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Predictors of fracture from falls reported in hospital and residential care facilities: a cross-sectional study

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ABSTRACT

Objectives: Fall-related fractures are associated with substantial human and economic costs. An improved understanding of the predictors of fall-related fractures in healthcare settings would be useful in developing future interventions. The objective of this study was to identify such predictors by exploring associations between fall-related factors and fracture outcomes through logistic regression analysis of routinely collected fall incident data.

Design: Retrospective cross-sectional study.

Setting: 197 public healthcare facilities in Queensland, Australia.

Participants: We included data from incident reports completed after falls among admitted adult hospital patients (n=24 218 falls, 229 fractures) and aged-care residents (n=8980 falls, 74 fractures) between January 2007 and November 2009.

Primary and secondary outcomes: The outcomes of interest were fall-related predictors of fracture.

Results: Hospital patients who reported to have been screened for their risk of falling at admission were less likely to fracture after a fall (OR: 0.60, 95% CI 0.41 to 0.89) than those who had not been screened. Further, falls from standing (OR: 2.08, 95% CI 1.22 to 3.55) and falls while walking (OR: 1.86, 95% CI 1.32 to 2.62) were associated with higher fracture odds than falls during other activities. In line with these results, falls while reaching in standing (OR: 3.51, 95% CI 1.44 to 8.56) and falls while walking (OR: 2.11, 95% CI 1.24 to 3.58) were also predictive of fracture in the adjusted residential care model.

Conclusions: Our findings indicate that screening of hospital patients for their risk of falling may contribute towards the prevention of fall-related injury. Falls from upright postures appear to be more likely to result in fractures than other falls in healthcare settings. Further prospective research is warranted.

INTRODUCTION

Falls among older people in institutional settings are an issue of growing concern.[1] While not all falls are injurious, the ones that cause serious injuries, such as hip fractures, are responsible for the major portion of the economic[2] and human cost[2 3] described in the literature. As a result, preventing fall-related fracture is an important public health priority.[4]

Typically, fall prevention trials have implemented interventions targeting modifiable risk factors for falls among older people identified as being at risk of falling, and some have been successful in reducing fall rates.[5–7] Nevertheless, due to the large numbers of older people who would be considered to be at risk of falling in hospital and residential care settings, such broad approaches can be expensive to implement and sustain. A more cost-effective approach would be to focus directly on the prevention

of injurious falls among older people at risk of sustaining fall-related injury. However, our understanding of the predictors of fall-related injury in healthcare settings is currently inadequate to develop such targeted interventions. The aim of this study was to advance an understanding of fall-related fracture predictors in hospital and residential care settings, by examining incident reports completed after falls in these environments.

METHODS
Design
This retrospective cross-sectional study utilised clinical incident reports completed after adult falls in healthcare settings (hospital and residential care) and explored predictive relationships between fall-related factors and fracture outcomes using logistic regression analysis.

Participants
All adult fall-related incidents reported on the Queensland Health (QH) clinical incident reporting system (also known as 'PRIME') between 1 January 2007 and 30 November 2009 were included in our dataset.

Setting
QH operates 167 hospital facilities with 8859 beds, 27 residential care facilities with 1798 beds and four specialised psychiatric residential facilities with 458 beds, respectively. QH hospital facilities are geographically scattered with 15 facilities in metropolitan areas, 78 in regional areas and 74 in remote areas across the state. All but one facility (a 538 bed tertiary metropolitan hospital in southeast Queensland) utilise the PRIME reporting system.

The PRIME reporting system is accessible online by QH staff. Once basic information about the individual is entered, the reporter inputs incident details through a series of drop-down fields pertaining to the specific incident type (eg, a fall or pressure ulcer). The system generates additional fields on subsequent pages based on the incident type chosen by the reporter. Some fields are mandatory and required to be completed before progressing to subsequent sections. Reporters are able to save incomplete reports and exit at any point, with the option to return and finalise the report at a later stage. The reporting interface is designed to be usable by reporters without prior experience with the system; however, regular training sessions are available for staff in addition to comprehensive online resources and local support from expert users. To ensure report accuracy, ward managers are responsible for reviewing incidents periodically. The QH Patient Safety Centre monitors overall system functionality and coordinates system improvements as necessary.

