

Patient safety begins with proper planning: a quantitative method to improve hospital design

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ABSTRACT

Background A quantitative methodology that enhances design of patient-safe healthcare facilities is presented. The prevailing paradigm of evaluating the design of healthcare facilities relies mainly on postconstruction criticism of design flaws; by then, design flaws may have already negatively affected patient safety. The methodology presented here utilises simulation-based testing in real-size replicas of proposed hospital designs. Other simulations to assess design solutions generated mainly qualitative data about user experience. To assess the methodology, we evaluated one patient safety variable in a proposed hospital patient room.

Method Fifty-two physicians who volunteered to participate were randomly assigned to examine a standardised patient in two hospital room settings using a replica of the proposed architectural plan; the two settings differed only by the placement of the alcohol-based hand-rub dispenser. The primary outcome was the hand hygiene compliance rate.

Results When the dispenser was in clear view of the physicians as they observed the patient, 53.8% sanitised their hands. When the dispenser was not in their field of view (as in the original architectural plan), 11.5% sanitised their hands ($p=0.0011$). Based on these results, the final architectural plans were adjusted accordingly.

Conclusion The methodology is an effective and relatively inexpensive means to quantitatively evaluate proposed solutions, which can then be implemented to build patient-safe healthcare facilities. It enables actual users to proactively identify patient safety hazards before construction begins.

Although medical errors continue to affect patient safety, little attention has been given to the causal relationship between hospital design and care providers' acute failures.¹ Design solutions often influenced by organisational dictum may later result in acute failure.^{2–3} For example, insufficient light, and poor doorway and furniture design may each cause patient falls, which are serious patient-safety events.^{4–5} Analysis of design failures following completion of construction is challenging, and remediation difficult.⁶ Consequently, these hazards often persist or are sometimes further supplemented by suboptimal solutions, which also have not been rigorously evaluated before implementation.^{7–8}

This study addresses hospital design from a patient-safety perspective. The primary objective was to assess the efficacy of a quantitative methodology that uses a mock-up of a proposed hospital room design to test compatibility between care processes and built environment with an emphasis

on certain aspects of patient safety. We posit that this approach will reduce latent failure, which may cause or contribute to acute failures after building the facilities.

Simulators and mock-ups have been extensively used to test aircraft and automobiles since 1946.^{9–11} During the past decade, simulations have also been used to design courthouses.^{12–13} These simulations have used either full-scale replicas or virtual reality to address issues such as work flow, lighting and air conditioning.¹⁴

More recently, simulations have been introduced to evaluate proposed design of hospitals, departments (eg, operating room and central sterilisation department) and patient rooms.^{15–18} These simulation modalities use either virtual reality, such as the Second Life project (<http://www.secondlife.com>),¹⁹ actual replicas^{14–15} or 3D modelling to examine the proposed design of central supply. In most simulations, qualitative data were collected from focus groups composed of various stakeholders and patients; others used stakeholders' input for mathematical process modelling.²⁰ A full-scale replica was used to assess the spatial requirement for the shower in a patient room; however, instead of trained care providers, the researchers used students to move a simulated patient in and out the designated space.²¹

To focus on one quantifiable variable in the design, we evaluated the impact of the proposed placement of an alcohol hand-rub dispenser on hand hygiene compliance. Hundreds of other variables could be tested before the onset of construction. However, we chose this aspect because healthcare-associated infection is a critical patient safety issue that links hand hygiene and hospital design.²² Data suggest that hand hygiene compliance among healthcare providers is suboptimal and that hospital design should incorporate new solutions to reduce the risk of healthcare-associated infection.^{23–27} Despite the criticality of healthcare-associated infection, the proper location of a sink or a dispenser of alcohol-based hand rub within the patient room is still a controversial issue.^{22–24–28–30} Therefore, we used this realistic patient safety problem to assess the efficacy of mock-ups to test design solutions.

METHODS

A leading US architectural firm was hired to design a new university hospital and provided their proposed plans for standard hospital rooms. A real-size replica of one room was constructed in an empty commercial space on the medical campus. A 1-litre alcohol-based hand rub dispenser was wall-mounted in one of two locations. Location 1 was

positioned immediately adjacent to the patient so that it was clearly visible to anyone facing the patient's bed. Location was sited across from the patient's bed near the door to the room. Location was in partial view of the patient but was hidden from the healthcare provider when facing the patient. This was the approximate location of the sink in the original architectural drawings.

