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LETTER TO THE EDITOR

Debbie Gregory
The Biomechanics of Patient Room Standardization

Debajyoti Pati, PhD, MASA, FIIE, LEED®AP; Carolyn Cason, RN, PhD; Thomas E. Harvey, Jr., FAIA, MPH, FACHA, LEED®AP; Jennie Evans, RN, BS, LEED®AP; and Andrea M. Erwin, MSN, RN

Abstract

Background: The prevailing focus on cognitive load reduction in healthcare environment standardization excludes a domain of healthcare delivery that could contribute significantly to safety and efficiency through standardization, but it has escaped discussion in the context of the biomechanics of care delivery. Inappropriate biomechanics not only can harm caregivers but compromise care delivery. Little, however, is known regarding the biomechanics of patient care and the way it interacts with the configurational issues typically targeted in healthcare environment standardization.

Objectives: Examine the types of potentially harmful or stressful actions exhibited by nurses during patient care delivery in an acute medical/surgical setting. Examine the sources influencing unsafe actions.

Method: Twenty nurses provided three types of simulated care in an experimental setting involving nine care configurations that were systematically manipulated. A kinesiology expert coded 80 simulation segments representing two types of task and two levels of environmental challenge to identify potentially stressful and harmful actions. Exploratory and regression analyses were conducted on the data.

Results: Analysis suggests that a considerable proportion of potentially harmful and stressful actions are associated with the design of the physical elements as opposed to the configurational factors typically addressed in standardization. Both of these factors interact to produce work-arounds that result in unsafe actions.

Conclusion: The standardization of healthcare environments needs a larger framework to address both cognitive lapses and the biomechanics of care delivery.

Key Words: Standardization, biomechanics, ergonomics, safety, efficiency, evidence-based design, medical/surgical unit, bed unit, inpatient unit, healthcare design, patient room

The contemporary focus in healthcare environment standardization has been on reducing the cognitive load of caregivers, and rightly so. The reduction of cognitive load has been addressed via the consistency of location and the design of...
Consistency in the physical environment of care across all instances can be viewed on different scales, ranging from the element level (headwall, interior of supply cabinet, and so forth) to the caregiver zone level, the patient room level, and the unit level.

Elements in the patient care environment across all instances; for example, the concept of same-handed patient rooms, where all of the patient rooms in a unit, or across all units, in a hospital are designed to be identical in configuration and design (Cahnman, 2006; McCullough, 2006; Reiling, 2007).

The term element in this paper refers to the smallest physical entity that has an independent identity in the care delivery process. Examples of elements include the patient bed, the headwall, the medication cabinet, the supply cabinet, the intravenous (IV) pole, the patient chair, the sink, and so forth. Design of elements means the way an individual element is designed. The design of an element affects numerous actions, for instance, bed height, angle, and other attributes that influence the work of caregivers. The design of a sink determines whether hand washing can be a hands-free task; the height of a sink determines the degree of bending required, and so forth.

The distinction between design and location is crucial to the optimization of standardization. It is possible that an element (the hand-washing sink or the supply cabinet) is standardized in location (located in the exact same place in all rooms in a unit or hospital) but not in design. The reverse is also true. An element can be standardized in design but not in location. Furthermore, location has three dimensions, which can vary even though a design is standardized: the two axes representing the floor plane and vertical height from the floor.

The term configuration or physical configuration in this paper means the relative position (relative arrangement in space) of the individual elements vis-à-vis one another and the circulation paths. Thus, if the individual elements in a patient room are located to optimize a right-sided approach to the patient, it creates a right-handed configuration. It is noteworthy that the creation of a standardized configuration is possible without standardizing the design of individual elements.

Consistency in the physical environment of care across all instances can be viewed on different scales, ranging from the element level (headwall, interior of supply cabinet, and so forth) to the caregiver zone level, the patient room level, and the unit level (Pati, Cason, Harvey & Evans, 2010). The argument in favor of the consistent design and location of physical elements or groups of elements is the resulting reduction in the complexity of human interactions with the
physical environment and in search-and-locate tasks, which during emergencies could save valuable time and reduce errors (Reiling, 2007; McCullough, 2006). Although it has not been tested empirically in the domain of healthcare design, evidence in the aviation industry literature shows that standardization of the flight deck—with particular emphasis on such attributes as system layout, displays, and color philosophy, among others—improves safety (Spitzer, 2006).

