard work is established through analysis, observation, and employee involvement. Employees are involved because the people closest to the work understand it best (Manos & Vincent, 2012). As we strive to improve healthcare delivery processes, we can simultaneously seek better facility solutions that support safer environments. By incorporating risk assessment as standard work, design professionals can increase rigor of informed design and decision making.

By incorporating risk assessment as standard work, design professionals can increase rigor of informed design and decision making.

Background

This case study article describes two examples of how risk assessments have been used in hospital design projects. Hospital A is a replacement critical access hospital with a total capacity of 25 beds accommodating medical/surgical, critical care, and obstetric patients. Hospital B is a rural integrated hospital and clinic with a phased replacement project with 50 beds.

In early 2000—at the urging of The Joint Commission—hospitals started using the Failure Mode and Effects Analysis (FMEA) to analyze medication errors. FMEA is a model used to prioritize potential defects based on their severity, expected frequency, and likelihood of detection (MoreSteam.com, 2013), with broad potential for application, including in design. John Reiling, past CEO of St. Joseph's Hospital in West Bend, Wisconsin, that opened in 2005, authored several articles about the design process used to focus on safety. The use of failure mode and effects analysis, patient focus groups, mock-ups with employee evaluation, and checklist safety design principles (latent conditions and active failures) helped St. Joseph's create the safest room they could envision (Reiling, Hughes & Murphy, 2008).

Begun in the 1940s by the U.S. military, FMEA was further refined by the aerospace and automotive industries. The purpose of the FMEA is to take actions to eliminate or reduce failures (American Society for Quality, 2013a). Failures in healthcare have become increasingly transparent via website reporting of infections and satisfaction comparison ratings. Healthcare reform has exposed the high incidence and unacceptable cost of preventable infections and injuries. Six

Sigma training includes FMEA as part of the *"Define" and "Improve"* phases (MoreSteam.com, 2013) of the DMAIC methodology:

- *Define* a problem or improvement opportunity;
- *Measure* process performance;
- *Analyze* the process to determine the root causes of poor performance;
- *Improve* the process by attacking root causes; and
- *Control* the improved process to hold the gains (American Society for Quality, 2013b).

With the continued high rate of harm in hospitals, design professionals must be alert to assessing risk potential in their design projects. The case studies presented here offer two examples of two questions raised: one during design, and one during occupancy planning, which should have been addressed during design. This article does not advocate one solution for each question, but rather promotes the risk assessment process to expose the best design decision for high risk areas.

Method

For Hospital A, the author conducted a current state workflow assessment at the start of pre-design that involved individual interviews and observation. Opportunities for improvement were documented and prioritized based on workflow issues with a space impact. The location of the intensive care unit was identified as a top priority. With differing opinions about the location of this high risk patient care area, the author recommended the FMEA process.

For Hospital B, during the occupancy planning phase, the author conducted Lean A3 problem solving training, then individual interviews with hospital leadership to assess their problem-solving process. The lab leadership interviews identified a workflow challenge created by design decisions that needed resolution prior to occupancy. The problem concerned the high risk handling of frozen specimens and the author recommended the FMEA process.

The FMEA process was recommended in both cases because of the time constraints related to the building projects. The intent of the just-in-time study with the FMEA tool was to influence decision making; the research involved the investigation of whether the FMEA process did benefit facility decisions. The process involved the following steps in a workshop setting facilitated by the author, a trained quality professional in Lean and Six Sigma, serving in a consultant role:

1. An interdisciplinary team was assembled, representing content expertise, executive leadership for prompt decision making, and at least one individual not familiar with the process who could ask probing questions.
2. The team was provided with just-in-time training about the FMEA tool with a healthcare example.
3. A high-level flow diagram of the process being analyzed was developed.
4. From the flow diagram, a process step was selected as a priority for the risk assessment.

5. Using the FMEA tool, the team:
    - Discussed potential failures involved in the process step.
    - Identified the *effects* of each failure.
    - Scored the level of *severity* (on a scale of 1–10 with a definition of each level).
    - Identified the potential *causes* of the failure.
    - Scored the *likelihood* that each cause might occur (1–10).
    - Identified the *controls* in place for the failure.
    - Scored the probability that the controls would *detect* each cause (1–10).
    - Multiplied each of the scores for the *risk priority number* (RPN), therefore: severity × occurrence × detection = RPN.
    - Finally, documented the *recommended actions.*

Hospital A—Critical Access Hospital

Design question: Should the two-bed intensive care unit (ICU) be located adjacent to the emergency department (ED) or the medical/surgical (med/surg) inpatient unit? This question often arises in small hospitals that need to cross-train nursing staff to flex between units based on census.

