Validation of the Hendrich II Fall Risk Model: A Large Concurrent Case/Control Study of Hospitalized Patients

Ann L. Hendrich, Patricia S. Bender, and Allen Nyhuis

This large case/control study of fall and non-fall patients, in an acute care tertiary facility, was designed to concurrently test the Hendrich Fall Risk Model. Cases and controls (355/780) were randomly enrolled and assessed for more than 600 risk factors (intrinsic/extrinsic). Standardized instruments were used for key physical attributes as well as clinician assessments. A risk factor model was developed through stepwise logistic regression. Two-way interactions among the risk factors were tested for significance. The best fitting model included 2 Log L chi square statistic as well as sensitivity and specificity values retrospectively. The result of the study is an easy to use validated Hendrich Fall Risk Model with eight assessment parameters for high-risk fall identification tested in acute care environments.

PATIENT FALLS REMAIN the most common of the adverse events reported in acute care facilities and result in morbidity, mortality, and fallophobia—the prolonged fear of falling again. For many elderly people, this fear causes restrictions in activities and mobility, which can shorten the life span. Morse (1997) identified three classifications of patient falls: accidental (caused by the patient slipping or tripping, usually attributed to some environmental hazard such as water on the floor), anticipated physiological (falls by persons considered at risk of falling), and unanticipated physiological (falls attributed to physiological factors that cannot be predicted before the first fall). Anticipated physiological falls comprise 78% of hospital falls (Morse, 1997); therefore, they have been the focus of much research attempting to identify fall risk factors. The ultimate goal of these studies is to identify at-risk patients so they can be targeted for fall prevention measures.

Several recent retrospective case-control studies have been performed to identify fall risk factors. These studies generally start with a long list of possible risk factors and use logistic regression analyses to determine which of these factors have a significant association with falls. Hendrich et al. (1992) studied the medical records of 102 patients who fell and 236 control patients in a general acute care hospital and found seven significant risk factors: history of falls, depression, altered elimination, dizziness/vertigo, cancer diagnosis, confusion, and altered mobility. Watson and Mayhew (1994) studied 77 patients who fell and 77 control patients in a long-term care population. They found four factors to be significantly associated with falling: impaired mobility, visual impairment, restraint orders, and the use of antihypertensive medication. Gluck and co-workers (1996) studied 50 elderly (>75 years of age) patients who fell and 50 controls and found these significant risk factors: a history of falls; the presence of confusion or disorientation; and incontinence, diarrhea, or requiring help to toilet. Morse (1997) studied 100 patients who fell and 100 controls in a 1,200-bed urban hospital. She found six significant risk factors: history of falling, presence of a secondary diagnosis, the use of ambulatory aids, intravenous therapy or heparin lock, impaired gait, and poor orientation of the patient to his or her own ability. Oliver et al. (1997) examined 116 patients who fell and 116 control patients, all of whom were at least 65 years old, and identified seven significant risk factors: a transfer and mobility score of 3 or 4, falling as a presenting complaint, frequent toileting, visual impairment, agitation, unstable gait, and the use of antiarrhythmic medication. Another sig-

Ann L. Hendrich, MS, RN, *Former Nurse Executive, Methodist Hospital, Indianapolis, IN;* Patricia S. Bender, MSN, GNP, *Private Practice, Indianapolis, IN;* Allen Nyhuis, MS, *Biostatistician, Eli Lily & Company, Indianapolis, IN.*

Address reprint requests to Ann L. Hendrich, MS, RN, 430 W. CR 200N, Greencastle, IN.

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nificant study was conducted by Mendelson (1996), who studied 253 patients who fell, and 253 control patients in a general teaching hospital. He examined their medical records to determine whether sedative medications had any effect on falls and determined that antidepressants, hypnotics, benzodiazepine minor tranquilizers, and major tranquilizers were all significantly associated with falls.

Anticipated physiological falls comprise 78% of hospital falls (Morse, 1997); therefore, they have been the focus of much research attempting to identify fall risk factors.

There are several limitations to these studies that make it difficult to compare them and draw conclusions. First, they were performed on different populations. Morse (1997), Mendelson (1996), and Hendrich et al. (1992) conducted their studies in general hospital populations; the other three studies were conducted upon elderly patients only. Second, many (but not all) of the risk factors examined are not objective risks that can be measured, but subjective risks assessed by medical or nursing judgment. Third, the study by Mendelson (1996) examined only sedative use and did not address any of the other risk factors that were evaluated in the other studies. Finally, all of these studies were performed on relatively small populations, ranging from 50 fall patients and 50 controls (Gluck, Wientjes, & Rai, 1996) to 253 fall patients and 253 controls (Mendelson, 1996). When five of these six fall studies are compared (excluding Mendelson [1996] because it dealt with fall risks of sedative therapy only), impaired mobility is the only significant risk factor that is common to all five studies. However, each of the five studies expressed the concept of impaired mobility in a different way, making comparisons between studies impossible.

