Designing the Built Environment for A Culture and System of Patient Safety – A Conceptual, New Design Process

Kenneth N. Dickerman, ACHA, AIA, FHFI; Paul Barach, BSc, MD, MPH

Abstract

There is growing recognition that the risks and hazards of injury and harm associated with health care are a result of problems with the design of systems of care rather than of poor performance by individual providers. Furthermore, substantial evidence suggests that the design of hospital physical environments contributes to medical errors, increased rates of infection and injuries from falls, and to slow patient recovery and high nurse turnover. Growing research points to the need to change facility development and design methodologies used in the past to incorporate patient safety into the design. The design professions have been slow to comprehend the gravity and character of the problem. Designers appear to be taking "solution based" approaches rather than using intensive, focused research to develop environments that support caregiving processes. Key causes for these deficits relate to the way designers are trained, the way design knowledge is shared and propagated, and the history of architectural theory. In design, the notion persists that the same processes and tools used in the past will somehow result in the safe environments required for the present and future. The authors compare changes in medical education and architectural design training that illustrate the different approaches. Attention to systems thinking, evidence-based care, and the identification of a different design process that can be used to create health care facilities are needed.

Introduction

Hospitals occupy a unique place in our sensibilities. For some, they are safe havens; for others, they are the locus of dynamic civic and financial activity; and for still others, they have an image of being stressful places that provide only fragmented or even unsafe care. These mixed messages have created interest in obtaining a greater understanding of the relationship between quality of care and the physical environment.

One of the dangers in any emerging concept is that it will be taken over by forces that borrow the language but ignore the detail. Such appears to be the case in the area of "patient-safe" design for health care buildings. The need for a new approach to health care design is a byproduct of the national movement to reduce medical errors and prevent hospital-acquired infections. The current manifestation of the patient safety movement may date from the 1980s, when Lucien Leape[1] and others began investigating and writing about the problem. In this country, the issue was "brought in from out of the cold" by the Institute of Medicine's (IOM) 1999 report, *To Err Is Human*.[2]

The Nature of Error and Its Relation to the Designed Environment

The IOM was careful to point out that medical errors are a product of systems of care rather than the fault of individuals. In other words, causation is related to the design of systems and to the culture of care, rather than to individual human failures. James Reason[3] and Charles Perrow[4] established the theoretical basis for this understanding through their work in the study of human error and accidents. Reason illustrated his concept using what he called "the Swiss cheese model,"[3] which illustrates that there are many latent accident-causing conditions in the common environment, but that these are normally trapped by various layers of defense, such as training, supervision, and redundancy. However, each layer of defense is imperfect, and sometimes holes in each of the separate layers line up, allowing a causative event to result in patient harm. Perrow[4] contributed the idea that accidents are built into systems, and that safety is an inherent property of a system.

Unfortunately, much of the research relating to safety in medical care has focused on characteristics of the clinical system other than the environment in which it is delivered. Donald Norman, who has described some basic characteristics of the design of objects, including buildings, provides tools for avoiding or reducing hazard-rich design solutions.[5] However, his work does not discuss medical care environments. A literature search conducted by Ulrich and Zimmring[6] found a relatively small number of robust articles (out of approximately 600 articles reviewed) that related building design to patient safety. While the research base is small, a review of those studies and work published since demonstrates a link between quality of care and physical design.

This is not to say that evidence does not support current design conventions and techniques or that patient safety is being ignored in building design. A review of the history of health care design (conducted by the authors) clearly supports the contention that evidence has been highly respected in the past and that patient safety has been a key point in hospital development. The work of Filarte in Milan and the design of the British Army Field Hospital at Renkioi are just two of many examples.

Among the common themes in the history of hospital design is the need to have ever better methods for removing waste and the concept that adequate ventilation is essential for patient recovery. On a more current note, a review of the American Institute of Architects' *Guidelines for Design and Construction of Hospitals and Healthcare Facilities* by James Gregory (*Personal communication*) (see www.aia.org/SiteObjects/files/CHD%20WHITE%20PAPERS.pdf) identified over 100 design requirements that relate to patient safety. In addition, a great number of requirements relate to fire and life safety, independent of patient safety considerations.

