Title Page

1) Title of the article

Evaluating Nurses' Perception of Patient Safety Design Features in ICUs

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(4) Acknowledgments credits, or disclaimers and

NONE

(5) Disclosure of funding received for this work from any of the following organizations:

The study was financially supported by the following fellowships: Arthur N. Tuttle Jr. Graduate Fellowship by the American Institute of Architects (AIA) and the Graduate Summer Research Fellowship from the University of Kansas.

Abstract

A methodological study was conducted to test the validity and reliability of the patient safety (PS) scale developed by Rashid (2007) for evaluating nurses' perception of adult ICU design features related to patient safety. Data for the study were collected using a web-based survey instrument. A link to the survey instrument was posted on the website of American Association of Critical-Care Nurses (AACN) for ICU nurses in different US states to participate. A sample of 587 valid responses was divided into two halves for cross-validation. The first half of the sample was used for exploratory factor analysis (EFA) and the second half for confirmatory factor analysis (CFA). This method was applied to identify any latent factor structure in the PS scale. Based on the factor analyses, four relevant PS subscales – *Efficient Work Process*, *Patient Room*, *Accessibility and Visibility*, and *Maintain Sterility* – were identified. These PS subscales were used to investigate whether ICU unit characteristics, nurse characteristics and hospital type affected nurses' perception of ICU design features in relation to patient safety. The study shows that nurses' perception of ICU design features related to patient safety can be influenced by such factors as nurse characteristics and unit characteristics. When using the scales, therefore, the designers can be aware of the influence of these external factors on nurses' perception. It is hoped that the PS subscales evaluating nurses' perception of ICU physical environmental features related to patient safety would help designers and healthcare personnel make better ICU design choices.

KEYWORDS: intensive care unit, nurse perception, patient room, patient safety, scale development, unit layout

Introduction

In the United States, the Institute of Medicine found that medical errors were common and adversely affected patient outcomes in hospitals. [1] The report estimated that 98,000 fatalities result from medical errors every year in the United States. Intensive care units (ICUs) provide many opportunities for medical errors. ICUs are fast-paced and complex environments, which commonly require physicians with varying levels of critical care training to make urgent, high-risk decisions, often with incomplete data.[1] ICU patients are also highly vulnerable to medical errors. They have both underlying comorbidities and acute organ dysfunctions, and they require life-sustaining treatments, frequent interventions and medications, and highly technical medical care. [2]

To ensure patient safety, various environmental features of ICUs and ICU patient rooms play an important role. The layout of the unit and the patient room can provide easy access to patients from the nurse station. The finished materials in the unit and the room can be conducive to easy maintenance and cleaning to control infection.[3] The unit and the patient room can be designed to improve visibility from the nurses' workstation. Dedicated space for patient supplies and medication can reduce medical errors by reducing distraction, interruption, and fatigue.[4] Ergonomically designed patient rooms with appropriate support facilities can increase patient safety. [3] Therefore, there is a need for a measurement scale that evaluates design features related to patient safety in ICU.

Over the last several decades, many instruments assessing organizational and professional environments in ICUs have been reported in the literature. Some of these help measure common psychological stressors related to work and medical processes in the ICUs.[5 6 7] Others help measure autonomy, leadership, communication, coordination, problem solving, conflict management, team cohesiveness, and other organizational context traits that characterize ICU practice environments (see reference 8-15). However, scales evaluating design features in Adult ICUs remain rare (e.g., Rashid et al, 2014; Rashid, 2007)[16 17]. Among the scales evaluating design features in adult ICUs reported in the literature, Rashid's[17] scales are most relevant to the present study. These scales measure such ICU relevant constructs as patient comfort, patient privacy, patient safety, supportive staff working conditions, and family integration with patient care. As discussed in the next section, designed as a pilot study, Rashid[17] had several limitations. Therefore, the purpose of this study was to investigate the validity and reliability of Rashid's[17] scales for evaluating nurses' perception of ICU design features related to patient safety using a large national sample of ICU nurses, and to evaluate the effect of nurse characteristics, unit characteristics, and hospital type on nurses' perception of ICU design features using these scales.

Examining the existing patient safety scale

In the pilot study[17], the literature on the physical environment of the adult ICUs was reviewed to select 22 items belonging to the patient safety (PS) scale. The items in the questionnaire had 5-point Likert scale, and the items in each domain were grouped into room level and unit level. Here, we examine 1) the methods used for psychometric analysis in the pilot study, 2) the psychometric properties of the scale, and 3) the limitations of the pilot study.

Psychometric analysis of the scale

The methods used by Rashid[17] to conduct psychometric analysis are described below, and the methods are graphically represented in Figure 1.

Identify the Non-Variant items: The non-variant items indicated that staff members' perception of those items did not vary. Since the association of a non-variable item with other variables could not be statistically determined, it was discarded from the study.

Test for Internal consistency: Test for internal consistency of the remaining variant-items was done using Cronbach's coefficient alpha α. Coefficient alpha measures internal consistency reliability among a group of items combined to form a single scale.[18] According to Litwin, [18] this statistic reflects the homogeneity of the scale, indicating how well different items measure the same issue.

Principal Component Analysis (PCA): The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set, which consists of a larger number of interrelated variables while retaining as much as possible of the variation present in the data set. [19] In the study, the principal components (PCs) comprised of uncorrelated variables, which were then combined to form subscales. The new subscales were then tested for internal consistency reliability.

Correlation among scales and sub-scales: Correlation among scales and sub-scales were evaluated systematically both within and between domains. This analysis identified highly correlated factors that could be combined into a single construct. [20]

The psychometric analysis of the PS scale in Rashid[17] is shown in Figure 2. The 11 items in the patient safety scale had an unacceptable alpha value (α= -0.763). PCA was done on the 11 items, and the first four components were retained for a meaningful amount of variance. It was assumed that the rest of the components accounted for only trivial amounts of variance. Four subscales were created based on the PCs: PSS I, PSS II, PSS III, & PSS IV. The internal consistency was tested on these new scales. The three scales PSS I (0.88), PSS III (0.667), PSS IV (0.606) had acceptable reliability. Only PSS II (0.458) had low reliability, and was discarded.

Limitations

The PS scale and subscales were pilot tested with a sample size of seven respondents from best practice examples of adult ICUs built between 1993 and 2003.[17] Therefore, it is necessary to test the validity and reliability of the scales and subscales in a large and heterogeneous sample. Some of the items in the scale and subscales addressed more than one design feature. Therefore, the items can be broken down to address individual design feature. Additionally, the underlying dimensions or facets (e.g., sterility) of the PS scale were not properly assessed. Further, any evaluation of ICU design features from a nurse perspective may be impacted by characteristics of the nurse, the characteristics of the ICU, and the type of hospital in which the ICU is located. Rashid[17] did not examine these impacts. Therefore, further research is required to improve the usability of the PS scale and subscales.

Methods

Developing a framework for the study

A framework for the analysis of nurses' perception of the physical environmental features of the ICU is shown in Figure 3. The study begins by defining the items of the PS scale following Rashid[17]. Then, the study examines the underlying dimensions of the scale. Following this, the study provides evidence of validity and reliability for the scale. Finally, the study includes explanatory variables that may influence nurses' perception of ICU design features related to patient safety.

The items in the PS scale only focus on the physical environmental features that can be related to patient safety such as, but not limited to, HEPA filters, handwashing sinks, and easy to clean finishes. It does not include patient safety features related to medications, or any other safety culture features such as, but not limited to, communication, organizational characteristics, team factors, and managerial support.