OBJECTIVE

The study described in this article was designed to overcome the limitations of earlier studies. It was conducted in a general hospital population in a large urban acute care facility, rather than being restricted to an elderly or long-term care population. It examined a large number of fall patients (355) and controls (780), and, wherever possible, used standard, validated, objective instruments to measure each of the more than 600 potential fall risk factors examined. The purpose of the study was to develop a predictive fall risk factor model that could be used in diverse acute care populations to identify individuals at risk for falls.

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METHODS

Setting and Patients

Study patients were drawn from a 750-bed acute care hospital over a 2-year period. The Institutional Review Board reviewed and approved the study and patient consent forms before patient enrollment. All enrolled patients were either able to sign the consent for themselves and were cognitively intact or a designated healthcare representative reviewed the consent form and agreed to their participation in the study.

Fall cases were identified in two ways. First, fall data were retrieved from the hospital's incident reports (stored in the Medical Information System) by the Nursing Quality Improvement manager, who then notified the investigative team of a fall patient. Second, fall cases were identified by the Care Coordinators, nursing unit-based registered nurses who notified the investigative team of any reported falls within their caseloads.

Once a fall case was identified, the study was discussed with the patient and/or family and an informed consent was obtained. Two control patients who were admitted on the same day as the fall patient were then randomly selected from the daily admission log of the admitting department, and informed consent was obtained from the control patients. The study protocol required that informed consent be completed within 24 hours of

the fall event in order for the cases and controls to be eligible for study inclusion. Cases and controls were not matched by nursing unit. A previous study (Hendrich, 1992) found that matching cases and controls by nursing unit had the potential to overrepresent some diagnoses, because most units admit patients with similar types of diagnoses. If patients (cases/controls) were matched on diagnosis, age or other variable, statistical bias would inadvertently be introduced into the case/control risk factor analysis methodology.

Inclusion and Exclusion Criteria

All fall patients who completed informed consent and were assessed within 24 hours of their fall were included in the study. If patients were not able to complete the entire physical performance portion of the assessment, valid data were derived from the clinical record from the 8 hours preceding the fall event. The only patients who were excluded from the study were those who refused to consent or who had physician orders that might preclude their participation because of activity orders. Less than 10 patients refused to participate in the study.

INSTRUMENTS AND ASSESSMENTS

Patient assessments were performed either by the principal investigators or by one of four trained research assistants, all of whom were registerend nurses. All assessments were performed within 24 hours of the fall, and results were recorded directly on the Hendrich Falls Assessment Tool (HFAT). HFAT is a 12-page OPSCAN document developed by the project team specifically for this study and was used as the assessment and data collection tool. A summary of the more than 600 patient and fall-specific variables that were included on the HFAT is shown in Table 1. For controls, patient variables on admission and at the time of mobility assessment were recorded; for fall cases, patient variables on admission, at the time of the fall, and at the time of mobility assessment were recorded.

Patient variables on admission, including demographics, physical status, and medications (Table 1) were taken from the charts of the fall cases or controls. All variables in this group are objective measures with the exception of fall risk factors, which were based on subjective nursing opinion. The fall-specific variables for fall cases only were taken from the patient's records. Patient variables at the time of mobility assessment for both fall cases and controls were determined and recorded while the research assistants performed the assessments.

All variables in this group are objective measures with the exception of fall risk factors, which were based on subjective nursing opinion.

All patient variables at the time of mobility assessment were based on objective measures, most of which were standardized, validated instruments. The depression test was based on the Koenig II Depression Rating Scale (Koenig, 1995); the Mini-Mental Examination was based on the Folstein Mini-Mental State Exam (Folstein, 1975), and the activities of daily living test was based on the Katz Activities of Daily Living Index (Katz, 1963). The physical performance test included 14 items based on Tinetti's Performance-Oriented Assessment (Tinetti, 1986), the six-item Get-Up-And-Go Test (Mathias, 1986) (Fig 1), and A Quantitative Test of Average Functional Reach (Weiner, 1992). The Bender Elimination Test (BET) (Fig 2) was used to assess urinary and bowel elimination factors. The Koenig II 11 item tool was selected because it screens out questions from the Geriatric Depression Scale and the Brief Carroll Depression Scale, which might be confounded by physical illness (common in hospitalized patients) and it had been used in a clinical study examining predictors of falls in hospitalized patients (Koenig, 1992).