As a matter of note, the fire and life safety requirements were developed over a period of years in conjunction with organizations such as the National Fire Protection Association (NFPA). These provisions have been particularly successful in reducing the number of fire deaths in hospitals, which currently average less than 10 per year (*Personal communication*). Achieving this level of safety requires an extraordinary expenditure on building features that suppress, isolate, or eliminate fire threats. The unit cost per life saved is enormous.

How the Environment Contributes to Error

What symptoms of poor design in health care facilities could contribute to medical errors? Virtually any characteristic of the environment can have a supportive or detrimental effect on human performance and hence on patient safety. For example, consider lighting. A recent study correlated the relationship of medication errors to lighting levels. As lighting intensity approaches 1,500 lux,[7] the incidence of medication errors dramatically decreases. Poor lighting and the lack of daylight are linked to depression, increased need for pain medication, medication errors, and order entry errors.[8] Health care-acquired infections are related to air quality, ventilation rates, the presence of handwashing stations, the number of room occupants, and finishes.[9] Research showing that noise is a significant stress-inducing element in open office landscape design has direct application to many health care environments. Noise is also known to reduce communication comprehension. The distance between two "related" departments affects service time, throughput, and transfer risk. The form of the pathway (straight, crooked, or convoluted) affects travel time and increases the risk of falls or transport accidents. Exposing nurses to nature vs. non nature views decreases their stress levels and enhances their awareness to errors.[10]

A Comparison with Building Life Safety

Education and training about the patient safety problem, reallocation of certain building resources, and fundamental changes to the building design process are required in order to create buildings that are "patient safe." When comparing the characteristics of health care building life safety and patient safety, both involve cultural and organizational issues. Neither type of safety can be achieved solely by application of isolated, nonconnected protection features. Both types of safety have aspects of interdependence with the environments in which operations are conducted. In the case of fire and life safety, significant changes to design concepts and methods (in addition to operational concepts) were part of organization cultural changes. On the other hand, the design process for buildings that foster patient safety has not undergone such a transformation to date.

In this article, we make several comparisons between designing for building life safety and designing for building patient safety. For that reason, a few comments about the history of building fire safety are in order. Until the beginning of the 20th century, large loss fires were common in urbanized areas in the United States. The history of many cities—such as Chicago, Jacksonville, and San Francisco—is often retold from the time of "the big fire."

The 20th century did not have an auspicious beginning. On December 30, 1903, 602 people perished in Chicago's Iroquois Theater.[11] On June 15, 1904, barely a half-year later, 1,000 New Yorkers died when the steamship General Slocum burned to the water line.[12] Then, 7 years later in March 1911, 146 workers, mostly young women, perished in the Triangle Waist fire in New York City.[13] In May 1929, 123 people lost their lives in a fire at the Cleveland Clinic (*Personal communication*). While no loss of life in major fires in any given year has come close to equaling the loss of life in residential buildings, the large loss fires in the early 20th century gradually led to the development and enactment of the effective life safety regulations we have today. These

tragedies captured the attention of the public and policymakers and changed the culture of fire safety. Today, residential fires cause an even greater proportion of fire deaths than do those in institutional and commercial buildings, yet the public has been very slow to accept changes, such as residential sprinklers, that would save lives.

The Scope of the Problem

Medical mistakes, or errors, in which the design of the physical environment is a contributing factor, have a substantial cost in lives and injury. To date, no study of this problem has been published. The following is a crude estimate, which we offer for the purpose of discussion. The IOM stated that between 44,000 and 98,000 people die every year in U.S. hospitals due to medical errors. Klevens, et al., calculated that approximately 99,000 deaths can be attributed to hospital-acquired infections every year.[14] Accepting the smaller of the IOM numbers (which could also account for some overlap of the figures), total deaths each year would be 143,000. If we assume that the cause of death in these cases is proportionate to the ratio of capital expense to total operating expense, then 12 percent, or 17,160 deaths, would be related to the designed physical environment. For the purposes of conversation, this number is 1,700 times the number of deaths each year in U.S. hospitals due to fire.