Following institutional review board exemption, a total of 52 physicians volunteered to participate in the study and were instructed to perform an assessment on our standardised patient. The physicians were randomly assigned into one of two groups: group 1 examined the patient with the dispenser in location 1, and group 2 examined the patient with the dispenser in location 2. A trained actor served as a standardised patient, who purportedly had heart palpitations and was instructed on what to say during the encounter with the physician. This scenario was selected such that the study-subject physicians would be required to perform a physical examination, and therefore were expected to maintain appropriate hand hygiene before and after patient examination. Despite the somewhat unfinished look of the room, the physicians were instructed to view this scenario as an actual patient in a standard hospital room and to perform exactly as they would in a real patient care setting. They were told that this was a study to evaluate the layout of the proposed hospital room. The encounter was recorded so that the architects could review the details of physician movement especially as related to line of sight at entrance to the room and approach to the patient.

Data were collected by two observers: one observer was the standardised patient; the second observer was positioned outside the room and watched the encounter through the mock-up room's window. The US Centers for Disease Control and Prevention Guidelines require healthcare workers to maintain hand hygiene before and after every patient encounter.²³ However, because the simulated encounters in this study were terminated prematurely, post-encounter hand hygiene compliance data were not recorded. Data were analysed for statistically significant differences using the χ^2 test.

RESULTS

Fifty-two attending physicians and senior residents participated in the study and were assigned to two equally sized groups of 26. There was a statistically significant difference between groups 1 and 2, in which 14 (53.8%) and 3 (11.5%) ($p=0.0011$), respectively, washed their hands before patient examination. Based on these results, the final architectural plans were modified so that the sink was strategically located in direct view of the healthcare worker.

DISCUSSION

This study proves the efficacy of utilising a mock structure to evaluate proposed design in controlled studies. The study's results demonstrate that preconstruction testing can identify architectural design flaws that may affect patient safety and subsequently identify solutions before construction begins.

Hospitals remain a source of preventable human errors.³⁰ Medication errors have been attributed to many factors that individually appear to be an intuitive cause of error. However, root-cause analyses often reveal that these errors may result from non-obvious physical limitations of the hospital environment, such as insufficient lighting.^{31 32} Within the larger context of the built environment, care providers engage in complex patient care tasks and critical communications, but the physical

space may fail to support these activities and actually induce acute failures.²⁴

Patient-safety problems are multifactorial issues. The close interdependence between people, processes, technology and the design of a medical facility requires solutions that act synergistically to reduce human error and improve patient safety. Recent evidence from evaluating design solutions has now associated patient safety issues and facilities design.^{33 34} For example, studies suggest that noise due to poor design of healthcare facilities may potentially affect patient healing^{35 36} or may affect patient safety during surgery.³⁷ The momentum to incorporate patient safety concepts in new care facilities has grown in the past few years. Still, very few controlled studies have been conducted to test proposed solutions during the design phase.^{4 22} The importance of conducting controlled studies before construction cannot be overstated. After construction is completed, it may be impossible or cost prohibitive to modify architectural solutions that may potentially affect patient safety. In addition, the cost of a mock-up is a small fraction of discovering a design flaw after the facility is complete. Without proper preemptive testing, the (by-then already built) flawed designs may lead care providers at the sharp edge to 'invent' short cuts to offset those limitations, thus potentially reducing patient safety.^{7 8}

We used hand hygiene compliance to test the methodology because it represents a typical patient safety issue. It inherently involves people, processes and facility design. The study results reconfirm findings in multiple studies that healthcare workers have hand hygiene compliance rates below 55% despite education programs and formal guidelines.^{23 38-40}

Several factors may have accounted for the low hand hygiene compliance in our study. Although Purell is commonly used in hospitals, it may not be well recognised by all healthcare providers. In addition, the dispenser may not trigger the same response to a physician accustomed to the presence of a sink. Intuitively, the presence of a sink inside the mock-up room would have resulted in higher compliance rates. However, many studies evaluating hand hygiene have shown that compliance is low despite having a sink in the room. We believe that the observers had little effect on the results in our study. Data collection by standardised patient, and having an outside observer, is a common practice in simulation. In addition, video cameras are frequently used to capture more complex scenarios during simulation, which would be suitable for more complex mock-up testing. Finally, a less-than-optimal attitude towards hand hygiene may explain the low compliance rates.⁴¹⁻⁴³ It is interesting to note that a box of gloves was also placed within clear visibility in all simulations, but was only used by one physician, who did not use the alcohol-based hand sanitiser.