Procedure
The institutional human research ethics review committee of the Royal Brisbane and Women's Hospital (RBWH) approved this study. We included all mandatory and non-mandatory fields collected in relation to individual fall incidents across QH facilities for the observation period. Retrieved fields included date of incident, time of incident, the incident severity level, health district, facility, service area, ward/unit, date of birth, gender, universal reference number (patient ID), place of incident (such as bedroom, bathroom or toilet), injuries sustained, function when the fall occurred (such as standing, walking or sitting), activity when fall occurred (such as showering, grooming or resting), fall mechanism (such as slip, trip or overbalance), whether a fall risk screen or assessment was completed on admission, and whether the fall was witnessed. The QH clinical incident (CI) data dictionary provides definitions for a selection of fall-related field types. These are listed in table 1.

We examined raw data and eliminated duplicate records, along with records that pertained to community clients and falls that occurred while hospital patients or aged-care residents were outside the healthcare facility. We also excluded falls that related to hospital patients under the age of 18. In total, we removed 3812 records through this process, resulting in a final dataset of 33 198 incidents. The dataset was interrogated for inconsistencies through the creation of frequency tables, data ranges and histograms at various stages of the data preparation process.

For fields with multiple response options, we coded for the presence or absence of each response variable separately to enable logistic regression analysis. Similarly, for 'Age at time of fall', a continuous variable, we created age-ranges and then coded within these categories dichotomously. Prior to analysis, we separated records into hospital and residential care datasets. This decision was based on a review of the literature, which suggested that hospital and residential care populations were sufficiently different in terms of demographic characteristics, health status, risk factors, level of frailty, levels of activity and systems of care delivery to require separate analysis.[8–13]

Microsoft Excel 2002 and Access 2002 were used for data preparation and coding. We used Microsoft Excel 2007 to create tables and StatCorp Stata SE V.10 to perform all statistical analysis.

Data analysis
We examined the relationship between individual predictor variables and fractures using univariate and multiple logistic regression analysis. We clustered fall incidents by universal identification number employing robust variance estimates to account for the dependency between multiple fall records contributed by the same individual. We additionally subjected predictor variables to factor analysis (principal components) to explore between-variable colinearity prior to building a multiple logistic regression model as described by Hosmer and Lemeshow.[14] We started by including all univariate

Table 1 Fall-related field definitions*

Variable	Definition
Type of fall	
Slip	Fall or loss of balance occurring from loss of traction on surface
Trip	Loss of balance usually while walking resulting from portion of foot or lower limb contacting an obstacle
Legs gave way	Involuntary loss of mechanical support in the leg or legs
Dizziness	Loss of equilibrium, for example, a spinning sensation, or light-headedness or a feeling you are about to fall
Faint	Loss of consciousness
Overbalance	Movement of the body beyond its base of support
Activity at time of fall	
Walking	*(No definition provided)*
Standing	Standing without other overt activity
Sitting to standing	Moving from a sitting position to a standing position, for example, rising from bed or chair or toilet
Standing to sitting	Moving from a standing to sitting position, for example, lowering to a bed, chair or toilet
Standing from lying position	Moving from a lying to standing position, for example, getting out of bed
Standing to lying position	Moving from lying to standing, for example, getting in to bed
Rolling out of bed	Rolling out of bed on to the floor
Sitting	Sitting without other activity
Seating to seating	Transferring from one seated position to another, for example, chair or toilet to wheelchair
Reaching for object while seated	*(No definition provided)*
Reaching for object while standing	*(No definition provided)*
Function attempted by patient at time of fall	
Toileting	All activities involved in getting to and using the toilet
Bathing or showering	All activities involved in bathing or showering, including getting to the shower
Resting	Includes movement to the location of rest
Exercising	Activity undertaken for therapeutic or recreational purposes, eg, going for a walk, or a part of treatment programme
Grooming or dressing	Includes activities such as brushing hair or teeth, dressing, etc
Use entertainment	Includes activities such as picking up a book or turning on the TV

*Source: Queensland Health PRIME Clinical Incident Data Dictionary V 4.1 2008.

predictor variables with p values equal to or less than 0.25 in the initial model. We then adopted a stepwise backward elimination approach to progressively remove variables with the highest p values until all remaining variables in the model had p values equal to or less than 0.05. Excluded variables were subsequently re-entered into the model in order of statistical significance, and retained if they achieved p values of 0.05 or less in the final model.

RESULTS

The final dataset consisted of 24 218 hospital fall incidents and 8980 residential care fall incidents. Table 2 presents a comparison of demographic, fall and fall-related fracture characteristics for hospital and residential care subsets.