The prevailing focus on cognitive load reduction in healthcare environment standardization excludes a domain of healthcare delivery that could contribute significantly to safety and efficiency through standardization. The domain of caregiver biomechanics has to date escaped discussion. Appreciation of this expanded framework warrants revisiting the fundamental objective of standardization: improving safety, or providing safer care. In this context, standardization is defined as bringing “into conformity with a standard” (Merriam-Webster, 2010). This definition, in turn, poses a fundamental question regarding standards. What safety design standard should a patient room design conform with? Excluding life safety standards that are part of the building code and facility design guidelines (both representing standards of a different nature), no such standards have as yet been validated.

In the absence of an established core concept for a standard of safety, standardization of the healthcare physical environment can be viewed as a means of supporting the standardization of clinical activities such as workflow, processes, and the physical execution of tasks (Pati et al., 2010). The standardization of clinical practices can be viewed as conducting a task the same way every time when needed or wanted and when appropriate. In this framework of the standardization of clinical practice, physical environment standardization plays a crucial role in supporting such practices (Figure 1).

Figure 1. A framework for defining physical environment standardization in healthcare.
As and when evidence-based practices develop standardized care processes, the physical design standardization of the patient room environment can provide two kinds of support. It can support the standardized physical execution (behavioral support) of clinical tasks—the physical positions, actions, and biomechanics involved in a care task—by optimizing the configuration of the physical elements of the patient room. It can also support caregiver cognition and cognitive practices by improving familiarity with the physical environment of care, and thus, predictability (Pati et al., 2010). Predictability becomes especially compelling during emergency and life-threatening situations because familiarity can reduce search-and-locate actions and errors.

In this context, safety in care delivery (or unsafe care) involves more than caregivers’ simple cognitive lapses. It also involves unsafe physical actions not captured in prevailing discussions of standardization. Unsafe physical actions can originate from improper biomechanics and the laterality of the caregiver. Improper biomechanics (actions and postures that place undue stress and strain on caregivers’ muscles and joints) often occur during such physically demanding activities as reaching, pulling, lifting, and transferring a patient (Bashir, 2002). Back and musculoskeletal injuries attributable to such improper biomechanics constitute the largest occupational health problem (Bashir, 2002; Benyon & Reilly, 2002; Smedley et al., 2003; Trinkoff, Lipscomb, Geiger-Brown, & Brady, 2002) and contribute both directly and indirectly to unsafe care.

Caregiver laterality (a person’s internal awareness of up, down, left, and right) influences the way in which a particular task is conducted. It is well documented that individuals have a stronger side and a preferred posture (Ozcan, Tulum, Pinar, & Baskurt, 2004; Turkan, 2003). A caregiver’s physical actions can also vary based on such individual characteristics as height, weight, and handedness (one’s ability to distinguish between left and right and coordinate one’s eyes and hands in response to that knowledge [Whittingham, 2004]). Restrictions imposed by the immediate physical environment that challenge a caregiver’s laterality can affect safety and efficiency.

For instance, caregivers who suffer from back pain owing to injuries from improper ergonomics may approach on their weaker (less dominant) side to help a patient sit up or get out of bed. Such situations are not only ripe for further injuries to the caregiver, but they also may lead to a patient fall, thereby compromising safety. Sitting patients up on the side of the bed opposite the side on which the IV line and IV pole are located can stretch
the IV and other life-support tubing and result in accidental dislodgment. Less than optimal hand-eye coordination resulting from improper ergonomics (wrong side of the bed, wrong bed height, excessive bending, etc.) can interfere with patient care tasks that require precision and the use of one’s dominant hand.

A recent study examining physical configurations and caregivers’ behavior in acute medical/surgical settings (Pati et al., 2010) revealed empirical data suggesting the potential role of biomechanics in physical environment standardization. This paper articulates the case for examining caregivers’ biomechanics in standardizing patient care environments.