It is also possible that the simulation-based nature of the hospital room did not provide adequate suspension of disbelief as required for optimal simulations. A post hoc debriefing with the participants, however, suggested otherwise. The mock-up provided a relatively inexpensive and reusable method to evaluate proposed solutions in various healthcare domains. It can be used for designing new facilities and before renovation or remodelling projects of different healthcare facilities.

Hospital designers have initiated much activity to address patient safety in hospital design. The Center for Health Design has initiated the Pebble Project, which began with a study based on the hypothesis that fewer respiratory infections would occur as a result of improved air filtration. Although this approach generates valuable longitudinal data, it does not quantitatively examine patient-safety design issues.⁴⁴

A patient-safety approach to hospital design was recently implemented in several general and children's hospitals in the USA.^{16–19 45} All these hospitals used mock-ups, either real or virtual, to assess users' experience and to evaluate ergonomic solutions. Users included hospital's medical and administrative staff members as well as patients and families. Input was collected during walk-throughs and surveys. In one 80-bed hospital, the design solutions were based on analysis of human error and 'near miss' reports.¹⁶ The small scale of that hospital, however, may limit data extrapolation to larger hospitals. Unfortunately, the design solutions were not tested before implementation, and improvements were not quantified in previous reports. The lack of users assessing processes, as advocated by the Institute of Medicine, and the lack of quantitative metrics limit this method.³⁴

The study does not intend to solve the hand hygiene problem, which is a multifactorial issue. It rather intended to demonstrate that when processes are examined in the proposed settings, it could help uncover potential design problems that may affect patient safety. Issues related to hospital design are typically discovered after clinical care has begun, when an error or a near miss occurs. Since alterations to finished buildings represent significant new capital expenditures, the prevailing paradigm is the implementation of patchwork repairs, which may trigger other unanticipated problems. As a result, healthcare providers typically adjust to the space rather than redesign the space to accommodate their needs.

The gap between patient safety needs and implementation of actual solutions is wide. The movement to address design issues that relate to patient healing has generally failed to incorporate standards that specifically address patient safety.³ Even the Institute of Medicine report that introduced the era of 'patient safety' does not provide any specific quantifiable data about the effect of the built environment on human error.¹ Yet, information based on quantitative methods is essential for designing safer hospitals. Such methods will also reduce current costs of the 'trial and error' paradigm.

More studies that use additional and more comprehensive settings and larger numbers of participants that represent all stakeholders are needed to further validate this methodology. It is recommended that architects and engineers be present during the observation phase of design testing for obtaining first-hand impressions and for suggesting future test plans. Alternatively, these experiments can be recorded for subsequent review. Demonstration of the long-term effects of the methodology can be achieved by a longitudinal study comparing preconstruction and postconstruction test data.

Postconstruction evaluation was not performed in our study because the construction plans have been put on hold. Ideally, such evaluation could have provided additional evidence about the design solution, the methodology and the economic advantages of utilisation of mock-ups for testing at the design phase.

This study had an unintended consequence. As a result of low compliance rates, we have initiated a hospital-wide programme to improve hand hygiene compliance. In an ongoing effort to constantly address patient safety issues, we continue to evaluate hospital design, its impact on providers and other methods to improve hand hygiene compliance.

CONCLUSION

Mock-ups of proposed designs can be used as a method to test compatibility between care processes and existing design with an emphasis on certain aspects of patient safety. Currently, there is insufficient experience in healthcare to implement such

a method beyond the realm of anaesthesia, operating rooms and intensive care units. The documentation that such tests will generate will serve several purposes. Locally, it may improve patient safety as well as improve future models for mock-up testing of new units; nationally, it will serve as the benchmark for other institutions to develop solutions for their own institutional design needs. Testing proposed architectural designs before construction can allow for improvement of designs and ultimately the development of safer hospitals.

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