A pre-design workflow and facility assessment of the existing hospital condition identified risks with the isolated location of ICU being staffed with only one or two nurses who needed to focus on patient care while also needing to retrieve supplies and equipment stored away from the ICU rooms. To provide a safer environment, hospital officials wanted ICU to be immediately adjacent to either the emergency department or the med/surg unit for improved access to other nursing staff, supplies, and equipment.

Results—Hospital A

Design question: Should the two-bed intensive care unit be located adjacent to the emergency department or the medical/surgical inpatient unit?

After identifying the various support needs of ICU during the high-level flow discussion in the FMEA workshop (see Figure 1), participants agreed that the lack of proximity of supplies, equipment, and medications to nurses was the risk to analyze. The discussion identified the potentially serious implications of distant supplies, equipment, and medications as documented in the FMEA tool (see Table 1). Given the unacceptable cost of duplicating equipment, the adjacencies to ICU were essential in reducing risk. From this analysis, the decision was made to locate the ICU adjacent to Med/Surg based on (1) more similar care; (2) hospitalist overlap; (3) ICU nursing's ability to provide expertise to Med/Surg; (4) shared supplies; (5) shared meds; and (6) shared technology. The FMEA benefit realized in this case was the clear depiction of commonalities between ICU and med/surg, leaving no doubt in decision making. This hospital is under construction at the time of this writing.