Study Questions
The key questions addressed in this paper are:
• In the context of standardization of the patient care environment in inpatient settings, what types of potentially harmful or stressful actions are exhibited by nurses?
• What is the role of physical configuration versus the design of individual elements in influencing harmful or stressful actions?

Research Design
Setting and Subjects
This study focused on the acute medical/surgical setting. Since standardized environments are applicable at all levels of acuity, the medical/surgical setting constituted a logical starting point. Further, this setting represents the predominant care environment in an acute care hospital in terms of both physical design and care procedures.

A quasi-experimental design was adopted for the study. The Team Training Room (Figure 2) in a simulation teaching laboratory of a college of nursing was used for setting up and manipulating the physical configurations. The room was equipped with an identical array of redundant medical gases, provision for suction, and power outlets on both sides of a Hill-Rom bed. An adjoining control room was linked through a one-way mirror to unobtrusively observe, record, and monitor activities in the Team Training Room. Video and audio feeds from ceiling-mounted cameras were received and processed by custom-made software installed on computers inside the control room. Institutional review board approval for the study was obtained from the university in which the nursing program is located.

Subjects, recruited from among nursing students and faculty at the college of nursing, responded to an internal e-mail solicitation. Twenty nurses, 10 right-handed and 10 left-handed, participated in the study. Only female subjects were recruited because female caregivers constitute the majority of nurses in hospital inpatient units. Because this was a repeated measures study design and the study was preliminary in nature, a sample size of 20 was considered appropriate.

The subjects represented attributes of typical registered nurses working in U.S. hospitals. Their ages ranged between 21 and 62 years, with a median age of 53 years, which is equal to the median age of 1,740 respondents in a Nurse Spectrum/Nurse Week national survey conducted in 2009 (Nurse Spectrum/Nurse Week, 2009). Of the 20
subjects, one had a BSN degree and all others had at least a master’s degree in nursing. Work experience as a nurse ranged from less than 1 year to more than 30 years, with a median experience of 25 years (once again, the same median experience as the Nurse Spectrum/Nurse Week national survey conducted in 2009 [Nurse Spectrum/Nurse Week, 2009]).

The Protocol
Nine physical configurations of the caregiver zone were created using flexible rope partitions (Figure 3). The zone included the patient bed, headwall medical utilities, and five feet of space around the remaining three sides of the bed. The physical configurations ranged from an open scenario (no forced direction of approach) to direction of approach forced to the left or right of the patient. In addition to the manipulation of approach, the location of an IV pole was also manipulated. When placed on the left side of the patient, it indicated that the IV was in the patient’s left arm, and when placed on the right side, it indicated that the IV was in the right arm.
IV tubing was attached to the patient’s arm using a conventional adhesive tape. Attributes of the nine settings are outlined in Table 1 and illustrated in Figure 3. These nine configurations were created and manipulated to examine a question pertaining to same-handed patient care environments, which is explained in detail elsewhere (Pati et al., 2010).

This paper focuses on aspects of the data related to biomechanics during care delivery. All aspects of the environment other than the ones manipulated were standardized at the beginning of each simulation run, namely (a) the height of the patient bed was set at minimum; (b) the bed angle was set at 30 degrees; (c) bed rails were in the up position; (d) the over-bed table was centered at the foot of the bed; (e) the suction canisters were on a platform on both sides of