The study assumes that the patient safety construct is multidimensional. In other words, the items in the PS scale may group together or co-vary because they belong to a specific dimension within the scale, thus creating subscales. The plausibility of this assumption is tested by applying the statistical technique of factor analysis, which is discussed in data analysis section. The PS subscales are tested for reliability. In addition, the PS scale and subscales are also analyzed for construct validity through factor analysis.

To explore how nurses' perception of the design features may be influenced by nurse characteristics, ICU unit characteristics, and hospital type, the following explanatory variables were included in the study:

Nurse characteristics:

a) Gender: female or male
b) Professional Title: staff nurse, charge nurse, assistant or nurse manager
c) Position in the Unit: permanent, temporary, floating, per diem , contract, agency
d) Nursing Degree: LPN, Diploma, Associate, Bachelors, Masters, Doctorate
e) Years working: ,<1,1-6, 7-11, >11

ICU Unit Characteristics:

a) Number of beds in the unit

b) Care model: closed or opened
c) Life Support System: Headwall, Power Column, Pendant, other (Note: this questions included images of these systems)
d) Layout: Open, Corridor, Duplex, Racetrack, Courtyard, Cruciform, Radial, others (Note: this questions included images of these layout types)
e) Patient Mix: Coronary, Cardiovascular, Medical, Surgical, others

Types of Hospital:

a) Teaching Hospital
b) Community Hospital
c) Community-Based Teaching Hospital

Sample and Data Collection

Data for the study were collected from a large national sample of critical care nurses using a web-based survey. The Web-based survey was developed using the Qualtrics software. The survey was pretested by completing the survey repeatedly to make certain that it ran smoothly. The survey was also pretested for different internet browsers, such as google chrome and internet explorer, to ensure that the survey appeared and performed as it should during online survey.

Once the web-based survey development was completed, IRB approval was sought. The approved IRB document, along with the web-based survey was sent to American Association of Critical-Care Nurses (AACN) for assessment. After making necessary changes based on the AACN assessment, a link to the survey was posted on the e-newsletter in the AACN Website; and incentives in the form of a gift card was offered to respondents for completing the survey successfully.

Based on a pilot study using survey responses from 21 critical care nurses working at a teaching community hospital in Chicago, a mean duration of 10 minutes for completing the survey was determined. Therefore, all surveys completed under 10 minutes through the AACN website were deemed insincere and were excluded from the study. Each of the remaining surveys was examined for completeness and eligibility to include in the study. The study used the following three exclusion criteria to identify incomplete, unsatisfactory, and dishonest surveys from the dataset: (a) if responses from the scale questions were missing; (b) if all answers were the same (e.g., all "3" or "5"), indicating that the respondent did not give the survey their full attention or the survey responses were programmed; and (c) if the survey was completed in less than the mean duration of 10 minutes. The implementation of the criteria in the data resulted in 587 observations (Table 1).

- 36.3% of the responses were received from teaching hospitals, 38.8 % from community hospitals, and 24.9% were received from community-based teaching hospitals.
- More than half of the ICUs used an open patient care model (58.4 %), where the physician responsible for the patient admits the patient to the ICU and keeps the formal responsibility for the patient and his treatment. The rest of the ICUs (41.6%) used closed patient care model, when an intensivist takes over the responsibility of the patient.
- In the patient room, the most prevalent life support system is the headwall (59.5 %), followed by the power column (24.7 %). Only 14.1% had a pendant-type life support system.
- The most common ICU layout type was racetrack (21.6 %), corridor (20.2%), and radial (12.8%). To find out more on layout types in ICU, see reference 21 and 22.
- The ICUs had the following types of patient mix: Coronary (8%), cardiovascular (11.9%), medical (26.7%), surgical (8.4%) and others (45%).

- Regarding nurse characteristics, females constituted the larger portion of the sample (89.4 %).
- The sample included staff nurse (67.7%), charge nurse (24.1%), and nurse managers (0.08%)
- Most of the nurses had permanent position in the unit (86.0 %). The others held temporary, floating, per diem, contract and agency positions.

Data Analysis

Factor analysis was used to identify a smaller number of factors from a large number of items in the PS scale. As a precursor to factor analysis, the Kaiser-Meyer-Olkin (KMO) test was done to examine the factorability of the correlation matrix.[23] The data (n = 587) was randomly split into halves for conducting exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).The first half of the sample was used to explore the factor structure using EFA, and the second half was used to replicate the factor structure using CFA. This process of reproducing the hypothesized factor structure in a new sample is important for establishing validity. [24] Items in the scale with weak factor loadings were eliminated from the EFA analysis, and the EFA was rerun with the same sample. The latent dimensions were named to convey the ideas of the items in each factor.

The factors were examined for reliability using CFA-based reliability methods.[25-27] Based on the results of factor analysis, subscales were computed to investigate the effects of independent variables such as hospital type, unit characteristics, and nurse characteristics on nurses' perception of ICU design in relation to patient safety using the whole sample (n = 587).

EFA

Maximum likelihood (ML) was used to estimate the EFA model using Mplus 6 latent variable software. Factor selection was based on goodness-of-fit model indices. The cut off values for the goodness-of-fit indices were obtained from.[28] The goodness-of-fit indices for EFA in Mplus 6 included chi-square (χ^2), root mean square error of approximation (RMSEA<0.05), and root mean square residual (RMSR<0.05). A more interpretable solution was reached with promax oblique rotation. Factor loadings greater than or equal to 0.30 were interpreted as salient loadings. [28]

CFA

Maximum Likelihood (ML) was used for estimating parameters with the MLR option in Mplus6 because it provided standard errors and chi-square (χ^2) that were robust to nonnormality.[27] Goodness-of-fit was evaluated using standardized root mean square (SRMR), RMSEA, and its 90% confidence interval (CI), as well as the test of close fit (CFit), the comparative fit index (CFI), and the Tucker-Lewis index (TLI). Multiple indices were selected because they provided different information for evaluating the model, such as absolute fit, fit adjusting for parsimony, and fit relative to a null model.[29] Guided by Brown[28], Hu and Bentler[30], and Sun[31], acceptable model fit was defined using the following criteria: RMSEA (≤ 0.05 lower, 0.08 upper, CI ≤ 0.06, CFit *nonsignificant* (i.e., $p > .05$); SRMR (≤ 0.08); CFI (≥ 0.90, 0.95); TLI (≥ 0.90, 0.95). A chi-square difference test was computed for competing nested models.

Patient Safety Subscales

The effects of hospital type, unit characteristics, and nurse characteristics on nurses' perception of patient safety (PS) subscales were examined. To study the effects of categorical variables on nurses' perception, one-way ANOVA and MANOVA were used. To investigate the impact of continuous variables such as 'the number of beds' and 'the number of years working' on nurses' perception, simple regression was used. The variable 'the number of beds' had a number of missing cases. Therefore, the statistical technique of multiple imputation was applied. The results were pooled from 20 regressions. Therefore, in this case the R is an approximate parameter estimate. The subscales were created in Stata 13 by averaging the item score of each respondent. The statistical analysis of one-way ANOVA, MANOVA, and correlation were done using Stata 13.