Data Analysis

A total of 1,232 assessment forms were scanned by J & D Data Services (Plano, TX) to create a computer data set. This raw data set was then used to create a permanent analysis data set ready for use by SAS statistical software (Cary, NC). From the initial data set, 97 records were excluded for the following reasons: two patients were paraplegic or quadriplegic and not at risk of falling; 17 records were duplicates, coded only for the purpose of measuring inter-rater reliability; and 78 records were deleted because they were from patients who were sampled more than once during

Table 1. Patient and Fall-Specific Variables

Patient variables on admission	Patient variables on admission
Demographics	Patient variables at the time of mobility assessment
Admission date	Physical factors
Sex	Vital signs
Last grade completed	Height
Principal diagnosis	Hearing test (26 variables)
Age	Weight
Marital status	Vision test (39 variables)
Admission DRG	24-hour Glasgow (critical care patients only)
Principal procedure	Footwear/devices/restraints
Physical status	Restraints (9 variables)
Fall risk factors present (6 variables*)	Type of overlays (4 variables)
Height	Type of bed (6 variables)
Vital signs (4 variables)	Footwear/devices (10 variables)
24-hour Glasgow (critical care patients only)	Siderails (4 variables)
Activity level (7 variables)	Psychological factors
Weight	Depression test (11 items)
Patient condition†	Mini-mental examination (12 items)
Medications (including dose, frequency, and route)	Performance factors
Antidepressants (12 drugs)	Physical performance test (31 total items)
Antiepileptics (7 drugs)	Get-up-and-go Test (6 items)
Antimuscuranics/antispasmodics (6 drugs)	Functional Reach Test (3 trials)
Antiarrythmics (10 drugs)	Activities of daily living test (7 items)
Theophylline (2 drugs)	Elimination factors (Bender Elimination Test)
Narcotics (5 drugs)	Urinary elimination (7 items)
Anticholinergics (2 drugs)	Bowel elimination (6 items)
Calcium channel blockers (6 drugs)	Laboratory values within 48 hours of fall or mobility assessment
Alpha andrenergic blocking agents (3 drugs)	Hematocrit
Other drugs	Sodium
Antipsychotics (10 drugs)	Creatinine
Antihistamines (7 drugs)	Triglycerides
Beta-blockers (9 drugs)	Albumin
Vasodilators (4 drugs)	HCO_3
Benzodiazepines (14 drugs)	Glucose
Neruomuscular blocking agents (5 drugs)	Hemoglobin
Diuretics (7 drugs)	Potassium
Angiotensin converting enzyme inhibitors (5 drugs)	BUN
H_2 receptor antagonists (4 drugs)	Cholesterol
Fall-specific variables (fall cases only)	EKG
Date of fall	Chloride
Room number	Other variables
Witnesses to fall	Discharge DRG
Treatment as result of fall (7 variables)	
Place of fall (5 variables)	
Physical hazards at time of fall (6 variables)	
Restraints at time of fall (9 variables)	
Siderails at time of fall (4 variables)	
Time of fall	
Hospital day of fall	
Injury classification (8 variables)	
Footwear/devices at time of fall (10 variables)	
Activity at time of fall (8 variables)	
Patient response to fall (7 variables)	
Risk factors <24 hours before fall (7 variables‡)	

Abbreviation: DRG, diagnosis-related group; BUN, blood urea nitrogen; EKG, electrocardiogram.

*Confusion/disorientation, depression, altered elimination, recent fall, impaired gait/ability, and dizziness/vertigo.

†bedfast, amputee, or paraplegic/quadriplegic.

‡Confusion/disorientation, depression, impaired gait/ability, recent fall, altered elimination, dizziness/vertigo, and change in medication.

Directions	Skill Assessed	Score = 1	Score = 2	Score =3	Score = 4	Score
Have client sit in chair for 1 minute and observe. (Chair should be facing wall and three meters from wall.)	1. Siting Balance	Steady and stable without holding onto chair	Holds on to chair while sitting	Leans or slides down in chair	Requires assistance to prevent falling out of chair	O 1 O 2 O 3 O 4
Ask client to rise from chair and stand still for 5 seconds with eyes open.	2. Rising from chair	Able to rise in a single movement	Pushes up with arms, legs or walking aid, but successful in one attempt	Multiple attempts required but successful in rising	Unable to rise from chair without another person in assistance	O 1 O 2 O 3 O 4
Observe distance between toe of stance foot and heel of swing foot; observe from side. Do not judge first few or last few steps; observe one side at a time.	5. Step length	Approximately 1 to 1-1/2 the length of person's foot between the stance toe and the swing heel on both sides	Approximately less than one length of person's foot but equal on both sides	One foot moves up to other foot and not passed	Giant steps, length exceeds 1-1/2 length of person's foot	O 1 O 2 O 3 O 4
Observe from behind	8. Step continuity	Begins raising heel of one foot (toe on) as heel of other foot touches the floor; no stop or break in stride	Places entire foot (heel and toe) on floor before beginning to raise other foot	Stops completely between steps		O 1 O 2 O 3 O 4
Observe from front	9. Walking stance	Approximately 1-4 inches between feet as they pass	Feet have space between as one passes other (greater than 4 inches)	Feet almost touch each other (less than one inch)	Feet touch each other during step	O 1 O 2 O 3 O 4
Observe for lateral sway (observe from front)	11. Trunk stability	Trunk does not sway and is not held rigid	Trunk slightly sways but stays within the width of the hips	Trunk is held rigid	Trunk sway exceeds the width of the hips	O 1 O 2 O 3 O 4

Figure 1. Get-up-and-go Test.