Table 1. Key Attributes of the Nine Configurations Included in the Study

<table>
<thead>
<tr>
<th>Scenario Number</th>
<th>Direction of Approach</th>
<th>IV Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1 (S1)</td>
<td>Open</td>
<td>No IV</td>
</tr>
<tr>
<td>Scenario 2 (S2)</td>
<td>Open</td>
<td>IV on patient’s left</td>
</tr>
<tr>
<td>Scenario 3 (S3)</td>
<td>Open</td>
<td>IV on patient’s right</td>
</tr>
<tr>
<td>Scenario 4 (S4)</td>
<td>Approach from patient’s left</td>
<td>No IV</td>
</tr>
<tr>
<td>Scenario 5 (S5)</td>
<td>Approach from patient’s right</td>
<td>No IV</td>
</tr>
<tr>
<td>Scenario 6 (S6)</td>
<td>Approach from patient’s left</td>
<td>IV on patient’s left</td>
</tr>
<tr>
<td>Scenario 7 (S7)</td>
<td>Approach from patient’s left</td>
<td>IV on patient’s right</td>
</tr>
<tr>
<td>Scenario 8 (S8)</td>
<td>Approach from patient’s right</td>
<td>IV on patient’s left</td>
</tr>
<tr>
<td>Scenario 9 (S9)</td>
<td>Approach from patient’s right</td>
<td>IV on patient’s right</td>
</tr>
</tbody>
</table>
the bed; (f) a Dynamap was located at the nurses station; and (g) a suctioning kit was located at the nurses station. Tasks were assigned to the nurses using standardized instructions that were repeated uniformly before each scenario (Table 2).

Subjects were instructed to perform three frequently conducted tasks in each of the nine physical configurations. The tasks involved (a) checking vital signs using a Dynamap for blood pressure measurement; (b) suctioning the patient using a hand-held suctioning kit; and (c) helping the patient sit up to dangle the legs off the bed, and return to a semi-Fowler’s position. These tasks are tasks that nurses typically conduct, and they can be performed entirely within the caregiver zone. Furthermore, these tasks represented the need for a dominant hand to suction patients and help them sit up.

Each simulation run was video recorded. The three tasks and nine physical configurations totaled 27 simulation runs for each nurse. With 20 nurses in the sample, a total of 540 simulation runs were conducted for the study. The sequence of tasks and configurations was randomized. Irrespective of the task, nurses started from a makeshift nurses station located on the footwall of the room to provide an unbiased starting point. The video segments were shown to a team of experts in nursing and kinesiology, who separately coded the segments to document nursing behavior and identify potentially stressful or harmful actions. To avoid bias, external parties conducted all data coding and statistical analyses. This paper presents the data coding completed by the kinesiology expert.

### Independent/Experimental Variables

Handedness of the physical configuration was the independent variable in this study, which was represented by the nine physical configurations that were systematically manipulated. Aspects of the physical configuration that were manipulated included (a) right-handed, left-handed, and neutral-handed configurations; and (b) IV pole on patient’s left, IV pole on patients’ right, and no-IV pole conditions.

### Table 2. Standardized Instructions

<table>
<thead>
<tr>
<th>Task</th>
<th>Script</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitals</td>
<td>Please take your patient’s vital signs, and then return to the nurse station.</td>
</tr>
<tr>
<td>Suctioning</td>
<td>Your patient is a new admission who has a tracheotomy and will need to be suctioned now. Please pretend to suction your patient, and then return to the nurse station.</td>
</tr>
<tr>
<td>Sitting up</td>
<td>Please sit your patient on the edge of the bed and return to a semi-Fowler’s position, and then return to the nurse station.</td>
</tr>
</tbody>
</table>

The same patient actor served as the patient in all simulated care scenarios. All patient attributes were controlled; no patient variables were introduced in the study. The patient actor was instructed to assume the role of a conscious, cooperative patient with no pain who needed supportive assistance moving from a semi-Fowler’s position to sitting on the side of the bed with legs dangling off the side of the bed.
Dependent/Outcome Variables

Dependent or outcome variables in the study included the number of times certain behaviors and postures were observed in the nurses as they performed the three tasks. Behaviors coded included (a) direction of approach; (b) any hesitation in approach; (c) over-bed table use; (d) bed rail adjustment; (e) bed height adjustment; and (f) bed angle adjustment. In addition, the following postures were recorded: (a) stretch; (b) bend; (c) unstable; (d) lift; (e) twist; and (f) reposition. Operational definitions of the postures are included in Table 3.

Data Analysis

The kinesiology coding included identifying actions that were potentially stressful or harmful, and evaluating the physical environment to identify any environmental correlates of these actions. Coding involved two sets of video segments for each nurse: one for the suctioning task and one for sitting the patient up on the side of the bed. Video segments on checking vital signs were not included in the analysis because they were not considered to be associated with any safety issue arising either from the configuration or the design of the elements.