Results

EFA

The KMO measure of sampling adequacy (.83) indicated that the 21 items were suitable for factor analysis. The 21 PS items were submitted to an EFA (n = 294) with ML estimation and promax oblique rotation. Regarding goodness-of-fit model indices, in Mplus 6, EFA analysis adds one factor at a time, and the model fit is evaluated for each model (Table 2). The χ^2 statistics showed that the value was significant for every model. The estimated value of RMSEA showed poor fit for the one-factor model (0.102) and two-factor model (0.085). The estimated values of RMSEA for three-factor, four-factor, and five-factor (0.073, 0.066, and 0.061) were within the range of acceptable fit. So, a five-factor solution could be retained. However, the fifth factor had no salient loadings and, as a result, the four-factor model was retained. Promax oblique rotation was done and, as a more interpretable solution was reached, the factors were characterized as *efficient work process*, *patient room*, *accessibility and visibility*, and *maintaining sterility* (Table 3).

The rotated factor solution revealed two items with low loadings in all the factors. They are Item 3 - "clean sinks and waste disposal sinks are separated," and Item 15 - "patient beds convert easily into a chair" (shown in boldface in the table). Therefore, these items were deleted from the PS scale. After deleting the two items, EFA was rerun in the same sample to make sure that the factor structure remained unchanged.

Factor 1: Efficient work process. This contained four items (Items: 1, 6, 7, and 9) with loadings > 0.30, of which two items (Items: 6, and 9) had loadings > 0.50. Items 6 and 7 reflected PS features related to infection control in the patient room that can be performed effectively. Item 1 related to work movement regarding supplies and people in the unit. Item 9 related to efficient work movement. Item 11, "clinical staff can observe patients while working at their workstation," had cross-loading (0.315) on this factor. Examination of the content in Item 11 showed that it reflects the concept of efficient work process as well. In sum, the items in this factor reflected nurses' perception on efficiently controlling for infection and efficiently moving on the unit.

Factor 2: Patient room. This contained 10 items (Items: 12, 13, 14, 17, 18, 19, 20, 21, 8, and 2), of which six had loadings > 0.40. The majority of patient care happens in the patient room. The items reflected nurses' perception on ergonomics for efficient and safer handling of patients, availability of necessary technology and support facilities, and availability of necessary facilities to control infection.

Factor 3: Accessibility and visibility. This contained three items (Items: 10, 11, and 16) with loadings > 0.60. The items reflected nurses' perception on easy physical and visual access to patients. Item 17, "there is enough illumination to monitor a change in patient's color," has cross-loading (0.326) on this factor. Examination of the content in Item 17 showed that illumination is related to visibility, and that is why it has salient loading on Factor 3.

Factor 4: Maintain sterility. This contained two items (Items: 4 and 5) with loadings greater than > 0.60. It reflected nurses' perception on maintaining a sterile environment in the unit.

CFA with 19 items

The four-factor model of the PS scale from EFA was specified in CFA with the other half of the sample (n = 293). In CFA, three models were tested: (a) Model 1, a four-factor model representing the four factors identified in the EFA; (b) Model 2, a four-factor model with a correlated error; and (c) Model 3, a single-factor model with a correlated error, where all items were allowed to load onto a single latent factor. For Model 2, the error terms of Item 10, "it is quick and easy to get to patients from nurse stations," and Item 11, "clinical staff can observe patients while working at their workstation," were hypothesized to be correlated due to similar content and wording. For Model 3, all 19 items were loaded on a single latent factor to test the possibility of a unidimensional scale, rather than a four-factor model. Table 4 shows the goodness-of-fit indices for all three models.

Model 1: Four-factor model. Concerning model fit, the χ^2 test was significant, indicating the model did not exactly hold in the population. Both CFI (0.874) and TLI (0.853) was ≤ 0.90, indicating a mediocre fit. Yet, RMSEA (0.062) was within the range of acceptable fit (0.05–0.085), and the lower limit (0.052) of its 90% CI was ≤ 0.06, but the CFit test was statistically significant (p <0.001), indicating that the close test hypothesis was rejected. The SRMR (0.062) was less than 0.08, indicating an acceptable fit. In conclusion, both CFI and TLI were less than 0.90, indicating a mediocre fit, but as both RMSEA and SRMR were less than 0.08 (indicating an acceptable fit). Overall, the model fit was marginally acceptable.

Model 2: Four-factor model with a correlated error. In support of error theory predictions involving Items 10 and 11, MI (19.521) pertaining to the correlated errors revealed points of strain in the model. Therefore, the error covariance of Items 10 and 11 was specified and freely estimated in Model 2 (Figure 4). The revised model with a correlated error provided a better fit to the data showing $\chi^2(145) = 290.324$, $p < 0.001$, RMSEA = 0.058, 90% CI = 0.049–0.068. The CFit was significant ($p < 0.001$, SRMR = 0.061, CFI = 0.888, TFI = 0.868). The CFI (0.888) was positioned on the edge of acceptable fit (≥ .90). A χ^2 difference test (χ^2_{diff}) was done to see whether the model fit significantly. The $\chi^2_{diff}(1) = 362.9$, $p < 0.001$ was significant, and Model 2 was accepted.

Model 3: One-factor model with correlated error. All items in this model loaded on a single latent variable. This was done to test the possibility of a unidimensional scale rather than a four-factor model. The goodness-of-fit statistics for this model were $\chi^2(151) = 496.197$, $p < 0.001$, RMSEA = 0.088, 90% CI = 0.080-0.097, SRMR = 0.077, CFI = 0.735, and TFI = 0.699, indicating a poorer fit. These results supported a four-factor model over a one-factor model.

In conclusion, Model 2 was a better fit for the data. All factor loadings were above 0.40 (see Figure 4), which is the traditional cutoff value for factor loadings (Wang & Wang, 2012).

Reliability. The scale reliabilities of the factors (i.e., subscales) were acceptable, ranging from 0.65 to 0.80 (Table 5). The reliability of the items was accepted if the values was above 0.60.

- The scale reliability of the factor ***efficient work process*** was 0.65. Examination of the factor showed that Item 1 (0.286) and Item 9 (0.105) had item reliability, indicating that only 28.6% and 10.5% of the variance in the items was accounted for by the latent factor efficient work process.
- The scale reliability of the factor ***patient room*** was 0.80. However, it consisted of four items that had low reliability, and Item 2 (0.173) was one of the four items.
- The scale reliability of factor ***accessibility and visibility*** was 0.67 because out of two items, one item (Item 10) had low reliability (0.183).
- Lastly, the scale reliability of factor ***maintaining sterility*** was 0.75 as both the items in the factor had good item reliability (Item 4 = 0.504, Item 5 = 0.744).

Despite the fact that some items showed poor reliability, the subscales were usable for they had acceptable scale reliability, and most factor loadings were high.

Factor correlations. Factor correlations (Figure 4) for the PS subscales ranged from 0.217 to 0.796, indicating that they are within the range of cutoff ≤ 0.85 (Brown, 2006). Therefore, the PS scale indeed had four distinct dimensions or factors, defining four different subscales. The factor ***efficient work process*** had high correlation with ***patient room*** (0.796) and ***maintaining sterility*** (0.787). The bulk of patient care happens in patient rooms where maintaining sterility and work efficiency are necessary elements for patient care, as indicated by the high correlation between the factors. However, although the factor correlation met the cutoff value, a slightly lower correlation would have provided strong evidence against a more parsimonious solution (i.e., collapsing the factors).

Effects of Hospital, Unit, and Nurse Characteristics on Patient Safety Subscales

Hospital type. In the sample, 36.3% of respondents worked in a teaching hospital, 38.8% in a community hospital, and 24.9% in a community-based-teaching hospital. There was no significant effect of hospital type on nurses' perception of the PS subscales (**Table 6**).