Urinary Elimination

1. Do you ever wear a pad in your underwear for urine leakage?

O Yes O New Problem
O No O Prior to hospitalization
O Sometimes

2. Do you ever lose urine with any of the following: (sneezing, coughing, laughing, lifting, walking, changing positions - sitting to standing, standing to sitting)?

O Yes O New Problem
O No O Prior to hospitalization
O Sometimes

3. Do you ever leak urine on the way to the bathroom?

O Yes O New Problem
O No O Prior to hospitalization
O Sometimes

4. Most of the time, how often do you urinate?

O Less than ½ hour O Every 3 hours
O Every ½ hour O Every 4 hours
O Every hour O Greater than 4 hours
O Every 2 hours

5. Once you feel you need to urinate, how long can you wait?

O Not at all O 5-10 minutes O As long as
O 1-5 minutes O 10-20 minutes I need to

6. What is the number of times you need to get up at night?

O 1 O More than 5
O 2 O New problem
O 3 O Prior to hospitalization
O 4 O Has supervision

7. O Incontinent
O Wears catheter

Bowel Elimination

1. Do you ever soil yourself?

O Yes
O No (If no, go to next section)

2. How often do you have an accident?

O Never O Daily
O Less than weekly O 2-3 times daily
O Once per week

3. Do you lose stool by:

O No O Small amount
O Continuous oozing O Sudden large amount

4. Before you have an accident, do you have the urge to go?

O Yes O No

5. Once you need to have a bowel movement, how long can you wait?

O Not at all
O 1-5 minutes
O 5-10 minutes
O As long as I want

6. Incontinent?

O Yes O No

Figure 2. Bender Elimination Test.

the study. This duplicate sampling occurred when a patient fell more than once, was randomly sampled as a control patient more than once, or was randomly sampled as a control either before or after a fall. If a patient fell more than once or was sampled as a control more than once, one of the two records was drawn randomly. If a patient had been sampled as both a fall and a control, the patient was classified only as a fall patient and his/her control record was deleted.

The resulting final data set for analysis contained a total of 1,135 patients, made up of 355 fall cases and 780 controls. This data set contained more than 600 variables available for analysis. For this study, only variables that could be related to anticipated physiological falls (Morse, 1997) were included such as patient demographic factors (age, sex, marital status, educational level, and so on), patient medical results (blood pressure, respiration, temperature, pulse, and so on), absence or presence of specific patient diagnoses (cancer, acquired immunodeficiency syndrome, and so on), absence or presence of the subjective fall risk factors (confusion/disorientation, depression, altered elimination, a recent fall, impaired gait or ability, dizziness, or vertigo), the objective fall risk measures (the vision and hearing tests, performance tests, Mini-Mental examination, depression test, and BET), and medication data. For the objective fall risk measures, both the overall test scores and the responses to the individual items in the tests were used as variables. When evaluating the many medication variables, we narrowed our focus to include the total number of prescribed medications, the number of prescriptions from the 18 medication classes (Table 1) and the absence or presence of any prescriptions from each of the 18 medication classes. The 18 medication classes were selected from an extensive review of the literature. Only those drugs found in the literature to be statistically significant for increased fall risk were included in this study (Campbell, 1991).

Objective risk factor variables were created using appropriate performance tests. For example, a Mini-Mental Examination score of 16 or fewer points classified a patient as "positive" for the objective measure of Confusion or Disorientation. A score of 17 or higher classified a patient as "negative" for this risk factor. The cut-off for mild dementia is 24 but this study wanted to identify at what point on the range did the risk of falling statistically go up-not at what point is dementia measurable. Because the objective risk measures came from the patient performance tests, which had some missing values, they sometimes violated one of our primary goals: to not reduce the size of the valid analysis data set. To alleviate this problem, mixed risk factors were created. For a patient to be scored as positive for the new mixed risk factor for confusion or disorientation, that patient must have either (1) been subjectively considered confused or disoriented by the nursing staff on admission or at the time of the fall or (2) scored 16 or lower on the Mini-Mental Examination at the time of mobility assessment. Thus, even if a patient did not complete the performance test, he/she would still have a mixed risk factor value because the value would be derived from the subjective measure.

The mixed risk factor variables were measured at two or three distinct time points: on admission, at the time of the fall (fall patients only), or at the time of mobility assessment. After careful analysis, it was determined that the variables were most powerful statistically when considered positive if they were positive at any one of these time points. To be considered negative, a variable was required to be negative at all time points or negative at one time point and missing at the others. If these variables were missing at all time points, the overall variable was also coded as missing.

Our main objective in developing a risk factor model was to create a predictive clinical model that is practical for today's complex hospital environment, easy to add to a basic nursing assessment, and statistically accurate in predicting patient falls. We planned to convert this model into a simple algorithm in order to make it available to nursing personnel for use in identifying patients at risk of falling. With this objective in mind, before any variable could be considered a significant risk factor and added to the model, we considered the following criteria:

1. Is the risk factor statistically significant ($P < .05$), and does it remain significant when included in the model with the other risk factors? When a risk factor is a part of a model, its P value is called the adjusted significance level because it has been mathematically adjusted for the other risk factors in the model.