Within each set of video segments were two scenarios: the least challenging scenario and the most challenging scenario. The least and most challenging scenarios were identified based on the natural preference of approach and the location of the IV pole as a potential obstruction. The natural side preference of each nurse was identified from the first scenario (Figure 3), which involved neither a constraint in approach nor any obstruction in the care environment. As reported elsewhere, the natural side preference of the nurses was not consistently associated with their individual handedness (Pati et al., 2010). The least challenging case was the one in which subjects were on their preferred side and the IV pole was located on the opposite side. The most challenging case was the one in which subjects were not situated on their preferred side and the

Table 3. Operational Definitions of Posture Terms

<table>
<thead>
<tr>
<th>Posture Type</th>
<th>Operational Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretch</td>
<td>Performing tasks outside a 30” radius from one’s neutral (erect) position without bending, and then applying force.</td>
</tr>
<tr>
<td>Bend</td>
<td>Moving the spine (lower back) away from the erect position and applying force. Includes all directions.</td>
</tr>
<tr>
<td>Unstable</td>
<td>Bending or stretching while standing on one leg, and applying force.</td>
</tr>
<tr>
<td>Lift</td>
<td>Lifting patient from a height outside the range of one’s waist to shoulder area.</td>
</tr>
<tr>
<td>Twist</td>
<td>Twisting any part of the body or the entire body to accomplish a task, with or without applying force.</td>
</tr>
<tr>
<td>Reposition</td>
<td>Changing one’s physical location (distinctly) once a task is in progress to achieve better body posture or control.</td>
</tr>
</tbody>
</table>

Note: Definitions are based (with modifications) on descriptions provided by Feletto and Graze, 1997. In the definitions, "applying force" means (a) lifting an object or person, or (b) pushing or pulling an object or person, or (c) both.
IV pole was located on the same side as the subject. The IV pole was considered an obstruction for the nurses in these scenarios based on other data collected in the study and reported elsewhere (Pati et al., 2010). In this strategy, a total of 80 simulation segments were coded to identify potentially detrimental actions.

The kinesiology expert was tasked with examining the video segments and, for each subject and task, assessing the number of times the nurse was observed stretching, bending, unstable, lifting, twisting, and repositioning that represented a potentially harmful action. The expert also indicated whether the observed harmful action was associated with the physical configuration of the caregiver zone (direction of approach to the patient, location of IV pole), with the design of individual elements (bed and/or headwall), or both. Actions were attributed to the design of an individual element if it was observed that the action could be rectified by redesigning that specific element alone; changes in the physical configuration would not affect the action. Examples in this category include excessive bending to access bed controls or bending to access headwall utilities in the absence of any obstructions. This constitutes a bed or headwall design issue that can be resolved through element design alone, and it may not be influenced by modifying the configuration. Note that when an action involves multiple elements, the configuration becomes an issue by default.

Actions were classified as originating from configuration issues when it was determined that changing the design of individual elements would not alter the situation. For instance, a nurse positioned too far from the patient to be able to appropriately and safely apply force was considered a configuration issue. Such situations arise when nurses use their nondominant side because there is an obstruction that prevents the use of their preferred side. This situation cannot be rectified by changing the design of an element; it can be addressed only by focusing on the configuration (the space available around the patient bed and the location of equipment combined, to enable flexibility in decisions pertaining to positioning oneself vis-à-vis the patient).

Actions were attributed to both when solving a situation demanded actions on both the design of individual elements and modification of the configuration. Changing either the design or the configuration alone would not solve the problem. For instance, “the nurse having single-leg support and leaning between the IV pole and bed to attach suction to the wall” constitutes a configuration issue (the presence of the IV stand as an obstruction) as well as an element design issue (the vertical position of medical utilities on the headwall), thus requiring action on both fronts.

**Findings**

Data analysis indicated that a larger number of potentially stressful or harmful actions originated from nurses’ interactions with the bed and the headwall than with the configuration of the environment (direction of approach, location of the IV pole, and so forth). Table 4 provides a summary of the frequency of detrimental actions and their sources of influence for the suctioning and
sitting-up tasks. Of 674 potentially harmful or stressful actions identified by the kinesiology expert, 587 (87%) were related to the nurses’ interaction with the bed or the headwall. Physical room configuration accounted for the remaining 13%.