Table 3 provides unadjusted ORs for the likelihood of fracture when individual fall-related variables are present. Tables 4 and 5 present the models developed for hospital and residential care datasets, respectively, adjusted for the effects of other variables entered into the model. Results showed that male hospital patients were considerably less likely to fracture upon falling than female patients (OR: 0.42, p<0.001). Further, patients of advanced age (80 years and over) were the age group most likely to fracture upon falling in hospital (OR: 1.44, p<0.001).

We found a number of fall-related characteristics to be predictive of fracture. 'Falls while walking' were

Table 2 Characteristics of study sample: falls and fall-related fracture

	Hospital	Residential care facilities
Reported falls	24 218	8980
Mean age (SD)	70.14 (17.28)	80.48 (10.65)
Median age	74.35	82.37
Gender (Male %)	57	54
Reported fractures (% reported falls)	229 (0.94)	74 (0.82)
Mean age (SD)	75.83 (15.21)	82.63 (9.99)
Median Age	78.98	85.33
Gender (Male %)	33	44

Table 3 Univariate analysis of fall-related predictors of fracture outcomes in hospital and residential care settings

Variable	Hospital		Residential care	
	OR†,‡ (95% CI)	p Value§	OR† (95% CI)	p Value§
Activity factors				
Reaching in standing	0.67 (0.34 to 1.31)	0.251	2.64 (1.13 to 6.16)	0.024*
Rolling out of bed	0.29 (0.10 to 0.78)	0.015*	0.86 (0.26 to 2.76)	0.802
Sitting	0.23 (0.08 to 0.62)	0.004*	0.40 (0.09 to 1.67)	0.214
Walking	1.96 (1.50 to 2.56)	<0.001*	2.04 (1.27 to 3.27)	0.003*
Type of fall				
Trip	2.06 (1.32 to 3.22)	0.001*	3.88 (1.90 to 7.94)	<0.001*
Slip	0.70 (0.49 to 0.98)	0.043*	0.57 (0.27 to 1.20)	0.143
Function factors				
Resting	0.40 (0.22 to 0.73)	0.003*	0.33 (0.10 to 1.05)	0.062
Person factors				
Age between 40 and 60	0.46 (0.27 to 0.78)	0.004*	0.29 (0.04 to 2.21)	0.238
Age over 80	1.51 (1.16 to 1.96)	0.002*	1.27 (0.74 to 2.16)	0.377
Male gender	0.37 (0.28 to 0.50)	0.000*	0.67 (0.40 to 1.12)	0.132
Spatial/environmental factors				
Bedside	0.63 (0.46 to 0.84)	0.002*	0.45 (0.14 to 1.44)	0.179
Bedroom areas other than bedside	1.36 (1.00 to 1.85)	0.048*	1.50 (0.93 to 2.42)	0.091
Corridor/hallway	2.39 (1.58 to 3.62)	0.000*	0.88 (0.38 to 2.02)	0.770
Other areas—not classified	1.24 (0.45 to 3.35)	0.671	3.08 (1.11 to 8.55)	0.031*
Temporal factors				
1600–1700	0.92 (0.43 to 1.97)	0.844	2.12 (1.03 to 4.35)	0.040*
1900–2000	0.92 (0.41 to 2.07)	0.848	2.86 (1.35 to 6.05)	0.006*
Other factors				
Risk screened/assessed at admission	0.66 (0.48 to 0.92)	0.015*	0.41 (0.16 to 1.04)	0.061

*Significant variable (p equal to or less than 0.05).
†OR (95% CI).
‡Reference value for all comparisons using ORs are 1.00; each variable is compared against all other remaining variables within category. For example, within 'Activity Factors', odds for facture during falls while 'reaching in standing' are expressed as a ratio against odds for fracture after falls related to all other activity variables. Hospital and residential care results are presented in parallel but have been analysed separately.
§Significance level.

associated with higher odds of fracture in both hospital (OR: 1.96, p<0.001) and residential care settings (OR: 2.04, p<0.001) than falls during other functions. 'Falls due to trips' were strongly predictive of fracture outcomes across both settings as an unadjusted variable but only in residential care (OR: 2.89, p=0.006) once adjusted for the effects of other variables. Falls in certain physical locations were associated with an