2. Does the inclusion of the risk factor make medical and logical sense in terms of explaining higher (or lower) rates of patient falls in the presence of this risk factor? Or, is there prior documentary evidence of this risk factor's association with higher or lower patient fall rates?
3. If this risk factor is included, will it cause the size of the analysis data set to be reduced significantly, and if so, is this risk factor important enough to compensate for such a loss? When the data set is reduced, the model loses power.
4. If the risk factor was subjectively measured, is there an objective measure of the same risk factor that could be substituted with a similar level of statistical predictive power? Using objective measures makes the model applicable to a wider variety of patient care settings.
5. Can the results of the statistical model-fitting process be converted into easy-to-use risk points so that a nurse or physician can use a simple, additive formula to identify patients at risk of falling, and, just as important, to identify those patients not at risk of falling?

The final risk factor model was determined through a manual stepwise logistic regression process using whether or not the patient had fallen as the binary response variable. This process stopped after each step to clarify the statistical, medical, and logical validity of each new variable using the five questions above. Once the final model was agreed on, two-way interactions among the risk factors were tested for significance; none of these interactions was statistically significant.

Our main objective in developing a risk factor model was to create a predictive clinical model that is practical for today's complex hospital environment, easy to add to a basic nursing assessment, and statistically accurate in predicting patient falls.

Statistical measures used for determining the best-fitting model included the 2 Log L chi square statistic, as well as the well-known sensitivity and specificity values for retrospectively predicting patient falls.

RESULTS

Table 2 shows the final risk model determined by manual stepwise logistic regression. Statistically, the most important risk factor in the model is confusion/disorientation (defined as either being charted as "confused or disoriented" by the nursing

Table 2. Relationship Between Risk Factors and Patient Falls*

Risk Factor	Odds Ratio	95% Confidence Interval	*P* Value
Confusion/Disorientation (Mixed Definition)†	7.43	5.00-11.03	.0001
Depression (Mixed Definition)‡	2.88	1.74-4.79	.0001
Altered Elimination§	1.67	1.13-2.45	.0100
Dizziness/Vertigo (Subjective definition)‖	1.90	1.14-3.18	.0143
Gender (male)	1.69	1.16-2.46	.0066
Any prescribed antiepileptics	2.89	1.58-5.28	.0006
Any prescribed benzodiazepines	1.70	1.17-2.47	.0057
Get-up-and-go Test Item #2			.0001
Rising from chair			
Able to rise in single movement	1.00		
Pushes up, successful in one attempt	2.16	1.80-2.59	
Multiple attempts but successful	4.68	3.26-6.72	
Unable to rise without assistance	10.12	5.88-17.41	

*Calculated with 994 patients (254 fall patients and 740 control patients), intercept = −4.5852 and −2 Log L chisquare value = 372.195.

†Charted as confused or disoriented or a score of 17 on Mini-Mental Exam.

‡Charted as depressed or scored ≥8 on depression test.

§Charted with altered elimination needs or answered "yes" to any BET questions.

‖Charted with dizziness or vertigo.

staff, or scoring less than 17 points on the Mini-Mental Examination). Our risk factor model found that such a patient was at least 7 times (odds ratio [OR] = 7.43) more likely to fall than a patient who was negative for this risk factor. Various cut-off scores on the Mini-Mental Examination were tested, and a score of less than 17 points was found to be the *strongest* predictor of patient falls. A patient who was classified as positive for depression (either charted as "depressed" by the nursing staff or scoring eight or more points on the depression test) was nearly three times (OR = 2.88) more likely to fall than a non-depressed patient.

A patient with altered elimination needs (either charted as having altered elimination needs, or answering yes to one of the urinary or bowel elimination questions on the BET) was 1.67 (OR = 1.67) times more likely to fall than a patient with normal elimination patterns. A positive answer to one of the urinary or bowel elimination questions indicated that the patient suffered from leakage of urine or stool, was unable to wait when an elimination urge is felt, or got up four or more times at night to urinate.

No adequate objective measure was identified for the subjective risk factor dizziness or vertigo. Therefore, a patient was considered positive for this risk factor if he/she was charted by the nursing staff as reporting dizziness or vertigo. Such a patient was almost twice (OR = 1.90) as likely to fall as a patient without dizziness or vertigo.