The majority of detrimental actions in the suctioning task involved bending and twisting. In the sitting-up task, the majority of detrimental actions involved stretching, bending, and twisting. Tables 5 and 6 summarize the frequency of observations in the case of left-handed and right-handed nurses. The pattern for both is similar for both types of action; the proportions attributable to physical configuration versus the design of the headwall and bed are also similar.

A review of the exact nature of action provides a clearer picture regarding the role of biomechanics in standardization strategies. Many of the interactions are associated with both configuration

Table 4. Potentially Harmful and Stressful Actions and the Sources of Influence in the Suctioning and Sitting-Up Tasks

<table>
<thead>
<tr>
<th></th>
<th>Stretch</th>
<th>Bend</th>
<th>Unstable</th>
<th>Lift</th>
<th>Twist</th>
<th>Reposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Headwall/Bed Configuration</td>
<td>Headwall/Bed Configuration</td>
<td>Headwall Configuration</td>
<td>Headwall Configuration</td>
<td>Headwall/Bed Configuration</td>
<td>Headwall/Bed Configuration</td>
</tr>
<tr>
<td>Suctioning</td>
<td>1</td>
<td>0</td>
<td>46</td>
<td>1</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>41</td>
<td>115</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sitting Up</td>
<td>47</td>
<td>25</td>
<td>160</td>
<td>21</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>115</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>25</td>
<td>206</td>
<td>22</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>312</td>
<td>26</td>
<td>9</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The values in the table represent the number of times potentially harmful and stressful actions of each type was observed among all nurses in the study.

Table 5. Frequency of Potentially Harmful Actions Involving Patient Suctioning Task for Left-Handed and Right-Handed Subjects

<table>
<thead>
<tr>
<th></th>
<th>Stretch</th>
<th>Bend</th>
<th>Unstable</th>
<th>Lift</th>
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<td>Headwall Configuration</td>
<td>Headwall Configuration</td>
<td>Headwall/Bed Configuration</td>
<td>Headwall/Bed Configuration</td>
</tr>
<tr>
<td>Right-handed RN</td>
<td>1</td>
<td>0</td>
<td>32</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>74</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Left-handed RN</td>
<td>0</td>
<td>46</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>115</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The values in the table represent the number of times potentially harmful and stressful actions of each type was observed within each category of nurse.
and design factors. Examples of purely design factors include “inappropriate posture while attaching and removing the suction tube to and from the headwall,” “stretching down to lower and raise bed rails,” and “stretching to view bed controls” while delivering care.

Of greater importance are actions that are influenced by the design of individual elements as well as configuration. Such examples include “the nurse having single-leg support and leaning between the IV stand and bed to attach suction to the wall” and “grasping and positioning the suction tube around the IV.”

A factor that further complicates these interactions is the preferred side of individual nurses. As noted earlier, the study found that nurses’ preferred side was not necessarily the same as their handedness. Certain unsafe actions were related to the side preference of the nurses in the study, as revealed in this analysis of the sitting-up task:

The nurse stood farther away from the patient compared to the preferred side.
The nurse stood with a more erect posture on this (nondominant) side compared to preferred side.
Nurse stood erect and lifted the patient. Unsafe for both nurse and patient. On preferred side, she braced her body against the bed. On this (nondominant) side, she was unbraced.

To put these observations in context, these comparisons were being made regarding the observed behavior of the same nurse as she was performing the sitting-up task, but from two different sides of the patient. The preferred side of the nurse means the side that she naturally prefers to be on. As mentioned earlier, the natural preference of each nurse was identified from the first scenario.