Training for Design – A Tale of Deficits

How have architects and the design process they use been successful in reducing fire deaths in hospitals? The academic training of architects and engineers provides the foundation for their understanding of fire safety. During the period of apprenticeship, which generally follows graduation, the intern architect comes in close contact with specific building and fire safety regulations and standards. The National Council of Architectural Registration Boards (NCARB) licensing examination used by many States tests candidate architects on their knowledge and understanding of fire and life safety codes.[15]

Upon entering practice, the apprentice or intern architect finds that every nonresidential building design must pass the review of government examiners, who enforce fire and life safety codes. Complementing this system are the efforts of manufacturers, trade associations, and specialty consultants, who develop, test, and produce systems and materials that are classified by independent testing agencies as to their fire performance characteristics. Some of these systems are for active fire suppression and others for containment, depending on the requirements stated for occupancies defined in the codes. The added cost attributable to life and fire safety characteristics is enormous, yet there is little recognition and no complaint. The standard for performance has been set very high.

Since architecture schools train generalists not specialists, freshly minted architecture graduates are not likely to have been exposed to the issues of design for health care services, let alone the problems associated with medical error and mistakes. During their apprenticeship period, following graduation and preceding licensing, graduate architects might have an opportunity to work on health care projects. Others might start doing health care projects later in their professional careers. It is through this experiential avenue that most of those who ultimately become health care specialists begin receiving their training in this field. In the United States,

only two university programs have a graduate level curriculum in health care planning and design. Neither of these programs has a track that focuses on design for patient safety. Unlike life and fire safety, no regulations or codes are devoted to patient safety—i.e., freedom from medical errors and mistakes. Furthermore, architecture students get little training in ergonomics, process modeling, psychology, and anatomy that would help them understand how the users of the buildings would react and interact with their designs.

Subjects—such as structures, the mechanics of materials, and history—are taught in a lecture and recitation format, whereas design is generally taught in an experiential studio format. Studio classes might have some lecture periods, but most of the attention goes to student exercises. These could be 1-day quick studies or the focus of an entire class term. The student is given or develops a program for the proposed project and is asked to produce a design concept. The studio director typically visits with each student on a periodic basis and gives a critique that is intended to raise questions that the student explores through self-directed study. The work may be graded individually by the studio director or may be "juried" by the professor and fellow students.

One consequence of this format is that, while all students start with the same program, their resulting solutions may be quite different. This strategy is intended to develop the individuality and personal analytic skills of each student.

Now, picture the medical analogy: A group of interns is each directed to perform an appendectomy or to place a central venous access line, and each cuts the patient in a different location, in a different direction, and to a different depth. The chief medical resident concludes the exercise by telling the students that "each of these solutions is fine, although I like some better than others." The learning process for architects emphasizes individuality, intuition, and self-expression, but it excludes some helpful tools and disciplines. These can be hindrances when designing medical buildings.

Although architects are subject to legal liability for negligence in designing life safety features for a building, the legal system has paid little attention to exploring potential liability for designs that contribute to medical mistakes and errors. For damages and injuries resulting from structural failures, water migration (mold and mildew), and similar causes, the architect has the restraining benefit of the tort bar. Cases against architects alleging harm due to medical errors caused by the building environment are rare if not nonexistent.

The one area that does receive interest is that of hospital-acquired infections resulting from construction operations, but those cases typically involve the constructors and the owners because of their proximity to the causes and their deeper pockets. It is ironic that some practitioners tout the beneficial effects on staff and patients of well-designed environments, deplore the stress and fatigue caused by poorly designed environments, but yet are silent about their attendant responsibility for errors and harm, which may be attributable in part or in total to the environment.

Furthermore, many architects are trained in what Robert Sommer described as "formalistic design."[16] In contrast to "social design," formalistic design emphasizes rules, dictums, and

aesthetics for the sake of aesthetics. Social design focuses on the needs of users, on human scale and human interaction with the built environment, and especially on usability. An excellent (nonarchitectural) example of formalistic design is the work of the artist Mondrian. His paintings are composed of lines and rectilinear forms in rigid structures, which emphasize the relationship of the elements to each other by the use of various proportional schemas.