After testing all of the performance tests and their individual items for inclusion in the risk model, we included only one individual item from the Get-Up-and-Go test: Question #2, "Rising from Chair." This individual item was chosen over the entire Get-Up-and-Go test score because many patients failed to finish the entire test. The item was also slightly more statistically significant than the overall test score. The response to this question has four ordered categories that correspond to a descending scale of mobility for the patient. This question was tested for statistical fit both as a single linear variable and as four separate categorical variables. The linear fit was statistically stronger, meaning that each descending level of mobility gave the patient approximately the same increase in risk of falling. Therefore, a patient who must push up with his/her arms, legs, or walking aid to rise from a chair was 2.16 times more likely to fall than the patient who could rise in a single movement (OR = 2.16). The patient who took multiple attempts to rise was another 2.16 times more likely. The patient who could not rise at all was over 10 times (OR = 10.12 = 2.16*2.16*2.16) more likely to fall than the unimpaired patient.

Patients who were taking drugs from one or both of two different classes were also more likely to fall. Those who were charted as taking any of the seven different types of antiepileptics were found to be nearly three (OR = 2.89) times more likely to fall than those not prescribed any antiepileptics. A prescription for any of the 10 benzodiazepines listed on the questionnaire made that patient 1.70 (OR) times more likely to fall. Patient gender was also a significant risk factor: males were 1.69 times (OR) more likely to experience a fall than females.

Two additional risk factors were selected by the computer program as statistically significant negative risk factors; that is, if included in the model, these risk factors would appear to reduce the risk of falling. The first of these two risk factors was taking any of the theophylline drugs listed on the questionnaire ($P = .0192$). This did not make any logical or medical sense to our researchers, so the risk factor was excluded from further consideration. Advancing patient age also showed up as an apparent negative risk factor with statistical significance ($P = .0261$); that is, for each additional year of age, the patient was slightly less likely to fall. The resulting OR for patient age made it mathematically impossible to be used effectively in the risk point model being developed. Therefore, this negative risk factor was also excluded. Clearly, age alone cannot be considered a risk factor. Age and functional status had a significant interaction. Those without significant functional limitations did not have increased fall risk regardless of age.

The statistical risk factor model is important in and of itself, but it is most useful when converted into a risk points system that can be used to identify those patients who are at risk for falling. When used together, OR are multiplicative, though their corresponding logistic regression parameters (the β coefficients) are additive, and thus easier to use in making quick calculations of risk level. To make them even easier to use, the coefficients were converted to integers by multiplying them by 1.89 and rounding the product to the nearest integer. The

1.89 multiplier was found to optimally reduce the total amount of round-off error that resulted from rounding to integers.

The statistical risk factor model is important in and of itself, but it is most useful when converted into a risk points system that can be used to identify those patients who are at risk for falling.

Table 3 shows the statistical fall risk factor model after it has been converted to a risk points system. The resulting Hendrich II Fall Risk Model (Hendrich II model) is intended to be used by hospital nurses to predict each patient's risk of falling by evaluating the patient for each risk factor (either by objective performance testing or by subjective nursing judgment) and then summing the risk points corresponding to each factor present for that patient. The resulting score takes into account not only the number of factors present, but also the degree to which those factors have been shown to place a patient at risk, and therefore will allow nurses to focus fall prevention measures on those patients at highest risk.

Using this risk points system, we recommend that a patient be classified as high risk for falling if he/she has accumulated five or more risk points. Such a patient would be, on the average, 14 times (OR = 14.09) more likely to fall than a patient who has accumulated no risk points. If this five-point classification criterion is applied to the 994 patients in our data set, the sensitivity is 74.9% and the specificity is 73.9%. Therefore, if patients classified as high risk had been given specific fall prevention assessment nursing might have predicted almost 75% of the falls in this sample. Although risk factor assessment cannot guarantee fall prevention, there is significant opportunity to prevent most falls with targeted interventions based on specific risk factors. Patients should be assessed once a shift, or more often if their condition changes, and this can be accomplished within an overall nursing assessment. Based upon the patient assessments performed as part of the patient enrollment process and observation of the actual tool in clinical practice, we believe this can usually be accomplished in 1 to 2 minutes or less.

DISCUSSION

The findings from this study suggest that an evaluation of a limited number of clinical factors can be highly predictive of fall risk, and have led to the development of the Hendrich II Fall Risk Model: a specific, valid, and brief instrument to predict fall risk. The brevity of the Hendrich model is important for several reasons. In an attempt to predict fall risk, some studies have listed as many as 21 risk factors (Champagne et al., 1992). Administration of an instrument this size is time-consuming and may be difficult to quantify. A statistically valid instrument with a limited number of factors is more relevant to clinical practice and conserves scarce resources by allowing the talents of professional nurses to be used more effectively and efficiently to assess fall risk and administer fall prevention programs.

The findings from this study suggest that an evaluation of a limited number of clinical factors can be highly predictive of fall risk, and have led to the development of the Hendrich Fall Risk Model: a specific, valid, and brief instrument to predict fall risk.

The Hendrich II model is useful because it is both sensitive (74.9% of high-risk patients were correctly identified) and highly specific (73.9% of patients *not* at high risk of falling were correctly identified). This means that few patients were misidentified as patients at high risk of falling. Correct identification of high-risk patients focuses hospital and nursing resources on those patients truly at risk of falling, and prevents resources from being diluted by the misidentification of large numbers of low-risk patients.