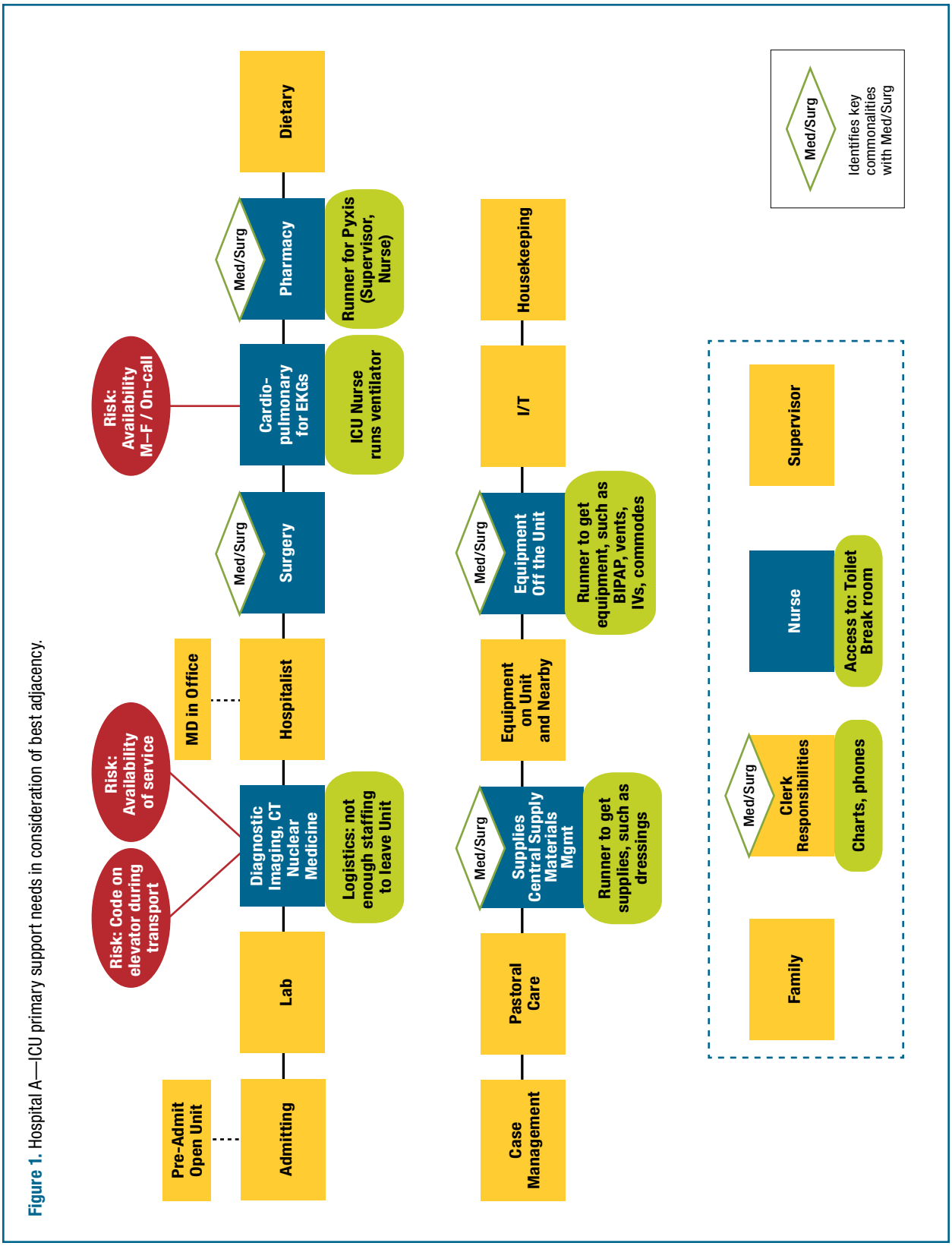

Figure 1. Hospital A—ICU primary support needs in consideration of best adjacency.

Hospital B—Rural Integrated Hospital and Clinic

Occupancy Planning Question: How can frozen specimens be transported safely and quickly from operating rooms (ORs) in a new building to the lab remaining in an attached facility? (See Figure 2.) During Lean A3 Problem Solving training sessions, this question was raised and the lab leadership agreed to hold an FMEA workshop because of the risks involved in handling frozen specimens. This question, as is the one for Hospital A, is frequently discussed during design when faced with the options of a STAT lab near surgery or a distance dilemma when timing is of the essence, as in this case, with a patient remaining in the operating room until pathology results are known. For this particular hospital project, it was decided late in design to remove the STAT lab (due to staffing and cost issues), though the operational impact was not addressed until occupancy planning was underway.

Occupancy planning question: How can frozen specimens be transported safely and quickly from operating rooms in a new building to the lab remaining in an attached facility?

Results—Hospital B

The FMEA workshop participants discussed the risks involved when pathology is not alerted to a STAT specimen from the OR, whether the specimen transport occurs via pneumatic tube or walked by courier as documented in the FMEA tool (see Table 2). The pneumatic tube usage for specimens from the OR was a new process for this hospital to plan for with

Figure 2. Hospital B—Distance concern for specimen transport from surgery to lab.

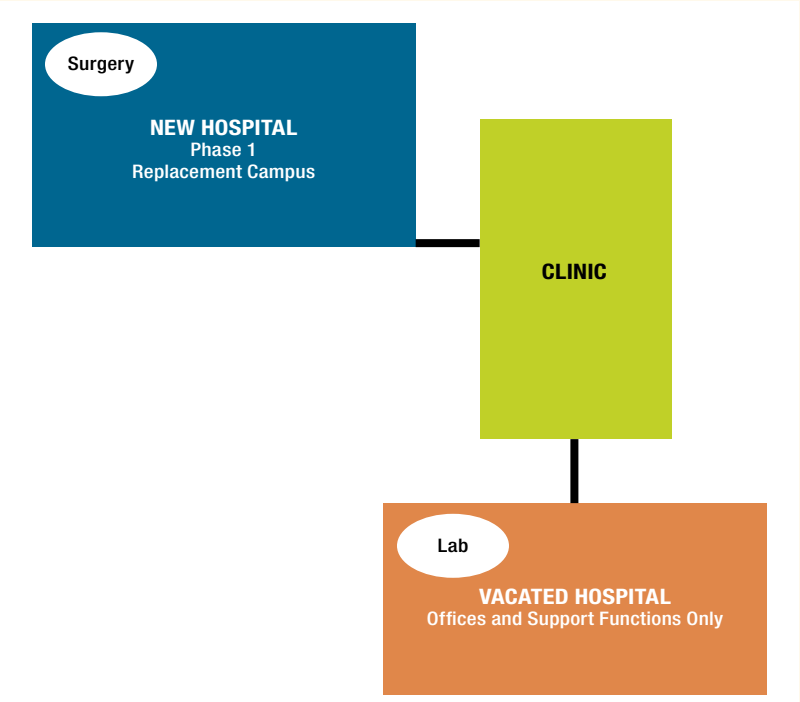

Table 1. Failure Modes and Effects Analysis (FMEA).