Table 6. Frequency of Potentially Harmful Actions in the Least and Most Challenging Scenarios Involving Patient Sitting-Up Task for Left-Handed and Right-Handed Subjects

<table>
<thead>
<tr>
<th></th>
<th>Stretch</th>
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<td>Headwall Configuration</td>
<td>Headwall Configuration</td>
<td>Headwall/Bed Configuration</td>
<td>Headwall Configuration</td>
</tr>
<tr>
<td>Right-handed RN</td>
<td>22</td>
<td>10</td>
<td>78</td>
<td>10</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Left-handed RN</td>
<td>25</td>
<td>15</td>
<td>82</td>
<td>11</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>25</td>
<td>160</td>
<td>21</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note: The values in the table represent the number of times potentially harmful and stressful actions of each type was observed within each category of nurse.*
(Figure 3), which involved neither a constraint in approach nor any obstruction in the care environment.

To examine further the factors contributing to potentially harmful actions, a 2 x 2 x 2 factorial design was adopted, and a regression analysis was conducted. The three factors were (a) challenge (least challenging and most challenging); (b) handedness (left-handed and right-handed); and (c) side preference (left side and right side). Separate analyses were conducted for harmful actions attributable to interactions with the headwall or bed and for those associated with physical configuration.

Tables 7 and 8 show the statistical significance of the chi-square estimate in the analysis involving suctioning and sitting-up tasks, respectively. The analysis shows that significant harmful actions

### Table 7. Significant Main Effects Involving Potentially Harmful Actions Associated With Suctioning Task

<table>
<thead>
<tr>
<th></th>
<th>Stretch</th>
<th>Bend</th>
<th>Unstable</th>
<th>Lift</th>
<th>Twist</th>
<th>Reposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenge (Least vs Most)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handedness (Left vs Right)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Side (Left vs Right)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *** (significant at .001); + (significant at 0.1)
Blank cells denote insufficient frequency of observation to conduct statistical testing.

### Table 8. Significant Main Effects Involving Potentially Harmful Actions Associated With Sitting-Up Task

<table>
<thead>
<tr>
<th></th>
<th>Stretch</th>
<th>Bend</th>
<th>Unstable</th>
<th>Lift</th>
<th>Twist</th>
<th>Reposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenge (Least vs Most)</td>
<td>0.30</td>
<td>0.000***</td>
<td>0.99</td>
<td>0.83</td>
<td>0.004**</td>
<td></td>
</tr>
<tr>
<td>Handedness (Left vs Right)</td>
<td>0.76</td>
<td>0.37</td>
<td>0.97</td>
<td>0.33</td>
<td>0.83</td>
<td>0.20</td>
</tr>
<tr>
<td>Preferred Side (Left vs Right)</td>
<td>0.51</td>
<td>0.68</td>
<td>0.16</td>
<td>0.83</td>
<td>0.46</td>
<td>0.052+</td>
</tr>
</tbody>
</table>

Note: *** (significant at .001); ** (significant at 0.01); * (significant at 0.05); + (significant at 0.1)
Blank cells denote insufficient frequency of observation to conduct statistical testing.
in suctioning tasks are mostly associated with interactions with the headwall or bed, confirming the findings of the preceding exploratory data analysis. Harmful bending and twisting are the most frequently observed actions. Handedness of the subject and preferred side were the significant main effects. On the other hand, potentially harmful actions in sitting-up tasks were related to physical configuration. Significant effects were observed in stretching, bending, and twisting. The level of challenge and preferred side had significant main effects.

Discussion
This paper presents data from a study examining the influence of the physical configuration of patient care rooms in acute medical/surgical settings on nurses’ behavior. Part of the data collected measured the frequency of actions that could potentially be harmful or stressful to the caregiver and hence contribute to unsafe care. Kinesiology coding of the nurses’ behavior captured in video segments examined the influence of physical configuration (approach direction, IV pole location, and so forth) and the design of physical elements, specifically headwall and patient bed, on the behavior observed. Analysis of the data suggests that harmful or stressful behaviors that can be attributed to the design of the headwall or patient bed far outnumber instances originating from the configuration of the setting. More critically, numerous instances included the influence of both the physical design of the elements and the configuration of the setting, resulting in unsafe work-arounds.

The larger proportion of unsafe actions originating from the design of elements is illuminating in that the attributes of the nine configurations (except for approach direction and IV location) were standardized, as outlined previously. If the nine configurations used in the study are hypothetically considered as nine separate rooms in a patient care unit, the environment of care immediately around the patient (the caregiver zone) can be considered standardized. Thus, even in a standardized environment of care, a large number of potentially detrimental actions occurred.

