Published in final edited form as:
Clin Nurs Res. 2013 August ; 22(3): 300–309. doi:10.1177/1054773812460867.

How feasible was a bed-height alert system?

Huey-Ming Tzeng, PhD, RN, FAAN* **[Professor of Nursing and Associate Dean for Academic Programs]**,
College of Nursing, Washington State University, Spokane, Washington, USA (tzenghm@gmail.com)

Atul Prakash, PhD [Professor],
Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan, USA, (aprakash@umich.edu)

Mark Brehob, PhD [Lecturer],
Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan, USA, (brehob@umich.edu)

Allison Anderson, BSN, RN [Staff Nurse],
University of Michigan Health Systems, Ann Arbor, Michigan, USA (akande@med.umich.edu)

David Andrew Devecsery, BS [Graduate Student Research Assistant], and
Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan, USA (ddevec@umich.edu)

Chang-Yi Yin, MA
Professor, Department of History, Chinese Culture University, Taipei, Taiwan (yinchangyi0405@yahoo.com)

Abstract

This qualitative and descriptive study examined the feasibility of a bed-height alert system as a fall-prevention strategy. The alpha prototype was developed to measure and record bed height, and to remind staff to keep patient beds in the lowest position. This pilot project was conducted in a 52-bed adult acute surgical inpatient care unit of a Michigan community hospital. Qualitative and quantitative information was gathered during semi-structured interviews of nursing staff (18 RNs and 13 PCAs; January–April 2011). Descriptive content analysis and descriptive analyses were performed. The overall response rate was 44.9%. The mean values of the feasibility questions are all favorable. Staff's comments also support the view that the alert system would promote patient safety and prevent falls. In short, this system was found to be somewhat useful, feasible, appropriate, and accurate. It has the potential to promote patient safety and prevent bed-associated injurious falls in inpatient care settings.

Keywords

Hospital; patient safety; beds; patient room; accidental falls

Corresponding Address: Huey-Ming Tzeng, PhD, RN, FAAN, Professor of Nursing and Associate Dean for Academic Programs, College of Nursing, Washington State University, 103 E. Spokane Falls Blvd, Spokane, WA 99210-1495, Telephone: 1-734-358-0358, tzenghm@gmail.com.

Declaration of Conflicting Interests The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

The authors declare that they have no competing interests.

INTRODUCTION

Fall-related injuries are among the most common and expensive hospital-acquired health conditions of adult inpatients (Simmons, 2010). Keeping patient beds in a low position, providing low-low beds to patients at greatest risk of falls, bed alarms, and implementing wider mattresses for patient beds are a few of potential bed-related interventions to reduce patient falls from their beds (Anderson, Boshier & Hanna, 2012; Fragala, Perry & Fragala, 2012; Haines, Bell & Varghese, 2010; Hignett, 2010). Anderson, Boshier and Hanna (2012) found that limited clinical trials have been conducted on testing the effectiveness of bed-related interventions. They concluded that the effectiveness of using bed exit alarms and low height beds in preventing bed-related falls and injuries remains uncertain.

As shown in the literature, the accuracy of bed-exit alarms in identifying bed-exiting body movements has been a concern; the pressure-sensitive alarm system combined with infrared beam detectors was found to be more accurate than the pressure-sensitive alarm in identifying bed-exiting body movements (Capezuti et al., 2009). The quality improvement project in two hospital inpatient care units conducted by Hubbartt, Davis and Kautz (2011) concluded that bed exit alarms used with confused and agitated patients may have helped reduce falls. In addition, Capezuti and associates (2008) emphasized that the height of patient beds that is too high (> 120% of lower leg length) or too low (< 80% of lower leg length) can impede safe transfer. Promoting safe transfer is meant to reduce injury if the person does fall when getting in or out of bed. Their retrospective observational study on nursing home residents found that the bed height of three fourths of these nursing home residents was greater than 140% of their lower leg lengths (Capezuti et al., 2008). However, the pragmatic, cluster randomized trial of a policy to introduce low-low beds to hospital inpatient care units conducted by Haines, Bell and Varghese (2010) did not find to reduce falls or falls with injury.