Given the proposition that the training of architects lacks information on subjects that would improve their ability to design safe medical environments, it is important to review the etiology of the factors in building designs that contribute to accidents:

1. Designer lack of knowledge of medical care systems.
2. Designer lack of knowledge of human factors.
3. Design process that limits comprehensive problem solving and devalues or ignores certain relevant disciplines.
4. External forces and limitations, such as regulations, budget, and schedule.
5. Limitations of available systems, designs, and materials.

Of these factors, we have addressed the first two in a limited way; we find that the fourth and fifth are beyond the scope of this paper: it is the third that we will now address in detail.

Problems with the Current Design Process

While the educational system for architects creates latent deficits for the aspiring health care facility designer, its most damaging effect may be the perpetuation of design processes that are inappropriate or inadequate for health care facility design. The conventional design process used by American architects has evolved into a unique system of project delivery. In many businesses, including some that utilize professional services, a single business entity undertakes product research, design, and production. The aircraft and automobile industries are excellent examples.

In architecture and medicine, the system of design and production is different. By the 20th century, the practice of architecture had separated from building construction. Just as physicians are “independent consultants” representing the patient, so architects are the agents of the client or owner, rather than the construction contractor. This process is dubbed “design/bid/build.”[17]

During the last quarter of the 20th century, a system of project delivery, in which designers and constructors posed as a single business entity with respect to their client, gained some prominence. This method, described as “design/build,” was touted as being able to deliver projects faster. Despite this methodology’s continuing gains, most major commercial and institutional projects continue to be delivered by the conventional design/bid/build method.

The design/bid/build process is linear. It starts with the development of a project scope; continues with the creation of a conceptual design; progresses through the preparation of construction documents, which are given to prospective contractors for competitive pricing (bidding); and then proceeds through the construction phase. In health care projects, the client, the architects, or a specialized consulting firm might prepare the “scope statement,” sometimes called a “functional program.” This document could be just a list of spaces by department and

usually does not include medical process information, flow diagrams, or information regarding patient safety issues.

During the conceptualdesign phase, the architects may interview clinicians and other staff to validate the program, to learn about special requirements, and to understand departmental and room adjacencies. If the owner has engaged a consultant to manage the project, contact between the designers and users might be limited.

During the conceptual phase of the project, disciplines other than architecture play a limited role, but this changes as the project begins to require greater detail. Structural, mechanical, and electrical engineers join the procession in order to design the systems and features for which they are responsible. At some point, equipment planners and information technology experts become part of the team. We use the term “team” loosely because nearly everyone sticks to his/her assigned “silo.”

When the architects are nearly done, interior designers might be invited to select furnishings, artwork, and special finishes. The strength of this process is that it is highly structured and organized. No more information is developed at any one time than is needed for the particular design questions being studied. Inconvenient concepts or facts can be shunted away. Almost everyone in the design and building sectors understands this process and has some conception of its strengths and weaknesses.

The weaknesses of this process are exactly the opposite of its strengths. Because of the rigid structure, disciplines that would benefit by cross-pollination and collaboration never have that opportunity. For instance, a decision about a medical process might be made before all available technologies and equipment are considered. Opportunities to improve process to achieve greater efficiency and quality are artificially limited. Rarely in these instances have we seen adequate research. Because the design/bid/build process is led by a representative of either the architect or the owner, there is little incentive to engage specialized consultants.

One example of this is in the area of human factors, or ergonomics, research. Although health care buildings contain hundreds of workstations, many of which are used day and night, the extent of design research typically involves asking a few users in a nonscientific manner how high the counter should be. That same counter is typically designed without specific knowledge of the monitor and computer or other devices to be installed into it and to be used by staff members. It is also designed without consideration of the physical characteristics of the staff who will use it. Engaging human factors engineers, medical informaticists, and other specialists at the outset of the project where they would have a chance to be effective would disrupt the rigid structure of the conventional project delivery system.