The examples related to the design of elements suggest that repeating the same headwall design across all rooms may reduce cognitive load, but it may not reduce potentially harmful or stressful actions originating from improper biomechanics that affect safety. Because the number of elements used in the study was limited, observations in actual settings may detect substantially more actions that are unsafe and influenced by the design of individual elements irrespective of the degree of uniformity in location, configuration, and design through standardization.

More importantly, instances pertaining to the combined influence of elements and configura-
tions articulated in this paper show that the biomechanics of care should be a crucial aspect of any standardization strategy, because a number of factors—more than simply the location and design of individual elements—work together during patient care to generate unsafe actions.

Examples pertaining to the sitting-up tasks demonstrate the role of handedness and laterality, especially in the context of side preference. Side preference is important because obstructions in the environment are major factors that influence a nurse’s decision regarding where to position herself vis-à-vis the patient. When positioned on her nonpreferred side, obstructions result in work-arounds that, in association with ergonomic factors, result in detrimental actions.

The observation that potentially harmful or stressful actions originate from the ergonomics of the patient care environment is not novel. Such topics regarding the healthcare environment have been covered in the literature and provided guidelines for design (for instance, Feletto & Graze, 1997). The fact that configuration factors can potentially interact with ergonomic design issues to influence actions points to the need to include ergonomic issues in the development of standardization. Consistency in the design and location of physical elements in combination with ergonomic design optimizes the standardization of the physical environment of care.

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Thus, standardization for safe care delivery involves more than addressing cognitive lapses. Standardizing the design and location of elements, although it reduces cognitive load through improved familiarity, does not completely eliminate unsafe care practices. One of the origins of unsafe actions is working around furniture and equipment. Even in the relatively sparse environment of care adopted in this study, there were instances in which nurses engaged in unsafe actions. In actual patient care settings and at higher levels of acuity, the environment around the patient can be considerably more complex owing to the amount and size of the equipment surrounding the patient.

From the viewpoint of cognitive support, a strategy to standardize the order and placement of the most frequently used equipment could improve familiarity significantly. However, unless such standardization rules examine the work-arounds that equipment placement engenders, the effect of standardization on safe care practices will be diminished. Moreover, from a biomechanical perspective, standardization should also examine
teamwork and the way team interaction may be facilitated or impeded by the standardized design and location of the physical elements around the patient.

It is interesting to note that, although substantial knowledge exists regarding safe postures and actions, and every hospital project includes a thorough review of room mock-ups to evaluate the care environment, there appears to be little similarity in the design of the physical components of patient rooms across hospitals. It is as if the lack of commonality among caregivers precludes the creation of standardized designs that work across different settings and systems. The key question is whether a range of physical design parameters can be identified that affords safe biomechanics for patient care.

The identification of a value-range of important parameters could help generate standardized physical environments that work effectively across hospitals. This optimization value-range (as opposed to a static value) would allow for diversity across patient rooms as well as customization without compromising safety. This is particularly important for clinical staff who work in more than one hospital (agency nurses and physicians) because they could, theoretically, move among sets of standardized environments optimized for safe care with few commonalities in terms of familiarity or the biomechanics of care delivery.

Owing to logistical and financial constraints, this study was limited to an experimental setting, three patient care tasks, 20 subjects, and a single kinesiology coder. From that perspective, the findings presented here are more theoretical in nature, insofar as they help produce an expanded framework from which to view the concept of healthcare environment standardization. The number of data points was not large enough to examine interaction effects statistically. Future studies on the topic should begin with a larger sample, in more realistic care settings, and with an expanded range of tasks. In addition, patient variables should be introduced in follow-up studies.

A limitation of this study was that the patient condition was kept constant. Because behaviors and actions are influenced by patient variables—type of illness, location of injury, acuity level, and so forth—introducing such variability is essential. Finally, additional studies should include a thorough examination of the way caregivers interact with physical elements and equipment interfaces, including, among others, the biomechanics involved in such interactions in both individual and team care.

References