In practice, patient beds are not typically kept in the recommended low position (Capezuti et al., 2008; Tzeng & Yin, 2009). When tasked with a very heavy workload, nurses tend to focus on primary jobs (e.g., patient assessment, medication administration) and neglect secondary jobs (e.g., adjusting bed to a low position, rounding to assess patients, setting bed alarms). Thus, neglecting these secondary jobs, such as adjusting bed to a low position, could possibly lead to failing to prevent bed-related falls (Lopez, Gerling, Cary, & Kanak, 2010).

Problem

Bed height has been identified as one of the extrinsic contributory factors of falls in adult inpatient care settings (Hignett, 2010). A study conducted by Tzeng (2010) shows that in adult acute inpatient care settings, 51.4% of all inpatient fall incidents and 56% of injurious falls are associated with an activity related to the bed (e.g., transfers to and from bed). Older adults and their families express that hospital beds were so high that patients' feet dangled when they were getting out of bed (Tzeng & Yin, 2009). Based on previous studies (Alexander et al., 2000; Roubenoff & Wilson, 1993; Tzeng & Yin, 2008), the height of the hospital bed, from the floor to the top of the bed surface in the horizontal position, should be adjustable to the average 100% patients' knee height (about 21.3 inches for men and 19.49 inches for women). However, for the hospital beds sold in the United States, the heights of hospital beds (beds and frames) are often higher than the average 100% patients' knee height.

Purpose of the Study

This qualitative and descriptive study examines the feasibility of a bed-height alert system as a fall-prevention strategy in a 52-bed adult acute surgical inpatient care unit. The system reminds staff members to keep patient beds in the lowest position. Semi-structured interviews were conducted with nursing staff. Donabedian's (1986) framework of structure, process, and health care outcomes guides this study.

In this study, we identify keeping patient beds in the lowest position as one of the nurse-centered process indicators that would make the patient-centered outcomes of falls and fall-related injuries less likely. The rationale is that the heights of most of the hospital beds (beds and frames) in the market are higher than the average 100% patients' knee height (about 21.3 inches for men and 19.49 inches for women) (Alexander et al., 2000; Roubenoff & Wilson, 1993; Tzeng & Yin, 2008). In the study unit, the height of the patient beds in the lowest position is 24 inches. Therefore, in this study, we recommend that staff should return patient beds to the lowest level after providing care and treatment. In addition, since the height-adjustment controller is located at the footboard, it is not accessible to the patient lying on the bed. We assume that the overall height of the bed is primarily adjusted by staff members and that family members may occasionally adjust the overall bed height.

THE STUDY

Design

This pilot project was conducted in a 52-bed adult acute surgical inpatient care unit of a community teaching hospital located in Michigan. The formative evaluation data of the bed-height alert system presented in this study is from an interdisciplinary collaborative pilot project. Qualitative and quantitative information was gathered during semi-structured interviews of nursing staff members.

The alpha prototype of the bed-height sensor network composed of 15 wireless sensors was developed to measure and record bed height (Tzeng, et al., 2012a). This system is meant to increase staff adherence to keeping beds in a low position as a fall prevention strategy. This system generates computerized reminders to enhance staff adherence to bed height recommendations. A sensor located under each bed collects bed height measurement and sends information to a central touch-screen computer in the nurse's station that displays the state of the bed. A sensor located under each bed measures the bed height every 10 minutes and sends the information through a wireless relay to a central computer in the nurse's station. The sensor locations were checked manually by the trained research assistants and updated in the computer system.

The lowest height of the beds in the study unit is 24 inches from the floor to the top of the mattress, which is higher than the average 100% patients' knee height (about 21.3 inches for men and 19.49 inches for women) (Alexander et al., 2000; Roubenoff & Wilson, 1993; Tzeng & Yin, 2008). To avoid false alarms, the research team decided that if a bed is left at 26 inches or higher (two inches above the lowest height), the central computer would issue a high-bed alert in the form of a blinking yellow light, which turns red after 30 minutes if the bed is not lowered (Tzeng, et al., 2012a).

Four staff education sessions were conducted by a trained research assistant with a nursing background. Three of the sessions were held in mid-September 2010, and a refresher session was given in late December 2010. A staff training manual was developed and left by the central computer. The bed-height sensor network and the reminder intervention were tested in the study unit from September 2010 through April 2011 (Tzeng, et al., 2012a). Interviews

were conducted from January through April 2011. This project was approved by the institutional review boards of the study hospital.