Unit characteristics. The effects of five different unit characteristics were examined on nurses' perception of PS subscales, as explained below (**Table 7**):

1. Care model: In the sample, 58.4% was open, and 41.6% was closed. There was no significant effect of care model on nurses' perception of PS subscales.
2. Life support system: In the sample, 59.5% was headwall, 24.7% was power column, 14.1% was pendant, and 1.7% was others. There was a significant effect of life support system

($F_{(3,583)}$ = 4.53, p = 0.0037) on nurses' perception of the patient room subscale. The MANOVA revealed a marginally significant overall effect of life support system ($F_{(3,583)}$ = 1.75, p = 0.0516) because of a significant effect on one of the four subscales (patient room).

3. Layout type: There were seven different types of layout options excluding "others." In the sample, 3.9% was an open layout, 20.2% was a corridor, 3.9% was a duplex, 21.6% was a racetrack, 9.8% was a courtyard, 8.0% was cruciform, 12.8% was radial, and 19.6% was others. There was a significant effect of layout type ($F_{(7,579)}$ = 2.07, p = 0.0454) on nurses' perception of the accessibility and visibility subscale. Because of this effect, the MANOVA revealed a marginally significant overall effect of layout type ($F_{(7,579)}$ = 1.38, p = 0.0892) on nurses' perception of PS subscales.
4. Patient mix: In the sample, 8.0% was coronary, 11.9% was cardiovascular, 26.7% was surgical, and 45% was others. The high percentage of the "other" option (45%) showed that most ICUs have a mix of different patient medical conditions. There was a significant effect of patient mix ($F_{(3,583)}$ = 2.89, p = 0.0218) on nurses' perception of the maintaining sterility subscale. There was also a significant effect of patient mix ($F_{(3,583)}$ = 2.44, p = 0.0460) on nurses' perception of the patient room subscale. The MANOVA revealed significant overall effects of patient mix ($F_{(3,583)}$ = 1.88, p = 0.0181) on nurses' perception of PS subscales. As a result, there was a significant overall effect on two of the four subscales.
5. Number of Beds: In the sample, the numbers of beds in ICUs were as follows: 16.4% had ≤ 10, 48.5% had > 10 and ≤ 20, 18.2% had > 20 and ≤ 30, and 17.6% had > 30. Multiple imputation was done for missing cases in the beds variable. The results were pooled from 20 regressions. Therefore, the R was an approximate parameter estimate. The correlation

revealed that there was a statistically significant association between beds and the maintaining sterility subscale (R = 0.109, p = 0.021), but the relationship was weak. The correlation also revealed that there was a statistically significant negative association between beds and the efficient work process subscale (R = -0.0912, p = 0.044), but the relationship was weak. This may suggest that nurses' perception on efficient work process decrease with the increasing number of beds in the ICU unit.

Nurse characteristics. The effects of four different nurse characteristics were examined on nurses' perception of PS subscales, as discussed below (**Table 8**):

1. Gender: The sample consisted of 89.4% female nurses and 10.6% male nurses. There was a significant effect of gender ($F_{(1,585)}$ = 4.43, p = 0.0357) on nurses' perception of the maintaining sterility subscale. There was a marginally significant effect of gender on the efficient work process subscale ($F_{(1,585)}$ = 3.55, p = 0.0601).
2. Professional title: In the sample, 67.7% were staff nurses, 24.1% were charge nurses, and 0.08% were managers or assistant managers. There was a significant effect of professional title ($F_{(2,584)}$ = 4.37, p = 0.0131) on nurses' perception of the maintaining sterility subscale.
3. Position in the unit: In the sample, 86.0% was permanent, 3.91% was temporary, 3.41% was floating, 3.74% was per diem, 2.04% was contract, and 0.85% was agency. There was a significant effect of nurses' assignments ($F_{(5,581)}$ = 3.23, p = 0.0070) on nurses' perception of the maintaining sterility subscale. The MANOVA revealed a significant overall effect of nurses' assignments ($F_{(5,581)}$ = 0.73, p = 0.5734) on PS subscales owing to the effect of one of the four subscales.
4. Year(s) working: In the sample, 15.3% of nurses worked ≤ 1 year, 42.6% of nurses worked >1 and ≤6 years, 24.2% of nurses worked >6 and ≤11 years, and 17.9% of nurses worked

>11 years. The correlations revealed a significant association between years of working and the maintaining sterility subscale (R = 0.122, $p = 0.003$), the efficient work process subscale (R = 0.084, $p = 0.048$), and the layout subscale (R = 0.084, $p = 0.41$); and marginally with the patient room subscale (R = 0.076, $p = 0.067$).

Discussion

PS Scale

The 21 items of the PS scale of Rashid (2007) assessed nurses' perception of ICU design features related to patient safety. According to this study, the PS scale measured four dimensions of patient safety: ***maintaining sterility, efficient work process, patient room,*** and ***accessibility and visibility***. The factorial structure of the PS scale was established through EFA analysis. Two items in the scale, Item 3 and Item 15, did not have any salient loadings on any of the four dimensions. Thus, these two items were deleted from the scale. The EFA was rerun in the same sample to ensure that the item deletion did not change the factor structure of the scale. The items in each factor were reviewed and the factors were named to capture the essence of the item clustering and to foster the conceptual interpretation of the factors. It is understood that researcher bias is present when labeling the factors. No expert panel of nurses and/or designers was asked to use terms that would concisely convey the ideas of the items in each factor.

The replication of the four-factor model in an independent sample was necessary to ensure that the PS scale has a sound factor structure. Thus, CFA analysis was undertaken to see how the model fit the new data. The CFA model was specified by prior exploratory analysis that had established the appropriate number of factors and pattern of item-factor relationships. In CFA, Model 2 was specified as a competing solution to the hypothesized model (Model 1), and it was hoped that it would provide a superior fit to the data. Model 2 was identical to Model 1, except that a correlated error was specified for Items 10 and 11. The correlated error was specified on the basis that some of the covariance in the items not explained by latent factors was due to another common cause. In this case, Items 10 and 11 had similar wording. The model fit improved significantly as a result of the correlated error. Lastly, comparing Model 3 (one-factor model) to Model 2 (four-factor model) provided further evidence for EFA, where multifactorial properties of the PS scale developed by Rashid (2007) were established.

Concerning reliability of the PS scale, the range of R^2 measuring the strength or relationship between an item and its underlying factor varied between 0.105 and 0.99. The range indicated that some items were weakly related and some items were strongly related to their purported factors. The scale reliability of the four factors within the CFA model was 0.65 for ***efficient work process***, 0.80 for ***patient room***, 0.67 for ***accessibility and visibility***, and 0.75 for ***maintaining sterility***. The scale reliability was accepted if it was above 0.60.

High factor correlation was observed between ***patient room*** and ***efficient work process*** (0.796), and ***patient room*** and ***maintaining sterility*** (0.787). Larger factor correlation (i.e., ≥ 0.85) may raise the question whether they represent distinct dimensions or in fact a single dimension indicating poor discriminant validity (Brown, 2006). Since the factor correlations were below 0.85, the four-factor model was retained.

In summary, the current study advanced the previous scale by: (a) investigating the underlying dimension of the scales and studying the internal structures of items hypothesized to be related to patient safety, and (b) providing evidence for reliability and construct validity using a considerably larger sample size than the pilot study reported by Rashid (2007).