The Hendrich II model requires that points for various risk factors be summed. The highest point values have been assigned by mathematical methods to those factors that were found to have the

Table 3. Type Classes and Names of Drugs

- Antidepressants
  - Amitriptyline hydrochloride
  - Desipramine hydrochloride
  - Imipramine hydrochloride
  - Nortriptyline sulfate
  - Phenelzine hydrochloride
  - Tranylcypromine sulfate
  - Trazadone
- Benzodiazepines
  - Alprazolam
  - Chlordiazepoxide
  - Clonazepam
  - Clorazepate dipotassium
  - Diazepam
  - Flurazepam hydrochloride
  - Lorazepam
  - Midazolam hydrochloride
  - Oxazepam
  - Temazepam
- Antipsychotics
  - Chlorpromazine
  - Clozapine
  - Haloperidol
  - Loxapine hydrochloride
  - Perphenazine
  - Proclorperazine
  - Risperidone
  - Thiothixene
  - Thioridazine hydrochloride
  - Trifluoperazine
- Narcotics
  - Fentanyl citrate
  - Hydrocodone bitartate
  - Meperidine hydrochloride
  - Morphine hydrochloride
- Antieplileptics
  - Carbamazepine
  - Divalproex sodium
  - Felbamate
  - Gabapentin
  - Phenobarbitol
  - Phenytoin
  - Valproic acid
- Neuromuscular blocking agents
  - Atacrium
  - Doxacurium chloride
  - Pancuronium bromide
  - Succinlycholine chloride
  - Vencuronium bromide
- Antihistimines
  - Cyproheptadine hydrochloride
  - Diphenhydramine hydrochloride
  - Promethazine hydrochloride
  - Trimeprazine
- Anticholinergics
  - Benztropine mesylate
  - Trihexyphenidyl hydrochloride
- Antimuscuranics/antispasmodics
  - Atrophine sulfate
  - Dicyclomine hydrochloride
  - Glycopyrrolate
  - Hyoscyamine sulfate
  - Oxybutynin chloride
  - Propantheline bromide
- Diuretics
  - Bumetanide
  - Chlorthalidone
  - Furosemide
  - Hydrochlorothiazide
  - Hydrochlorthiazide
  - Indapamide
  - Metalazone
- Beta-blockers
  - Atenolol
  - Esmolol hydrochloride
  - Labetalol
  - Metoprolol succinate
  - Nadol nadolol
  - Pindolol
  - Propranolol hydrochloride
  - Sotalol hydrochloride
  - Timolol maleate
- Calcium channel blockers
  - Amlodipine
  - Diltiazem hydrochloride
  - Isradipine
  - Nicardipine hydrochloride
  - Nifedipine
  - Verapamil
- Antiarrythmics
  - Amiodarone hydrochloride
  - Bretylium tosylate
  - Digoxin
  - Disopyramide phosphate
  - Encainede
  - Flecainide acetate
  - Lidocaine hydrochloride
  - Procainamide hydrochloride
  - Quinidine bisulfate
  - Tocainide hydrochloride
- Angiotensin-convering enzyme inhibitors
  - Capotpril
  - Enalapril maleate
  - Lisinopril
  - Quinapril hydrochloride
  - Benazepril
- Alpha adrenergic blocking agents
  - Doxazosin mesylate
  - Prazosin hydrochloride
  - Terazosin
- Vasodilators
  - Clonidine hydrochloride
  - Hydralazine hydrochloride
  - Isosorbide dinitrate
- Theophylline
  - Aminophyline
  - Theophylline
- H_2 Receptor Antagonists
  - Cimetidine
  - Famotidine
  - Nizatidine
  - Ranitidine bismuth citrate

highest OR. Thus, the higher the patient risk scores the greater the risk of falling. This provides a hierarchy of risk and allows targeting of the most stringent fall prevention measures to those patients at highest risk. In the instance in which the patient mobility assessment portion of the tool (rising from the chair) cannot be accomplished because of a temporary inability to assess the patient's status, it is appropriate to use the most recent observation until a current one can be completed to score the patient risk. If a patient is unable to perform any mobility maneuvers, other risk factors could still be assessed but nursing judgment would be required to determine the patient's actual risk of falling if they are incapacitated.

Another advantage of the Hendrich model is that it makes sense medically: it is easy to see how the factors that were statistically linked to falling can contribute to fall risk. For example, it seems logical that confusion/disorientation could make a patient unaware of limitations in his/her abilities or less likely to call for help when trying to move about, that a patient who has to get up frequently during the night to urinate has more opportunity to

Table 4. Hendrich II Fall Risk Model

Risk Factor (≥5 = High Risk)	Risk Points
Confusion/disorientation (mixed definition)*	4
Depression (mixed definition)†	2
Altered elimination‡	1
Dizziness/vertigo (subjective definition)§	1
Gender	1
Any prescribed antiepileptics	2
Any prescribed benzodiazepines	1
Get-up-and-go Test Item #2:	
"Rising from Chair"	
Able to rise in single movement	0
Pushes up, successful in one attempt	1
Multiple attempts but successful	3
Unable to rise without assistance	4

*Charted as confused or disoriented or scored <17 on Mini-Mental Examination.