ITEM: **Location of an Intensive Care Unit (ICU) in a Critical Access Hospital**
LEAD: Lean Six Sigma Consultant
CORE TEAM: Team: Administration, Nursing, Facilities, Architect

Process Step:	Identify systems and functions
Potential Failure Mode:	What are the potential failure modes that could occur in this function?
Potential Effect(s) of Failure:	What are potential effects of each failure mode?
Severity:	Severity of effects
Potential Cause(s) / Mechanism(s) of Failure:	What are the potential causes of the failure mode?
Occurrence:	Likelihood of each cause
Current Controls:	List controls for each failure mode
Detection:	Probability of detecting each cause with controls
R. P. N.:	Risk Priority Number S x O x D

Process Step: **Bringing resources to the ICU, especially supplies, equipment, medications.**

		Potential Effect(s) of Failure	Severity	Potential Cause(s) / Mechanism(s) of Failure	Occurrence	Current Controls	Detection	R. P. N.
Potential Failure Mode:	➤ IVs not on site	Life/death: med, supply, equipment	10	Space constraints	10	Par levels, centralized stock	1	100
	➤ No one available to help be a runner	Quality of care	9	Financial constraints (duplication of equipment, par levels)	10			
	➤ Don't have what's needed	Delay in care	8					
	➤ Insufficient storage	Staff satisfaction	6	Asset management	9	Hospital formulary for each Pyxis	6	
	➤ Don't want to duplicate	Patient/family satisfaction (staff running around)	6	Information management	9			
	➤ In use elsewhere (not enough due to cost)			Labor	9	Supervisors	4	
	➤ Can't locate what's needed							
	➤ Par level out so no one to restock							
	➤ Meds not on premises							
	➤ No bariatric furniture							

RECOMMENDED ACTION(S): ICU adjacency to med/surg based on (1) more similar care; (2) hospitalist overlap; (3) ICU can provide expertise to med/surg; (4) shared supplies; (5) shared meds; (6) shared technology.

the surgery department opening in a more distant location. The group realized they needed (1) more information from the pneumatic tube vendor about STAT alerts, and (2) to work with OR staff about calling to notify pathology of the OR specimen. This FMEA workshop occurred 5 months prior to occupancy.

The Lab Director of Hospital B (who had participated in the FMEA workshop) was interviewed 1 year post-occupancy and shared that:

> All frozens are successfully tubed from the OR. It was a "change" that the surgeons had to get comfortable with and have confidence in the pneumatic tube. Initially, some continued to walk the specimens over, but that ended very quickly. The team took each type of specimen, met with the areas that would be sending that type of specimen, determined the best flow, and created a chart as a guide for how to package and how to transport. It is attached to the pneumatic tube policy.

Table 2. Hospital B—Failure Modes and Effects Analysis (FMEA).

ITEM:	**Frozen Specimen from Surgery to Lab in a Rural Hospital — Distance Created with Design of Replacement Campus, Phase 1**
LEAD:	Lean Six Sigma Consultant
CORE TEAM:	Administration, Lab, Process Improvement, Quality

Process Step:	Identify systems and functions
Potential Failure Mode:	What are the potential failure modes that could occur in this function?
Potential Effect(s) of Failure:	What are potential effects of each failure mode?
Severity:	Severity of effects
Potential Cause(s) / Mechanism(s) of Failure:	What are the potential causes of the failure mode?
Occurrence:	Likelihood of each cause
Current Controls:	List controls for each failure mode.
Detection:	Probability of detecting each cause with controls
R. P. N.:	Risk Priority Number S x O x D

Process Step: **Lab specimen processing courier**

		Potential Effect(s) of Failure	Severity	Potential Cause(s) / Mechanism(s) of Failure	Occurrence	Current Controls	Detection	R. P. N.
Potential Failure Mode:	Specimen not marked STAT	Delay in reporting	7	Human error	7	Call from OR	2	98
		Delay in courier to pathology	7	Pneumatic tube does not alert (design failure from vendor)	3	Green form with specimen	2	42
		Delay in OR (Note: Not the right attendees to address delay in OR)						

RECOMMENDED ACTION(S): (1) Do an FMEA on the current control identified: call from OR; (2) consult with vendor regarding pneumatic tube alert.