Table 4 Adjusted ORs—hospital fractures

Logistic regression		Number of obs=17016 Wald $\chi^2(10)$=101.60 probability $>\chi^2$=0.0000 Pseudo-R^2=0.0554
Log pseudo-likelihood=−911.42064 (SE adjusted for 12 252 clusters in PtURN)		
Variable	OR (95% CI)	p Value
Witnessed by staff	0.51 (0.33 to 0.79)	0.003
Risk screened/assessed at admission	0.60 (0.41 to 0.89)	0.012
Standing	2.08 (1.22 to 3.55)	0.007
Walking	1.86 (1.32 to 2.62)	<0.001
Resting	0.52 (0.27 to 0.97)	0.043
Male gender	0.42 (0.30 to 0.58)	<0.001
Corridor/hallway	2.10 (1.23 to 3.58)	0.006
Age between 40 and 60	0.52 (0.27 to 0.98)	0.046
Age 80 and over	1.44 (1.05 to 1.99)	<0.001
1400–1500 h	1.97 (1.09 to 3.54)	0.023
2100–2200 h	1.73 (1.01 to 2.97)	0.044

Table 5 Adjusted ORs—residential care fractures

Logistic regression	Number of obs=8973	
	Wald $\chi^2(10)$=62.61	
	Probability $>\chi^2$=0.0000	
Log pseudo-likelihood=−406.85361	Pseudo-R^2=0.0510	
(SE adjusted for 12 252 clusters in PtURN)		
Variable	OR (95% CI)	p Value
Reaching in standing	3.51 (1.44 to 8.56)	0.006
Walking	2.11 (1.24 to 3.58)	0.006
Trip	2.89 (1.35 to 6.17)	0.006
Bedroom areas other than bedside	1.88 (1.15 to 3.07)	0.011
Other areas—not classified	3.19 (1.15 to 8.85)	0.025
0700–0800	2.56 (1.08 to 6.07)	0.033
1600–1700	2.59 (1.24 to 5.39)	0.011
1900–2000	3.33 (1.55 to 7.14)	0.002

increased probability of fracture outcomes. Considered individually, falls in corridors or hallways (OR: 2.10, p=0.006) were strongly associated with fractures in hospital, while falls in resident rooms (but not the immediate bedside environment) were similarly associated with an elevated risk of fractures (OR: 1.88, p=0.011) in the adjusted residential care model.

In the adjusted hospital model, we found that falls reported as having been 'witnessed' were half as likely to be associated with fracture outcomes (OR: 0.51, p=0.003) than falls reported as being unwitnessed. Among hospital patients who had been reported as having been screened for their fall risk at admission, falls were less likely to be associated with fractures (OR: 0.60, p=0.012) than among patients for whom a risk screen was not completed. Temporal factors were also associated with the likelihood of fall-related fracture outcomes across hospital as well as residential care models.

DISCUSSION

Cost-effectiveness is increasingly being seen as important in the evaluation of programmes aimed at preventing falls in hospitals.[15] Previous cost-of-falls studies have recognised that the economic burden of falls is heavily skewed towards falls that result in fracture.[13][16] The present study identified specific characteristics of falls (and fallers) which increased the likelihood of fractures. Such data are necessary for the development of future interventions to prevent these high cost falls.

Our results revealed that female hospital patients were almost twice as likely as male patients to sustain fractures upon falling. These results are directionally consistent with previous findings on gender-specific fall injury rates.[6][13] The lack of a comparable trend in the residential care dataset could be attributed to the smaller size of our residential care sample. However, previous studies have documented a reduction in the female gender bias for fracture in people of advanced age or the 'oldest' old group,[17] hypothesising an acceleration of

physiological bone changes in men of advanced age. As our residential care group was considerably older than the hospital group with a mean age difference of 10 years, such an explanation could be plausible.

In line with current biomechanical models for fall-related fractures,[18–20] our results support the premise that the likelihood of fracture is elevated for falls from more upright postures compared with falls from lower heights. In our hospital dataset, for example, falls while walking, falls while standing and falls in corridor areas were predictive of fractures. Conversely, falls reported to have happened when patients were resting had a lower association with fractures in hospital. A similar trend was observable in the residential care model in terms of activity and spatial factors. Falls while walking were strongly predictive of fracture in both adjusted models. Compared with falls from static positions, this could relate to higher impact forces from an additive effect of an individual's existing motion and the fall-related acceleration.

On adjusting for other variables in the hospital multiple regression model, falls that were reported as having been witnessed by staff were found to be half as likely to be associated with fractures than unwitnessed falls. It would be reasonable to assume that a number of these witnessed falls happened when patients were under the supervision of a staff member. Therefore, intervention by staff may have contributed to the reduced odds of fracture. At the same time, supervised patients might be less likely to engage in 'risky' activities than unsupervised patients would due to input from the staff member. For example, patients would be less likely to mobilise without their prescribed mobility aid if a staff member were present to encourage its use. While we recognise that a fall being 'witnessed' does not equate to the fall being supervised in all instances, our results do highlight appropriate supervision as an important part of a holistic approach to keeping older patients safe.