Factors Affecting Nurses' perception of ICU Design

The study used the total sample (n = 587) for analyzing the impact of hospital type, unit characteristics, and nurse characteristics on nurses' perception of patient safety. Using the PS subscales, the study found that nurse characteristics and unit characteristics affected nurses' perception, and that hospital type (teaching hospital, community hospital, and community-based teaching hospital) had no influence on nurses' perception of patient safety. These findings indicate that immediate variables such as nurse and unit characteristics may affect nurses' perception of ICU design features related to patient safety more than any distant variables such as hospital type.

Maintain sterility: Nurses' perception on sterility differed in many of the subgroups in the study **(Table 9).** Nurses' perception on the maintaining sterility subscale were impacted by patient mix, and nurses' gender, professional titles and positions (e.g., permanent, temporary, or contract). These findings suggest that maintaining sterility must be considered carefully in ICU design in terms of patient safety, because nurses' perception on this issue may vary depending on patient mix, and nurses' gender, professional titles and positions.

Efficient work process: Nurses' perception on efficient work process did not differ in any subgroups (**Table 9**). This is interesting, for it suggests that nurses' perception of ICU design features in relation to the efficient work process dimension of patient safety remains unaffected by nurses' characteristics, unit characteristics, and hospital types. To put another way, the relations of ICU design features to the efficient work process dimension of patient safety remain important in all contexts.

Accessibility and visibility: Among the three unit characteristics, the findings of this study suggest that nurses' perception of ICU design features in relation to the accessibility and visibility dimension of patient safety is only affected by unit layout type. Since the accessibility and visibility dimension of patient safety is an important aspect of ICU patient care, according to this finding unit layout must be considered as an important feature of ICU design (**Table 9**).

Patient Room: Nurses' perception on the patient room subscale was impacted by the kind of life support system used in the patient room, and by patient mix (**Table 9**). The first of the two findings can be explained by the fact that life support systems often dictate patient room arrangement and layout and, as a result, affect nurses' work area in the room. For example, the type of life support system (e.g., head wall) can restrict the nurses' movement around the patient bed. This, in turn, affects how nurses perceive patients' physical environment in relation to patient safety. The second finding can be explained by the fact that patient safety is often related to the severity of patient illness. The importance of these findings may lie in the fact that nurses' perception of the patient room dimension of patient safety is affected not only by what kind of life support system is used in patient room but also by what kind of patient would use the room. The severity of patient illness may determine how effective a life support system is in an ICU patient room in relation to patient safety.

Despite its many interesting findings, a multiple comparison test showing how group means are different from each other was not done in this study. Concerning this, no analysis was provided for whether staff nurse, charge nurse, and nurse manager have different mean scores on the patient safety subscales. Such multiple comparison involving tests of significance would provide more insight on the explanatory variables in the study. Staff nurses who are more involved in direct patient care may have different perception of functional efficiency in the patient room than a charge nurse who has a supervisory role and is responsible for allocating resources such as staff schedules, equipment, and inventory. Therefore, understanding which nurse group has a lower mean score on a subscale may facilitate further discussion on the topic. Future studies should also attempt to understand the factor structure of the scale separately among subtypes of nurse (e.g., staff nurse and charge nurse), that is, whether the factor structure will replicate in future studies involving more homogenous subgroups (e.g., charge nurse), and how the subgroups (e.g., nursing degree) differ in terms of average scores, variance, or ranges on any subscale.

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Table 1. Explanatory variables of Patient Safety (PS) Scale

	Variables		*N*	%
Types of Hospitals: Patient Safety Scales (*n = 587)*	Teaching hospital		213	36.3
	Community hospital		228	38.8
	Community-based teaching hospital		146	24.9
ICU Unit Characteristics:	Beds	≤ 10	73	16.4

	Variables		*N*	%
Patient Safety Scales (*n* = 587)	(*N* = 466, missing *N* = 121)	> 10 and ≤ 20	226	48.5
		>20 and ≤ 30	85	18.2
		>30	82	17.6
	Care model	Closed	244	41.6
		Open	343	58.4
	Life support system	Headwall	349	59.5
		Power Column	145	24.7
		Pendant	83	14.1
		Others	10	1.7
	Layout type	Open	23	3.9
		Corridor	119	20.2
		Duplex	23	3.9
		Racetrack	127	21.6
		Courtyard	58	9.8
		Cruciform	47	8.0
		Radial	75	12.8
		Others	115	19.6
	Patient mix	Coronary	47	8.0
		Cardiovascular	70	11.9
		Medical	157	26.7
		Surgical	49	8.4
		Others	264	45
ICU Nurse Characteristics: Patient Safety Scales (*n* = 587)	Gender	Male	62	10.6
		Female	525	89.4
	Professional Title	Staff nurse	397	67.7
		Charge nurse	142	24.1
		Manager or assistant manager	48	0.08
	Position in the ICU unit	Permanent	505	86.0
		Temporary	23	3.91
		Floating	20	3.41
		Per diem	22	3.74
		Contract	12	2.04
		Agency	5	0.85
	Year(s) working	≤1	90	15.3
		>1 and ≤6	250	42.6
		>6 and ≤11	142	24.2
		>11	105	17.9

Table 2. Exploratory Factor Analysis (EFA) Model Fit Information (N = 294)

Factors	Chi-Square x^2 (df) p	RMSEA	90% C.I	RMSR
1	770.04 (189) 0.000	0.102	0.095–0.110	0.081
2	527.03 (169) 0.000	0.085	0.077–0.093	0.062
3	387.009 (150) 0.000	0.073	0.064–0.082	0.050
4	299.448 (132) 0.000	0.066	0.056–0.075	0.042
5	239.252 (115) 0.000	0.061	0.050–0.071	0.038

Table 3. Exploratory Factor Analysis (EFA): Promax Oblique Rotated Factor Loadings (n = 294)

Item Number	Item Content	Factor 1	Factor 2	Factor 3	Factor 4
1(U)	The flows of clean supplies, dirty supplies, and people are separate in the unit.	0.464	0.005	-0.010	0.265
2(U)	The unit has enough handwashing sinks with hands-off controls, antiseptic gels, and/or foam at appropriate locations.	0.222	0.331	-0.001	0.108
3(U)	**Clean sinks and waste disposal sinks are separated.**	0.165	0.011	0.142	0.172
4(U)	Finishes are easy to clean and can withstand repeated cleaning with strong solutions.	0.022	-0.148	0.080	0.798
5(U)	Surfaces around any type of plumbing outlet are water-resistant, smooth, and sealed.	0.211	0.073	-0.114	0.671
6(R)	Individual air pressure control and HEPA filters for patient rooms allow better infection control.	0.506	0.141	-0.037	0.035
7(R)	Floor and wall surfaces of patient rooms are easy to clean and are resistant to microbial growth.	0.330	0.221	-0.027	0.241
8(R)	Patient rooms have private bathrooms eliminating the risks associated with carrying patient waste through other areas.	0.262	0.365	-0.063	0.035
9(U)	The unit is located close to other critical care support areas.	0.535	-0.063	0.103	-0.042
10(U)	It is quick and easy to get to patients from nurse stations.	0.230	-0.065	0.610	-0.087
11(U)	Clinical staff can observe patients while working at their workstations.	0.315	-0.116	0.708	-0.089
12(R)	Clinical staff has complete and clear access to patient 360-degree around the bed.	0.047	0.617	0.079	-0.095
13(R)	Electrical and data outlets are located conveniently.	-0.068	0.767	-0.034	0.043
14(R)	Patient beds provide turn assist functions.	-0.032	0.456	0.193	-0.054
15(R)	**Patient beds covert easily into a chair.**	-0.127	0.252	0.236	0.243
16(R)	Clinical staff has easy physical and visual access to patients.	-0.119	0.157	0.867	0.091
17(R)	There is enough illumination to monitor a change in patient's color.	-0.077	0.367	0.326	0.072
18(R)	Ergonomically designed patient room and support facilities help increase patient safety.	0.252	0.614	-0.011	-0.141
19(R)	Nurse server in each room allows easy access to high-usage care items and linens.	0.219	0.540	-0.022	-0.094
20(R)	Each room has adequate space and necessary technology for patient manipulation and care.	0.072	0.685	-0.055	0.019
21(R)	Facilities are provided to support order entry and data retrieval right at the bedside.	0.188	0.342	-0.032	0.031