When asked about the follow-up needed and identified in the FMEA process, the Lab Director responded that:

> The OR calls the pathology department when they are sending a frozen. This alert is working consistently and we have not had any delays. We are at 100% compliance for our turnaround goal of 20 minutes for frozen sections.

The formal FMEA risk assessment process helped the participants focus their discussion and prioritize next steps resulting in successful decision making and outcomes.

Conclusion and Recommendation

These two cases demonstrate the FMEA process informing facility decisions. For Hospital A, it resulted in locating the ICU adjacent to the medical/surgical unit and not the emergency department. For Hospital B, it resulted in transporting specimens from the operating room to pathology via pneumatic tube instead of physically walking the long distance. Both hospitals were faced with decisions that involved potential delays in patient care and the FMEA structured conversations generated solutions focused on safely integrating operations and the physical environment. The FMEA process brought clarity in situations in which the solutions were not obvious and there were differing opinions.

As referenced on The Joint Commission website, the physical environment is a cause of sentinel events (i.e., unexpected death or serious injury or the risk of these types of death or injury). There were a total of 901 sentinel events reported to The Joint Commission in 2012. The 10 most common root causes of these events are:

1. Human factors
2. Leadership
3. Communication
4. Assessment
5. Information management
6. Physical environment
7. Continuum of care
8. Operative care
9. Medication use
10. Care planning (Rodak, 2013)

Many of these categories can be influenced by healthcare design professionals who can explore with hospital leadership a broader role for risk assessment during the design process.

The evidence provided in this study suggests a compelling opportunity to increase rigor in making design decisions that have an impact on operations. Given the inherent risk in healthcare environments and the demonstrated benefit of the FMEA process for decision making, it is recommended that design professionals include risk assessment as standard work within the "task" of facility planning.

Implications for Practice

- Healthcare design teams are urged to include risk assessments as a routine and essential part of the facility planning process.
- As the pressure intensifies for hospitals to improve quality while reducing cost, facility planners need to understand the importance of risk analysis in decision making for design solutions.
- During pre-design, facility planners should bring forth the discussion with hospital leadership about who can fill the role as facilitator of risk assessment workshops as needed for design decision making.
- Structured conversations about potential risk add rigor to decision making about design solutions.
- Failure Modes and Effects Analysis (FMEA) is a proactive risk assessment process that can be included in a professional development training program.

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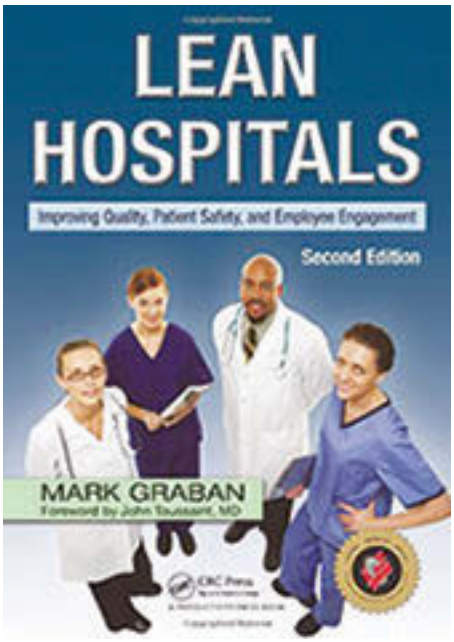
Lean Hospitals: Improving Quality, Patient Safety, and Employee Engagement

2nd Edition



Graban, Mark. (2012). Boca Raton, FL: CRC Press, Taylor & Francis Group

Review by Kurt Hanft, BS ENGR, MBA, ASQ-CSSBB, Lean Six Sigma Master Black Belt

Lean is most effective when everyone in the "Gemba" (the place were the work gets done) has a growing understanding of what the lean philosophy, process, and methods are all about. The second edition of *Lean Hospitals: Improving Quality, Patient Safety, and Employee Engagement* is an effective resource for engaging everyone from the front line staff to executives in studying how to operationalize the Lean process in the healthcare setting. The book is organized into 12 chapters. The content is rich with practical examples that show how a Lean manufacturing culture is very applicable in the healthcare and service industry. The author, Mark Graban, BS, MS, MBA, started his career in the manufacturing industry and starts the book by reinforcing how well Lean translates to other service industries and especially healthcare.