The design/build delivery system, which is an abbreviated form of the traditional design/bid/build approach, is even less flexible and more averse to user-tailored design.

A Proposed Solution – A Conceptual Model of a New Design Process

If the conventional system were malleable, adding the appropriate additional disciplines at the correct time might be possible. However, the process is not malleable because its very rigidity

creates its structure. The solution is to create a new system of project delivery that is not bound by the constraints of the old system.

If the conventional system can be visualized as linear, a better process or system could be visualized as a series of concentric circles, as shown in Figure 1. In the center is a circle that represents the functional systems of the organization: medical care systems, administrative systems, and support systems. The rings around the center represent increasing amounts of knowledge and increasing levels of decisionmaking about the project. Each ring is populated by representatives of each of the disciplines appropriate for the questions at hand. In addition to the architect and engineers, there would be risk managers, clinicians, human factors engineers, medical informaticists, equipment specialists, interior designers, and it is hoped, past and present patients. The concept is to look at all problems and issues with a very broad perspective, so that all kinds of solutions can be developed and tested.

For example, an owner may wish to switch from paper-based to electronic medical records. This switch could have implications for the amount of (electronic) storage space needed, where it should be placed, and the type of environment needed for preservation. It could also affect the way physicians and nurses complete charts and write clinical orders. It might mean that work environments would need to be suitable for computer monitors rather than paper forms. The number and location of charting monitors would have a significant impact on the way doctors care for their patients. In the process, the change from paper-based to electronic medical records might seem at first glance only an "information technology" issue, but in fact it has a huge impact on the workflow and quality of clinical decisionmaking.[18]

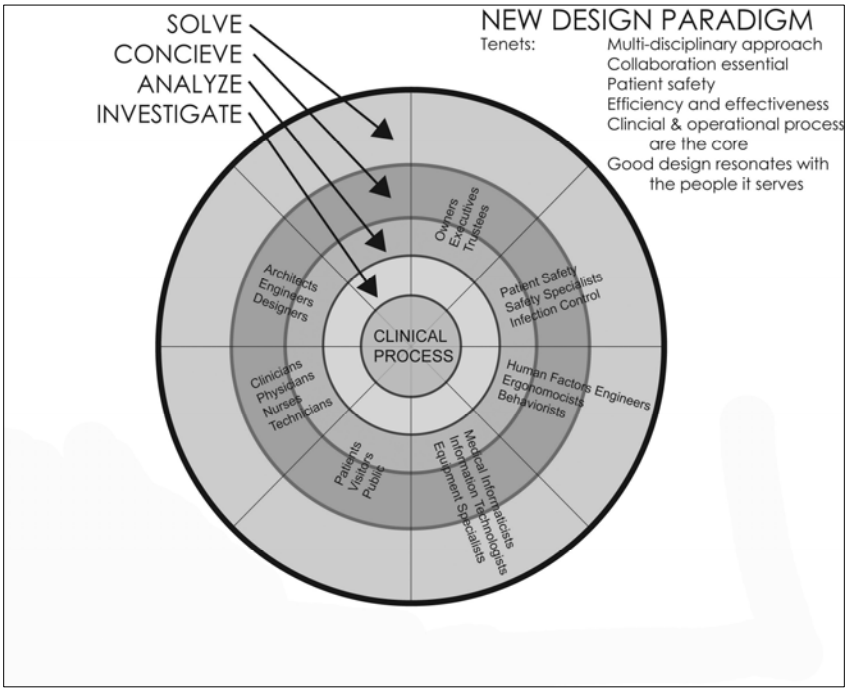

Figure 1. New conceptual model for design process.

In fact, the physical environment would have a significant impact on the success of introducing electronic medical records. New computers might add significant heat load, lighting that was appropriate for working with paper could be totally inadequate for viewing computer screens, and the number of input locations might be insufficient. The best way to avoid these and many other mistakes is to have a project team composed of individuals who understand the interrelationship of systems and have a sufficient voice in design decisions to forestall poor choices or inadequate research.