Note. Factor 1 = Efficient work process, Factor 2 = Patient room, Factor 3 = Accessibility and visibility, Factor 4 = Maintaining sterility; U = Unit level item, R = Room level item

Table 4. Confirmatory Factor Analysis (CFA) Fit Indices for Models (n = 293)

Model	Absolute Fit Indices			Parsimony Corrected Index			Relative Fit Indices		
	X^2	df	P Value	SRMR	RMSEA	RMSEA 90 CI	CFIT ns P Value	CFI	TFI
Model 1	309.821	146	0.000	0.062	0.062	0.052–0.071	0.022	0.874	0.853
Model 2 (Four-factor, Correlated error)	290.324	145	0.000	0.061	0.058	0.049–0.068	0.000	0.888	0.868
Model 3 (One-factor, Correlated error)	496.197	151	0.000	0.077	0.088	0.080–0.097	0.000	0.735	0.699

Table 5. Patient Safety Subscales: Reliability

Subscales	No. of Items	Scale Reliability $((\Sigma \lambda_i)^2/[(\Sigma \lambda_i)^2 + \Sigma \theta_{ii}])$	Item Reliability Range ($R^2 = \lambda^2$)	Factor Loading Range (Item Validity = λ)
Efficient Work Process	4	0.65	0.105–0.568	0.324–0.535
Patient Room	10	0.80	0.131–0.505	0.362–0.711
Accessibility and Visibility	3	0.67	0.183–0.990	0.428–0.995
Maintain Sterility	2	0.75	0.504–0.744	0.710–0.863

Table 6. Effects of Hospital Types (categorical variables) on Nurse Perceptions of Patient Safety Subscales

Hospital Type: Teaching, Community, Community-Based Teaching Hospital	$F_{(2,584)}$	Prob > F
Maintaining Sterility	0.01	0.9859
Efficient Work Process	0.16	0.8539
Accessibility and Visibility	2.85	0.0589
Patient Room	0.08	0.9252
Overall Effect of Subscales	0.90	0.5169

** Prob= Probability*

Table 7. Effects of Unit Characteristics (categorical and continuous variables) on Nurse Perceptions of Patient Safety Subscales

Unit Characteristics	Patient Safety Subscales	F	Prob > F
		$F_{(1,585)}$	
Care Model: Open or Closed	Maintaining Sterility	0.99	0.3190
	Efficient Work Process	1.86	0.1737
	Accessibility and Visibility	0.78	0.3769
	Patient Room	1.48	0.2244
	Overall Effect of Subscales	0.57	0.6865
		$F_{(3,583)}$	
Life Support System: Headwall, Power Column, Pendant, Others	Maintaining Sterility	1.22	0.3007
	Efficient Work Process	0.65	0.5830
	Accessibility and Visibility	0.18	0.9079
	Patient Room	4.53	0.0037 $p < 0.01$
	Overall Effect of Subscales	1.75	0.0516 marginally
		$F_{(7,579)}$	
Layout Type: Open, Corridor, Duplex, Racetrack, Courtyard, Cruciform, Radial, Others	Maintaining Sterility	1.24	0.2799
	Efficient Work Process	0.10	0.9985
	Accessibility and Visibility	2.07	0.0454 $p < 0.05$
	Patient Room	0.81	0.5829
	Overall Effect of Subscales	1.38	0.0892 marginally
		$F_{(3,583)}$	
Patient Mix: Coronary, Cardiovascular, Medical, Surgical, Others	Maintaining Sterility	2.89	0.0218 $p < 0.05$
	Efficient Work Process	1.95	0.1007
	Accessibility and Visibility	1.65	0.1607
	Patient Room	2.44	0.0460 $p < 0.05$
	Overall Effect of Subscales	1.88	0.0181 $p < 0.05$

Number of Beds

Subscales	Coefficient	Constant	R	R^2	$t_{(df)}$	Prob > |t|	Sig
Maintaining Sterility	0.01	1.67	0.109	0.01	$t_{(202.4)} = 2.33$	0.021	$p < 0.05$
Efficient Work Process	-0.01	2.35	-.0912	0.01	$t_{(282.1)} = -2.02$	0.044	$p < 0.05$
Accessibility and Visibility	0.01	1.77	0.073	0.01	$t_{(183.7)} = 1.55$	0.124	
Patient Room	-0.00	2.34	-0.071	0.01	$t_{(183.7)} = -1.60$	0.111	

** R and R^2 are approximate value; Prob= Probability*

Table 8. Effects of Nurse Characteristics (categorical and continuous variables) on Nurse Perceptions of Patient Safety Subscales

Nurse Characteristics	Patient Safety Subscales	F	Prob > F
		$F_{(1,585)}$	
Gender: Female or Male	Maintain Sterility	4.43	0.0357 $p < 0.05$
	Efficient Work Process	3.35	0.0601 marginally
	Accessibility and Visibility	0.18	0.6740
	Patient Room	0.34	0.5624
	Overall Effect of Subscales	1.80	0.1267
		$F_{(2,584)}$	
Professional Title: Staff Nurse, Charge Nurse, Manager, or Assistant Manager	Maintain Sterility	4.37	0.0131 $p < 0.05$
	Efficient Work Process	0.72	0.4874
	Accessibility and Visibility	0.23	0.7982
	Patient Room	0.28	0.7588
	Overall Effect of Subscales	1.31	0.2332
		$F_{(5,581)}$	
Position in the ICU Unit: Permanent, Temporary, Floating, Per Diem, Contract, Agency	Maintain Sterility	3.23	0.0070 $p < 0.05$
	Efficient Work Process	0.69	0.6347
	Accessibility and Visibility	0.65	0.6617
	Patient Room	1.22	0.2998
	Overall Effect of Subscales	2.60	0.0001 $p < 0.05$

Year(s) Working							
Subscales	Coefficient	Constant	R	R^2	$t_{(585)}$	Prob >| t|	Sig
Maintaining Sterility	0.02	1.70	0.1222	0.02	2.98	0.003	$p < 0.05$
Efficient Work Process	0.01	2.16	0.0843	0.01	1.98	0.048	$p < 0.05$
Accessibility and Visibility	0.01	1.79	0.0842	0.01	2.05	0.041	$p < 0.05$
Patient Room	0.01	2.20	0.0757	0.01	1.84	0.067	marginally

* *R and R^2 are approximate value; Prob= Probability*

Table 9. Patient Safety Subscales: Unit and Nurse Characteristics Affecting Nurse Perception

	Subscales			
	Efficient Work Process	Patient Room	Accessibility and Visibility	Maintain Sterility
Unit Characteristics				
Life Support System		$p = 0.004$		
Layout			$p = 0.045$	
Patient Mix		$p = 0.046$		$p = 0.021$
Nurse Characteristics				
Gender				$p = 0.035$
Professional Title				$p = 0.013$
Position in the Unit				$p = 0.007$