Data Source and Collection

The research team developed a short semi-structured interview guide for data collection. The first part of the interview includes two open questions: (1) What comments do you have about the alert for lowering the bed? (2) What experiences did you have using the alerts that were beneficial or detrimental to your work in patient care? The second part includes four feasibility questions based on a 10-point Likert scale: (1) Please rate the usefulness of the bed-height alert system, where 1 is not useful and 10 is very useful. (2) Please rate the feasibility (i.e., practicality) of the alert system, where 1 is not feasible and 10 is very feasible. (3) Please rate the appropriateness of the setting of the alerts, where 1 is not appropriate and 10 is very appropriate. (4) Please rate the accuracy level of the alerts, where 1 is not accurate and 10 is very accurate.

A trained research assistant made five visits at different times of day to interview nursing staff working day, evening, and night shifts. Inclusion criteria for staff interviews are 21 years or older, able to communicate in English, employed as regular staff members for the study unit, and responsible for directly delivering patient care. A total of 40 registered nurses (RNs) and 29 patient care assistants (PCAs) working in the study unit met the inclusion criteria. Each interview lasted about 5 minutes, and each participant was given a token gift to show our appreciation for their participation. The unit director gave permission for the interviews to be conducted during work hours. We recorded all the interviews sessions with each participant's permission and did not document any identifiers of the participants.

Data Analyses

Interview recording was transcribed by the trained research assistant. Two members of the research team used the descriptive content analysis method and independently assessed the transcripts. They identified themes of the staff members' replies. Discrepancies between the themes they identified were discussed until a consensus was reached. Descriptive analyses (e.g., means, medians, standard deviations) of the four feasibility items on a 10-point Likert scale were performed with Statistical Package for the Social Sciences (SPSS ver. 16.0 for Windows; SPSS, Chicago, IL, USA). The skewness and kurtosis values of these feasibility items were examined and acceptable. As a result, these items were treated as continuous variables in this study.

FINDINGS

During the study period from September 2010 to March 2011, the nursing hours per patient day (HPPDs) ranged from 8.54 to 10.00 and the registered nurse HPPDs ranged from 4.83 to 5.68. The total fall rates per 1000 patient days ranged from 2.02 to 8.22. The injurious fall rates per 1000 patient days ranged from 0 to 2.02. A total of 18 RNs and 13 PCAs were interviewed. The overall response rate is 44.9%. Nine interviews (29.0%) were conducted during the day shift, 15 (48.4%) during the evening shift, and 7 (22.6%) during the night shift.

Responses to the question "*What comments do you have about the alert for lowering the bed?*" are summarized into four themes: (1) promoting patient safety and preventing falls; (2) effectively monitoring bed heights from the nurses' station, but not from the hallway; (3) difficulty tracking the sensors because of beds frequently being moved off the unit; and (4) visible and audible alerts. The participants were also asked "*What experiences did you have using the alerts that were beneficial or detrimental to your work in patient care?*" Most of the

participants said they were present at the educational sessions but had not used the bed-height sensor and reminder system on a regular basis. No themes emerged. Detailed results can be obtained from the corresponding author and can be found at the study conducted by Tzeng and associates (2012b).

Participants were also asked to rate the bed-height sensor and reminder system using a scale of 1 to 10, where 1 is not favorable and 10 is very favorable. Table 1 summarizes the findings. For exploratory purposes, independent *t* tests were conducted to compare RN ratings with PCA ratings, and no significant differences were found ($\alpha = 0.05$).

DISCUSSION

This study examines the feasibility of a bed-height alert system as a fall-prevention strategy with the goal of proof of concept. The mean values of the four feasibility questions are all greater than 5 as being favorable (range, 6.57–8.97), indicating that the bed-height alert system was somewhat useful, feasible, appropriate, and accurate. Staff comments also support the view that the alert system would promote patient safety and prevent falls. This notion is consistent with the recommendations from previous studies that the height of patient beds can impede safe transfer and result in falls (Capezuti et al., 2008; Tzeng & Yin, 2009). In short, we found this system to be somewhat useful, feasible, appropriate, and accurate. It has the potential to promote patient safety and prevent bed-associated injurious falls. It is warranted that there is a need for a centralized bed-height alert system in adult acute inpatient care settings.