Patients should be a part of the design team. Designers, builders, administrators, and even clinicians have objectives and agendas that might obscure astute and appropriate observations from the customers of the health care enterprise. Health care now tends to focus on the illness of the patient rather than on his/her care. Talking to patients and their families might reveal valuable insights about the layout and design of the care environment.

Conclusion

Managing a large and diverse design team is a challenge, even on the smallest project. Leadership is needed to give the team a few, tangible, overarching objectives and guidelines for participation. We believe that highly diverse teams, if properly managed, have the best chance of producing health care environments that not only foster the culture of patient safety, but also support the mission of caring.

We also contend that education about patient safety, reallocation of certain building design resources, and fundamental changes to the design process used to create health care buildings are required in order to correct the disparity between life safety and patient safety. Both types of safety involve cultural issues or characteristics of health care institutions; neither type is achieved solely by application of isolated, nonconnected protection or regulatory features. Both types of safety have aspects of interdependence with the environments in which operations are conducted. In the case of fire and life safety, significant changes to design concepts and methods were part of cultural changes to organizations. On the other hand, health care has not undergone such a transformation to date. The need is compelling and immediate.

Next Steps

We propose a design process that has significant differences from the most common current process. These differences, which are characteristics of the new process, include the following:

- A high degree of collaboration is required among design team members.
- The design team comprises a very wide range of stakeholders, including disciplines not normally part of current design commissions (i.e., human factors).
- The entire design team must work together from the start of the project.
- The entire design team must complete various levels, or stages, of the project simultaneously so that information can be shared.
- Advanced techniques must be used to obtain information regarding process and user performance.
- Project leadership concepts and techniques must be suited to the new design process.

Assuming that a particular institution might wish to use a design process of this type for a project, we would offer several first steps and suggestions.

1. An institution should be aware that any new process or technology might have both latent problems and obvious advantages. Institutional management must assess their culture and capabilities to assure that they are willing and able to work through these during the course of

the project. The process we have proposed is not designed to minimize "first costs." The goal of this new process is to provide safety for patients primarily and safety for staff and operational efficiency as secondary by-products.

2. Team members should be selected based on their willingness to work under the new process and their understanding of its goals.
3. All stakeholders should be willing to develop contractual and relational incentives that support the objectives and the new process. No problem is more intractable in a building project than having team members who are "incentivized" in different ways and toward different goals. Conventional, "industry standard" contracts should be examined carefully.[19] It is natural for parties to want to separate their risks from those that might be borne by others. A highly interdependent and collaborative approach might threaten the "comfort levels" of some.
4. The project execution plan should be created with the informed input of all stakeholders and should address the work of all stakeholders and team participants. The schedule should allow time for completion of each level of detail before proceeding with the next. The schedule should allow time for testing of concepts through simulation, mock-ups, or other tools.
5. The design team should engage regulators by explaining the proposed design process, schedule, and objectives and by requesting waivers or exemptions where necessary. (We are not suggesting waivers to life or public safety requirements, but rather to the review process and requirements.) The design process would produce a set of documents that describe the proposed project, just as the conventional process has done. However, with the proposed process, more information in greater detail would be available.

Our concluding suggestion is that AHRQ expand its role as a catalyst in this area by extending its outreach and its research on the relationship of the design process to the "production" of buildings that enhance safety. Of particular importance is the impact that an organization like AHRQ can have in avoiding certain pitfalls, such as creating "design fads," which should be recognized as a serious threat in an industry (design) that traces many of its current stylistic roots to the "compounds" of the 19th century.[20]

Author Affiliations

Leo A. Daly Company, Jacksonville, FL (Mr. Dickerman); Department of Anesthesia, Utretch University Medical Center, Netherlands and College of Medicine and Public Health, University of South Florida, Tampa, FL (Dr. Barach).

Address correspondence to: Kenneth N. Dickerman, ACHA, AIA, FHFI, Leo A. Daly Company, 11721 Village Lane, Jacksonville, FL 32223; telephone: 904 613 8278;
e-mail: medspace@comcast.net.

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