Lean Hospitals begins with a discussion about why Lean is needed and how it can be used in healthcare. Chapter 2 provides an overview of Lean that lays the foundation for the rest of the book. Each subsequent chapter provides definitions for terms unique to Lean, defines the value of Lean, educates the reader about the Lean process, and places the content into perspective using case studies and practical examples. Each chapter also provides a conclusion, Lean Lessons, and Points to Ponder for discussion. The organization of the book provides a perfect format for assigning chapters in a class setting for healthcare work teams and executives can read at the same content, discuss content and specific points in a formal setting, and implement the concepts in their own work setting.

The book discusses finding "waste" in work processes and teaches the reader the steps of value stream mapping and standardizing the work processes. The Kanban and 5S processes are described, which are processes that can be easily grasped and appreciated. Graban adds a sixth "S" specific to healthcare, *safety,*

which is an important consideration. An entire chapter (Chapter 8) is devoted to preventing errors—critical to this industry. By the time the reader gets to Chapter 7, Graban has built excitement in the material with opportunities and examples that can be used in the reader's own setting. The concept and process for A3 problem solving are introduced in the middle of Chapter 7, an appropriate time for the reader's growing appetite for change. The author provides a systematic method for understanding the reader's current situation, conducting a root cause analysis, and identifying a counter measure and implementation. Not all hospitals initiate Lean with a system-wide initiative, and the A3 tool is perfect for individuals to get started on analyzing the problem with focused detail. For departments or work teams new to the Lean process, A3 problem solving empowers employees to personally "own" the improvement process, and ultimately create an organization of problem solvers, which is a key part of the Toyota culture.

Lean Hospitals is an excellent resource for new learners empowering them with new skills for problem solving and enables them to keep true to the Lean philosophy. Unlike Lean training material developed for a class or seminar, the content in *Lean Hospitals* is presented in context to its application, surrounded by examples and case studies that facilitate the learning process and application in the learner's own setting.

Lean Hospitals has been adopted as the text of choice at Sharp HealthCare to teach our executive and work teams about the Lean process. At Sharp, we start each team meeting with a "Lean Moment," which lasts about 10 minutes. We use this as an opportunity for team members to take turns presenting Lean Lessons and Points to Ponder for Discussion from *Lean Hospitals* chapters that are timely and meaningful to the participants. Taking the time for continuous and reflective learning has been very successful in engaging the team and challenging them to apply what they have learned from the current assigned chapters and topics. Training Lean concepts in one class is not very Lean (Batching). We have found that presenting the concepts when applicable to the teams' experience focuses them and is more meaningful and effective to the learning process. The structure of *Lean Hospitals* provides content that can be read in any order, in which each chapter can stand alone as a reference.

Creating a Lean thinking team can be challenging in the beginning, because most Lean facilitators are working with a cross section of contributors to your value stream and your processes that create value to your customers. *Lean Hospitals* can be used as a formal academic text or as a work team's supplement in the hospital setting in expanding the knowledge, skills, and appreciation of healthcare executives, physicians, and employees about the Lean process.

KURT HANFT joined Sharp in April 2005. After 13 years in the manufacturing industry where, using Lean Six Sigma tools, he saved $1.2 million over 3 years, he decided to change course and join healthcare. His manufacturing experience was primarily at Honeywell, where he led Six Sigma improvement teams as a Principle Process Engineer. He received his Bachelor of Science in Manufacturing Engineering in 1992 at California Polytechnic University, Pomona, and his Master of Business Administration from San Diego State University. Kurt is currently leading Emergency Department Lean Teams and teaching Lean Six Sigma at Sharp Healthcare and at the University of San Diego. He can be reached at kurt.hanft@sharp.com

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Letter to the Editors: Post-Anesthesia Care Unit and Six Sigma Process