However, the small sample is a limitation of the study. Further development of the bed-height alert system (e.g., tracking and automatically reporting changes in sensor location, and improving the alert display and staff notifications) and miniaturization of the sensors are essential for future clinical trials studying the effectiveness of the system in preventing falls. Refinement of the alert system is warranted because beds that do not have an alert system need to be retrofitted. Additional research is needed to evaluate the attitudes of nursing staff toward the bed-height recommendation and their adherence to the recommendation. Additional study is needed to evaluate the awareness of physicians and ancillary health care providers regarding the importance of keeping beds in the lowest position. Future research should also investigate the relationship between nursing staff adherence and falls in acute inpatient care settings.

APPLICATION

The findings imply that nursing staff value the needs of having a bed height alert system and adopting low beds in acute care settings to create a safer hospital environment for patients. In the current hospital bed market in the North America, there are a few choices of medical/surgical low bed models for acute care settings and limited hospital bed models with a local high-bed status alert system located on the panel or at the lower corners of the foot board (e.g., CHG Hospital Beds, 2012; Stryker, 2012). However, limited products with a centralized bed-height alert system are currently available in the market. For example, White Board manufactured by WestCall (2012) has the capability to display data directly from each patient bed (e.g., bed exit and bed height alarms) on a monitor screen in nursing areas. For now, nursing administrators may consider adopting low beds in acute care settings and/or hospital beds which have a high-bed status alert system to decrease the occurrences of bed-associated injurious falls.

Acknowledgments

Funding:

The authors disclosed receipt of the following financial support for the research of this article. This project was supported by grant number UL1RR024986 from the Michigan Institute for Clinical and Health Research (MICHR) and the Michigan Center for Health Interventions (MICHIN), the University of Michigan, Ann Arbor, Michigan. The content is solely the responsibility of the authors and does not necessarily represent the official views of MICHR and MICHIN.

Biographies

Huey-Ming Tzeng, PhD, RN, FAAN, is a Professor of Nursing and the Associate Dean for Academic Programs at College of Nursing, Washington State University, Spokane, Washington.

Atul Prakash, PhD, is a Professor at Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan.

Mark Brehob, PhD, is a Lecturer at Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan.

Allison Anderson, BSN, RN, is a Staff Nurse at the University of Michigan Health Systems, Ann Arbor, Michigan.

David Andrew Devecsery, BS, is a Graduate Student Research Assistant at Department of Electrical Engineering and Computer Science, College of Engineering, University of Michigan, Ann Arbor, Michigan.

Chang-Yi Yin, MA, is a Professor at Department of History, Chinese Culture University, Taipei, Taiwan.

REFERENCES

Alexander NB, Galecki AT, Nyquist LV, Hofmeyer MR, Grunawalt JC, Grenier ML, Medell JL. Chair and bed rise performance in ADL-impaired congregate housing residents. Journal of the American Geriatrics Society. 2000; 48(5):526–533. [PubMed: 10811546]

Anderson O, Boshier PR, Hanna GB. Interventions designed to prevent healthcare bed-related injuries in patients. Cochrane Database of Systematic Reviews. 2012; 1:CD008931.

Capezuti E, Brush BL, Lane S, Rabinowitz HU, Secic M. Bed-exit alarm effectiveness. Archives of Gerontology and Geriatrics. 2009; 49(1):27–31. [PubMed: 18508138]

Capezuti E, Wagner LM, Brush BL, Boltz M, Renz S, Secic M. Bed and toilet heights as potential environmental risk factors. Clinical Nursing Research. 2008; 17(1):50–66. [PubMed: 18184978]

CHG Hospital Beds. [Accessed on July 1, 2012] CHG hospital beds®. 2012. Available at http://www.lowhospitalbed.com/lowhospitalbed/index.php.

Donabedian A. Criteria and standards for quality assessment and monitoring. Quality Review Bulletin. 1986; 12(3):99–108. [PubMed: 3085044]

Fragala G, Perry B, Fragala M. Examining bed width as a contributor to risk of falls from bed in long-term care. Annals of Long-Term Care: Clinical Care and Aging. 2012; 20(6):35–38. Available at http://www.annalsoflongtermcare.com/article/examining-bed-widthcontributor-risk-falls-bed-long-term-care.