* $p < 0.05$

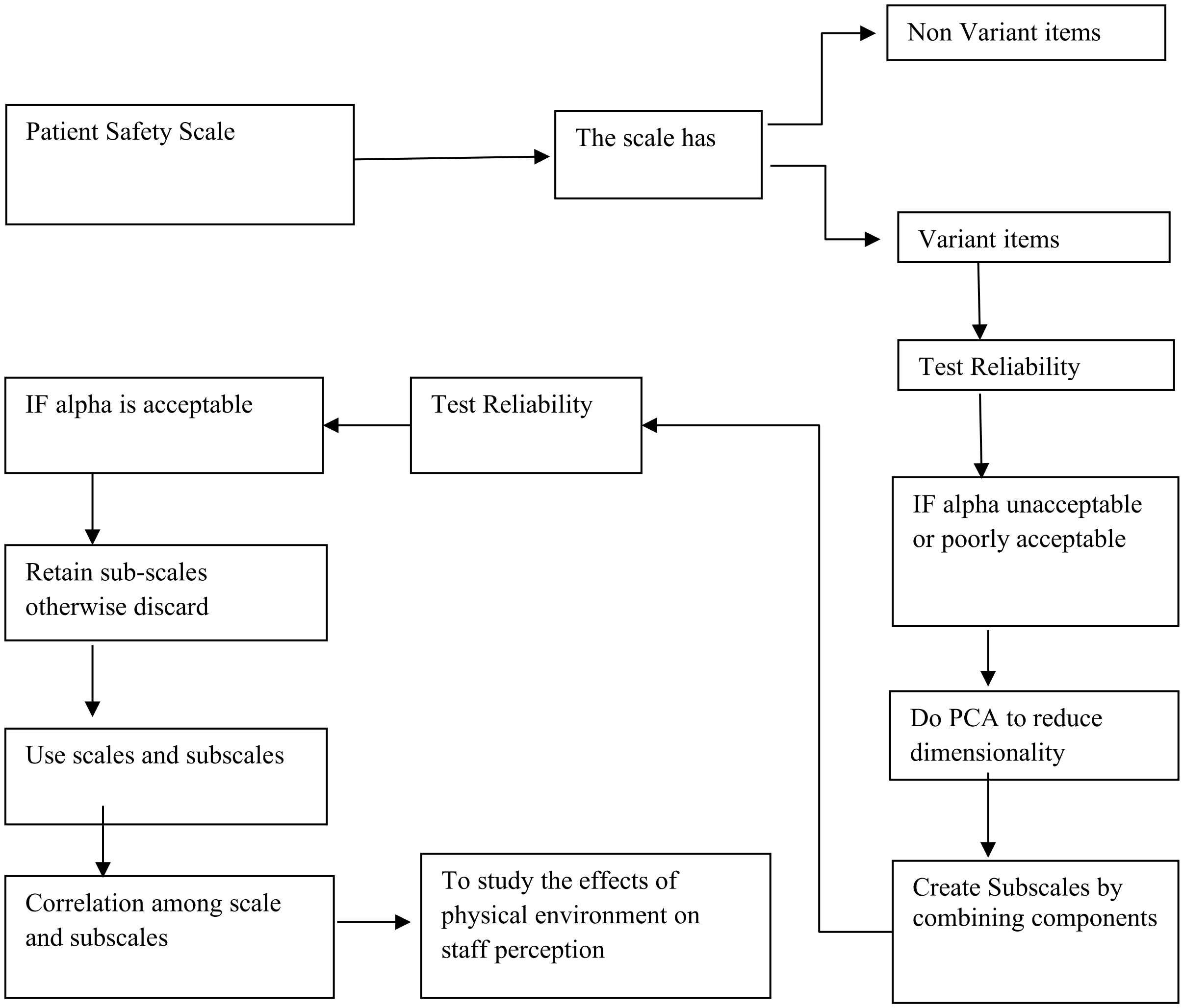

Figure 1. Pilot study analysis method represented graphically.

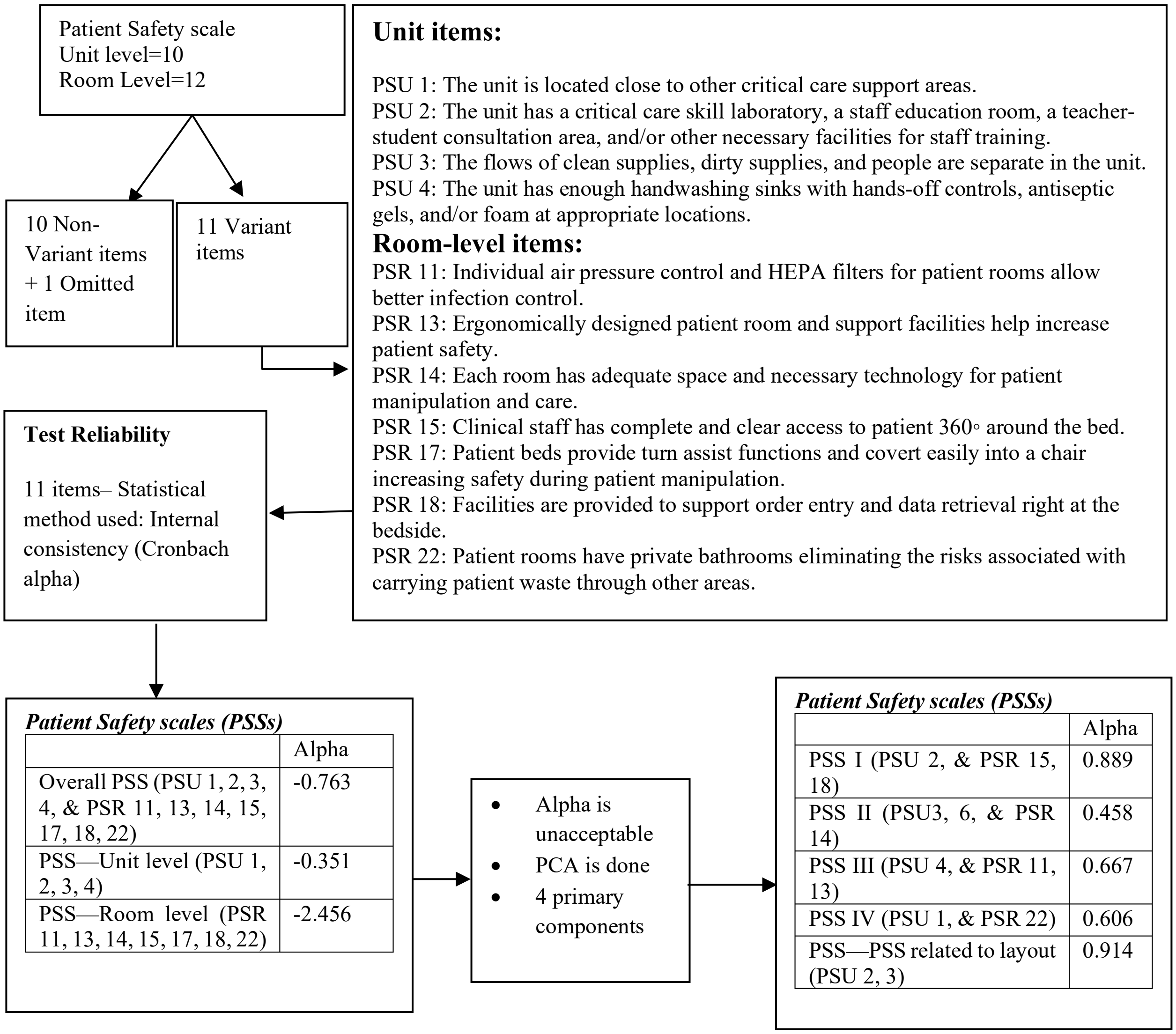

Figure 2. Psychometric analysis of patient safety scale.