Falls that were reported as having occurred between the periods from 14:00 and 15:00 and 21:00 and 22:00 hours were associated with increased fracture odds in

hospital after adjusting for other variables in the multiple logistic regression model. These periods potentially intersect nursing shift changeover times. As previously posited in this paper, the reduced availability of supervision could be a factor influencing the risk of fall-related fracture outcomes during such periods. We also identified relationships between falls in certain time periods and fractures in the residential care settings. These were falls between 7:00 and 8:00, 16:00 and 17:00 and between 19:00 and 20:00. Although convergence was not readily identifiable between all of these periods and any single daily activity routine or known physiological phenomena, a composite influence of underlying factors may be an explanation. Owing to the relatively high odds of fracture from falls during these periods in residential care settings, further investigation is warranted.

Our results suggest that patients who suffered serious falls were less likely to have been screened for their risk of falling on admission. While such an association has not been previously discussed in the literature, there are possible mechanisms through which falls risk screening could preferentially prevent injurious falls. Theoretically, patients identified to be at risk of falling may receive interventions more frequently that those patients whose risk has not yet been established. If some of these interventions have a greater effect in preventing falls associated with fracture, it would explain our results. An example of this would be the completion of mobility assessments for patients identified to be at risk of falling. Patients who receive mobility assessments would be safer while mobilising, thereby reducing the risk of falls while walking, which is a type of fall associated with fractures in our data. It should be noted that there is considerable heterogeneity in falls risk screening processes across QH facilities with a mixture of validated falls risk screening tools, formal and informal clinical judgement-based approaches being employed.

A parsimonious adjusted model proved elusive for hospital as well as residential care datasets, with a number of variables retaining p values equal to or less than 0.05. Despite this, the final model explained only a modest proportion of the overall variance in the outcome variable. While this could be indicative of type I error or a high degree of random chance governing fracture phenomena, it is at least partly due to the recognised multifactorial nature of fall-related fractures. A comprehensive explanatory model would require the inclusion of other independently predictive intrinsic variables such as diagnosis, frailty, cognitive and mobility status in addition to the variables we considered here.

A recent landmark study examining causative mechanisms for falls in older people highlighted tripping as a frequent cause of falls in institutional settings.[21] In our study falls due to tripping were also independently predictive of fractures in hospital and residential care settings. Consequently, there is a need for greater emphasis on managing low-level trip hazards for older people and improving their ability to safely negotiate institutional environments.

Limitations

There are a number of important limitations to our study, several of which are known shortcomings of cross-sectional research with routinely collected incident data.[22 23] As our sample was extracted from a voluntary incident reporting system, it is recognised that many unreported incidents would be missing from analysis. Admittedly, a reporting bias towards injurious falls might also introduce an unknown degree of skew. Variations in incident reporting culture are unavoidable in large heterogeneous organisations such as QH, which consists of numerous facilities spread across large geographical areas and servicing diverse populations. These variations in reporting can be a substantial confounder for cross-sectional studies such as this where data is aggregated across multiple sites.

We recognise that by using 'fracture' as the outcome variable, we are aggregating fracture types with known differences in injury mechanisms.[24] This approach could therefore conceal underlying divergences in risk factors. Additionally, there is some suggestive evidence that activities preceding fracture producing falls vary depending on the resultant fracture type.[25]

Another potential confounder is that most falls in health facilities are unwitnessed by staff. In our sample, fewer than 25% of hospital falls and 16% of residential care falls were reported as having been witnessed. It is likely that details relating to these unwitnessed incidents are based on information collected from patients or residents themselves, other observers and the reporter's investigation of the circumstances surrounding the fall. It is possible that any extrapolation on the part of reporters could introduce error and negatively influence veracity of the data.

An important weakness of our study is the inability to account for the effect of exposure rates with this approach. In this study, we identified fall-related predictors of fracture outcomes by comparing falls resulting in fracture with falls that did not. While this approach is useful in identifying fall types that are associated with high injury risk, it is not possible to estimate the overall risk of fall-related fracture associated with particular activities or situational factors. For example, while our data allows us to compare the odds of a fracture outcome from falls during mobilisation with the odds of fracture from other fall types, we cannot comment on the overall risk of fall-related fracture during mobilisation without the addition of information on exposure rates and activity-related fall rates. Nevertheless, such cumulative estimates of risk were outside the scope of the present study and could be the focus of future work.

Within the limitations listed here, our results would be useful in the development of future intervention strategies to address the problem of injurious falls in hospital and residential care settings.

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