Haines TP, Bell RAR, Varghese PN. Pragmatic, cluster randomized trial of a policy to introduce low-low beds to hospital wards for the prevention of falls and fall injuries. Journal of the American Geriatrics Society. 2010; 58(3):435–441. [PubMed: 20398112]

Hignett S. Technology and building design: initiatives to reduce inpatient falls among the elderly. Health Environments Research & Design Journal. 2010; 3(4):93–105. [PubMed: 21165854]

Hubbartt B, Davis SG, Kautz DD. Nurses' experiences with bed exit alarms may lead to ambivalence about their effectiveness. Rehabilitation Nursing. 2011; 36(5):196–199. [PubMed: 21882797]

Lopez KD, Gerling GJ, Cary MP, Kanak MF. Cognitive work analysis to evaluate the problem of patient falls in an inpatient setting. Journal of the American Medical Informatics Association (JAMIA). 2010; 17(3):313–321. [PubMed: 20442150]

Roubenoff R, Wilson PWF. Advantage of knee height over height as an index of stature in expression of body composition in adults. The American Journal of Clinical Nutrition. 1993; 57(5):609–613. [PubMed: 8480674]

Simmons, J. [Accessed on July 1, 2012] Reducing in-hospital patient falls. HealthLeaders Media. 2010. Available at http://www.healthleadersmedia.com/print/MAG-257370/Reducing-InHospital-Patient-Falls.

Stryker. [Accessed on July 1, 2012] Medical/surgical beds: Stryker S3 MedSurg bed. 2012. Available at http://www.stryker.com/enus/products/PatientHandlingEMSandEvacuationEquipment/Beds/MedSurgBeds/S3/index.htm#.

Tzeng HM. Understanding the prevalence of inpatient falls associated with toileting in adult acute care settings. Journal of Nursing Care Quality. 2010; 25(1):386–394.

Tzeng HM, Yin CY. Heights of occupied patient beds: A possible risk factor to in-patient falls. Journal of Clinical Nursing. 2008; 17(11):1503–1509. [PubMed: 18482143]

Tzeng HM, Yin CY. Perspectives of recently discharged patients on hospital fall-prevention programs. Journal of Nursing Care Quality. 2009; 24(1):42–49. [PubMed: 19092478]

Tzeng HM, Prakash A, Brehob M, Devecsery DA, Anderson A, Yin CY. Keeping patient beds in a low position: An exploratory descriptive study to continuously monitor the height of patient beds in an adult acute surgical inpatient care setting. Contemporary Nurse. 2012a; 41(2):185–190.

Tzeng HM, Yin CY, Anderson A, Prakash A. Nursing staff's awareness of keeping beds in the lowest position to prevent falls and fall injuries in an adult acute surgical inpatient care setting. MedSurg Nursing. 2012b In Press.

WestCall. [Accessed on July 21, 2012] White Board. 2012. Available at http://www.westcall.com/Docs/new/WhiteBoard_Rev3.pdf.

Table 1

Summary of the descriptive analyses on the four feasibility questions of the bed-height sensor and reminder system using a scale of 1 to 10, where 1 is not favorable and 10 is very favorable

Feasibility question		Mean/Median	SD	Range
Please rate the **usefulness** of the bed-height alert system, where 1 is not useful and 10 is very useful.	All participants	6.57/7.00	3.03	1–10
	RNs[~]	6.47/7.00	2.81	1–10
	PCAs[*]	6.69/7.00	3.40	1–10
Please rate the **feasibility** (i.e., practicality) of the alert system, where 1 is not feasible and 10 is very feasible.	All participants	7.19/7.00	2.37	3–10
	RNs[~]	7.22/7.50	2.37	3–10
	PCAs[*]	7.15/7.00	2.48	3–10
Please rate the **appropriateness** of the setting of the alerts, where 1 is not appropriate and 10 is very appropriate.	All participants	8.97/10.00	1.82	3–10
	RNs[~]	9.33/10.00	1.46	5–10
	PCAs[*]	8.46/10.00	2.18	3–10
Please rate the **accuracy** level of the alerts, where 1 is not accurate and 10 is very accurate.	All participants	8.41/10.00	2.47	1–10
	RNs[~]	8.27/10.00	2.49	3–10
	PCAs[*]	8.58/9.50	2.54	1–10

[~]Registered Nurses.

[*]Patient care assistants.