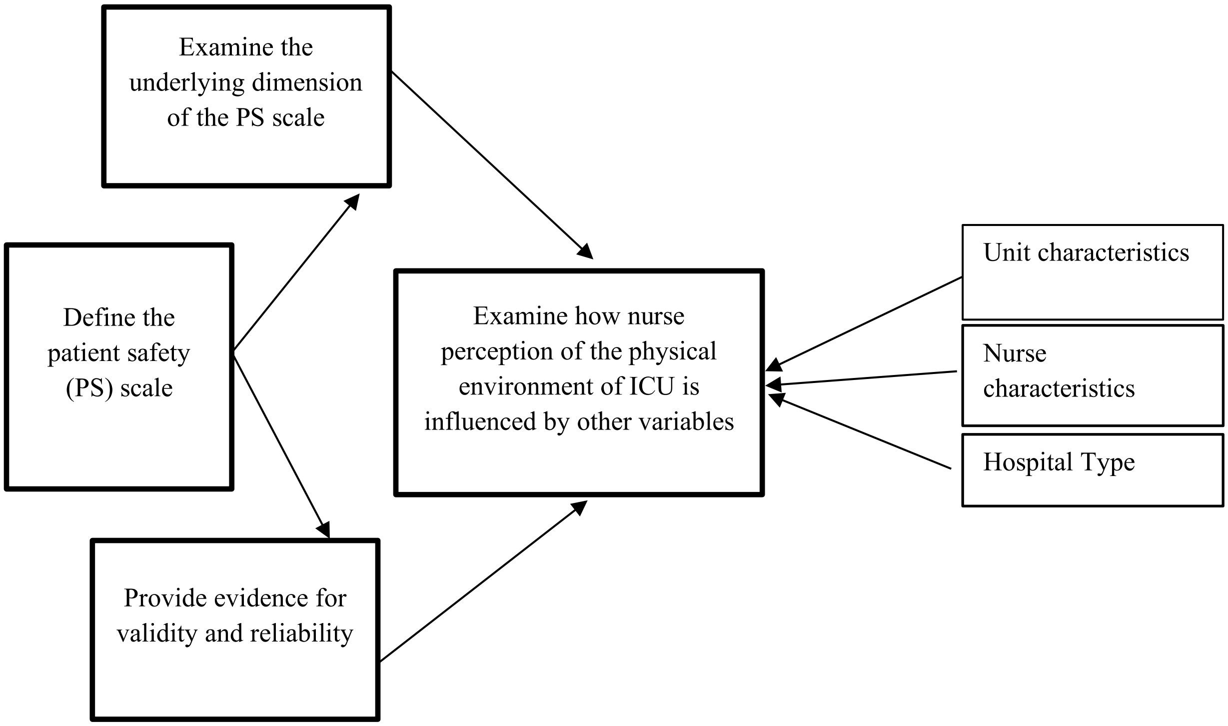

Figure 3. Framework for the current study.

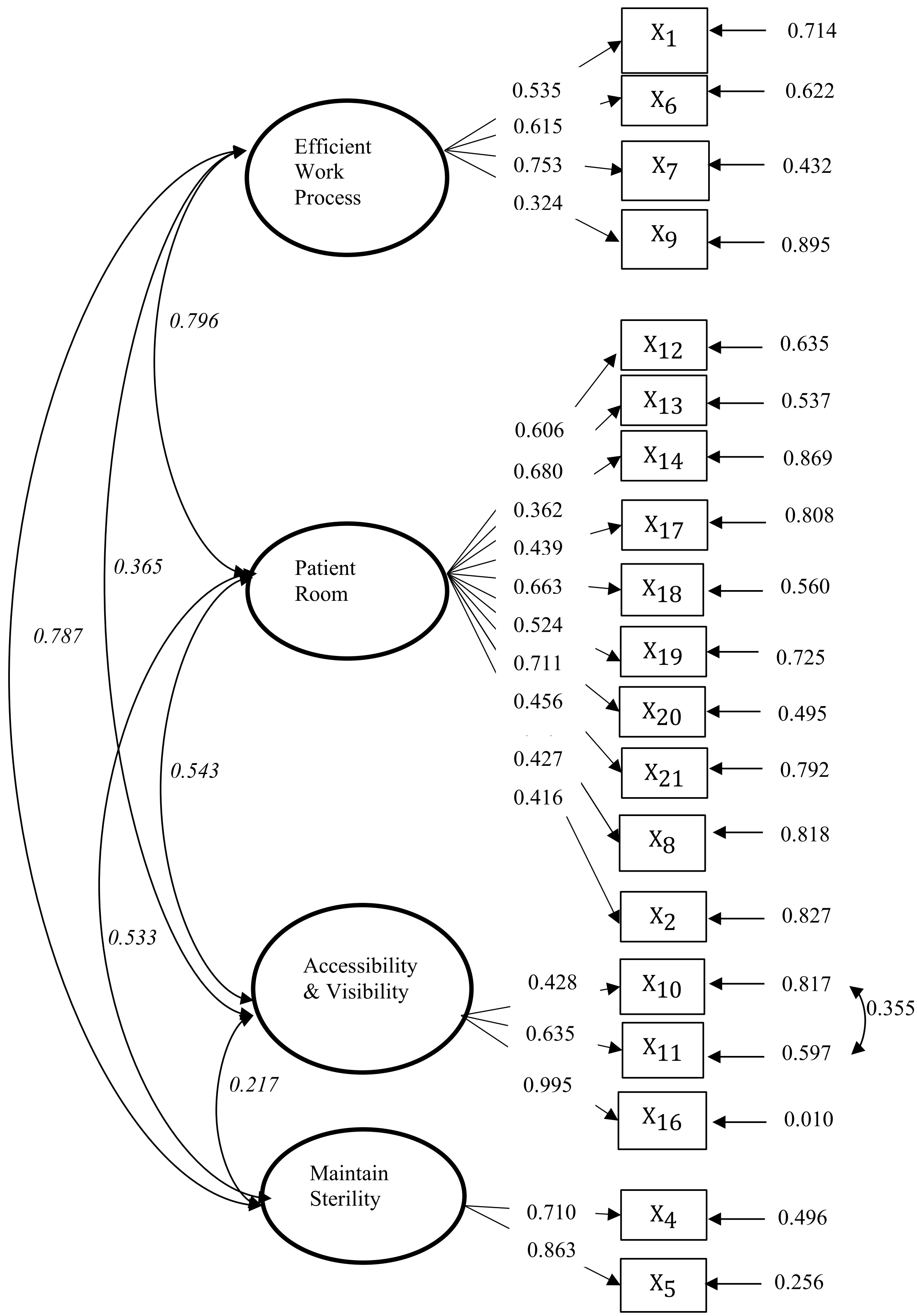

Figure 4. Model 2 parameter estimates (completely standardized). Estimates are statistically significant ($p < 0.001$). * Values in italics are factor correlation. **X represents Item.