†Charted as depressed or scored >8 on depression test.

‡Charted with altered elimination needs or answered "yes" to any BET questions.

§Charted with dizziness or vertigo.

fall, and that male patients may be more likely to take risks and less likely to ask for assistance. Clinicians can understand and value the fall risk factor model and the implications for best practice. It is a research-based tool that is predictive in nature and has the ability to help medicine and nursing reduce human suffering and fiscal loss.

The framework of the Hendrich II model is closely related to our observation that patient assessment based upon clinical intuition (the subjective risk factors) was very closely related to patient assessment based upon the objective measures from the standardized tools. In short, clinicians' judgment, based on their assessments, agreed with the score from the more complex assessment completed with the research tool. Statistically, we were able to successfully use either assessment method to determine significant fall risk factors. Thus, while objective measures can be quite useful when they represent careful assessments and are available, the inability of a patient to complete a performance test or the lack of practicality in today's hospital need not preclude the assessment of that risk factor; instead, we may choose to rely upon good clinical nursing judgment.

This study evaluated only intrinsic factors that contribute to falls; that is, it evaluated only those falls that Morse called "anticipated physiological". Our large data set also contains a vast amount of information on extrinsic factors, but those were not included in this study. Extrinsic factors such as lighting, footwear, position of bedrails, and the use of restraints are also important contributors to fall risk, and have been investigated by Hendrich (Hendrich, 1988, 1992, 1995).

Medications and their associated increased fall risk correlation were studied. Very few drugs withheld statistical analysis to be identified as a fall risk factor. We believe this can best be explained by the fact the drug, in and of itself, does not equate to a risk factor. It is whether or not the drug side effects (mobility, gait, cognition, mood, elimination changes) occur in the individual that results in increased fall risk. For example, one of the researchers' parents takes more than twenty pills daily, representing more than six classes of the high-risk drugs, and yet they have not exhibited side effects nor have they fallen. If they had been assessed solely by the number and classes of drugs based on other previous study conclusions, they would have been identified as high risk.

Antiepileptics and benzodiazepines (predominantly long-acting) were identified as having significant relative risk values. Significant side effects attributed to antiepileptics include cerebellar ataxia, weakness and dizziness. Reported occurrences of these side effects are not necessarily correlated with serum drug levels (Luef, 1994). We believe this may explain why antiepileptics are found in this study as a marker for increased fall risk. Benzodiazepines have been well documented in the literature as posing significant increased fall risk due to sedation, central nervous system depression and prolonged half-life (Chaimowicz, Ferreira, & Miguel, 2000).

CONCLUSION

The Hendrich II model provides a logical, sensitive, specific method for predicting patient falls. It uses objective patient assessment when possible, relies upon clinical judgment when objective assessment is not possible, and is statistically valid in either case. The tool can be inserted into existing documentation forms, as a single document with related interventions targeted to reduce risk (Hendrich, 1995) or as part of an electronic record where risk analysis and automated calculations are performed routinely with alpha prompts and alerts. A significant number of hospitalized patients is anticipated to be identified to be at risk for falling

due to the acuity and aging prevalence within acute care hospitals. This evidenced-based tool helps conserve nursing resource and time by supporting practice with a research based tool. Currently, patient risk may be overlooked or over identified when non-research based factors are used. Once risk factors are identified, nursing interventions should be matched against individual factors to reduce or manage the risk of falling. For example, the availability of caregivers to assist with toileting and assistance in a patient with altered elimination and impaired mobility can significantly reduce the patient's overall risk of falling. When large numbers of high risk patients (such as long-term care and high risk hospital units) are present nursing will need to identify care models that use supportive roles to assist with the activities of daily living if risk is to be managed (falls, fractures, and death). The current staffing shortages and workload indexes can result in an increased fall index (falls/thousand days) if nursing does not have the time necessary for appropriate patient care management. Among nursing's many challenges is how to create care models for the future that design out rote tasks and functions that do not improve care. The new models should be built on research and best practice to improve professional nursing practice/satisfaction/retention and patient outcomes. Future studies should focus on (1) nursing interventions, matched against these risk factors, to determine the overall effectiveness and efficacy of specific interventions to reduce individual risk and (2) replicated studies of sensitivity and specificity when subjective assessments are used to evaluate risk factors rather than formal risk tools with the identified predictive indicators from this study.

The current acute care environment is very challenging, and it is often described as a complex milieu in which episodes of care are delivered. There are few opportunities as simple and as important as fall risk identification to improve patient outcomes and to increase patient safety. The researchers believe this tool holds significant promise for patient safety when predictive risk factors and matched interventions are used to reduce individual risk by establishing best practice(s) for hospital care delivery.

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