Submitted by Roger Haenke, MDiv, MSNc, RN, NEA-BC

I understand that you have an upcoming issue focused on Lean Six Sigma [*HERD* Vol. 7, No. 1]. I wanted to share with you and your readers an exciting projected that we just completed using the Six Sigma process as the first step in redesign of the post-anesthesia care unit (PACU) at Sharp Mary Birch Hospital for Women & Newborns (SMBHWN), which is 20 years old and in need of renovation in specific areas to meet new clinical and patient volume demands. This project was unusual in that it used the Six Sigma process to define work flow process prior to commencing the design process and clinical nurses were heavily involved in the process. If we had simply initiated the design process, we would potentially missed some critical design features that would have affect patient care and nurses' and other professionals' workflow. I really want to emphasize the critical importance of using the Six Sigma process first to ensure that nurses think through their work before starting the design process with the architects.

The PACU at SMBHWN provides post-anesthesia care to approximately 240 patients per week with a total of 11 PACU bays, and three spaces in the Surgical Admissions Overflow Room (SAOR), where patients are cared for prior to surgery. Direct-care nurses, the Engineering Department, and Environmental Services focused on enhancing the flexibility of the PACU and the SAOR by adding one PACU bay (for a total of 12 bays) and adding one SAOR bay (for a total of four bays), allowing for more patients to be attended to in the PACU and the SAOR. The two additional bays had previously been used for the storage of supplies and equipment. By centralizing essential supplies and equipment, and disposing of that which was not needed, additional care space was created. This improved the workflow efficiency between the Pre-Operative Room, providing

care for more patients in the SAOR, and the operating room, caring for patients post-operatively in the PACU.

The second focus was on centralizing the location of supplies and medications. Direct-care nurses, the Engineering Department, and Materials Management created a space in the PACU to centralize supplies and medications for nurses instead of going to separate places to collect both supplies and medications. This minimized nurses' time away from the bedside and allowed for more time to be spent with the patients during this vulnerable stage of their care.

The third and final focus was on standardizing the most frequently used materials at the bedside so that nurses could anticipate that all beds having the same supplies in the same areas. This further minimized the time spent looking for supplies and concentrated on keeping what is essential at the bedside while discontinuing to order supplies that are not critical for nurses to provide effective care at the bedside.

We also quantified the measurement of "success" for (1) Quality/Delivery, (2) Cost, and (3) Safety. A survey was used to measure staff satisfaction with the changes in the existing PACU pre- and post-implementation of the Six Sigma event, and the staff satisfaction survey revealed a higher total mean score (pre = 2.88, post = 4.98; using a 5-point Likert scale), which was a statistically significant result ($p = 0.05$). The Six Sigma process and changes to the existing facility before we initiated the design process resulted in a projected cost savings of $51,264 per year resulting from time saved through the standardization of bed space and bedside supply carts and the centralization of supplies and equipment in the unit. If we had not done pre-design, we might have missed the importance of standardization in the design outcome. By centralizing supplies, we actually created more space around the patients' beds and in the traffic corridors from the operating room to the PACU, making the workflow safer for patients, families, physicians, and nurses. Before implementing Six Sigma, respiratory emergency equipment and supplies were not standardized at the bedside, so this change enhanced patient safety as well.

As a result of standardizing supplies and equipment into a centralized space and getting rid of unnecessary items, we were able to add two clinical beds in spaces that were previously used for "junk." This change also enhanced the overall look and feel of the unit and the quality of care. Patients and staff have commented about the pleasant environment that has resulted from this process.

Direct-care nurses learned the Six Sigma processes that went beyond simple productivity improvement. They learned how to humanize their workplace environment by eliminating excessive "stuff" and eliminating waste. Through this project, they identified an opportunity to improve their work environment, analyzed the process collaboratively with other healthcare providers and other departments, developed optimal solutions, studied the results, and standardized

the solution with their fellow peers. Six Sigma facilitated clinical nurses' involvement and they have witnessed that changing their environment can improve their clinical work and the patient experience, which is in fact within the scope of practice.

ROGER HAENKE is the Former Director of Perinatal and Neonatal Services at Sharp Mary Birch Hospital for Women and Newborns in San Diego, CA. He can be reached at RHaenke@hotmail.com; (619) 301-0724.