Falls in Home-dwelling Patients with Stroke during the First Three Months after Hospital Discharge: Immediate Mechanisms and Predictors

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Background and Purpose: This preliminary study investigated the immediate mechanisms leading to falls in the first three months after patients with stroke were discharged from hospital and identified the predictors of fallers. **Methods:** Post-discharge falls of nineteen patients with stroke were monitored in biweekly follow-ups up to three months after discharge, and home visits were arranged whenever falls occurred. The immediate mechanism of each fall was categorized according to the body part primarily perturbed during the fall, i.e. the centre-of-mass (COM) or base-of-support (BOS). Cognitive and physical performances were assessed in the week before discharge, serving as potential predictors of fallers. **Results:** Seventy-six and twenty percent of all 25 falls were due to COM and BOS perturbations, respectively. Seventy-six percent of the falls occurred during routine activities in familiar environments. Poorer motor function (upper extremity ≤ 46/66, lower extremity ≤ 28/34 of the Fugl-Meyer Assessment) proved to be the best overall predictor (sensitivity ≥ 80%, specificity ≥ 88%) of individuals prone to falls. **Conclusions:** The majority of the falls of recently discharged patients with stroke were due to COM perturbations while performing daily functional activities. Pre-discharge programmes should target at improving COM control in high-risk patients of post-discharge falls, i.e. those with poorer motor function as revealed by the Fugl-Meyer Assessment. (FJPT 2010;35(4):275-283)

Key Words: Stroke, Accidental falls, Patient discharge, Sensitivity and specificity

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Falls are among the most common complications in patients with stroke.[1] Past research on falls in this population has initially focused on surveying falls occurring during hospitalization.[2-8] Immediate attention can be paid to these falls by the medical staff, and precautions against them can be implemented daily. It is only later in time that accidental falls occurring among community-dwelling stroke survivors are deemed as a serious health problem in society.[1,9-22] A longitudinal study reported that the incidence of falls in this population dramatically increases during the first six months after hospital discharge.[1] Thus, the first few months after hospital discharge are a critical transitional period that deserves special attention.

It is imperative to develop effective interventions to prevent the occurrence of early post-discharge falls and to reduce their consequences in patients with stroke residing in the community.[12,18] An effective prevention program will benefit from an understanding of the mechanisms underlying early post-discharge falls and the use of clinical assessments that can accurately identify high-risk fallers in this period. However, to date, only three groups of researchers have focused on accidental falls among patients with stroke during the transitional period after hospital discharge. Although both Forster and Young[12] and Mackintosh et al.[18] described the activities leading to falls, only the former reported the immediate cause leading to each fall based on answers recalled eight weeks and six months after discharge by the fallers. The long interval between the time of the fall events and the post-fall interviews can reduce the accuracy of patients' recollection. In addition, the answers given by patients may not specifically relate to the exact balance control mechanisms, which otherwise could be targeted in pre-discharge treatment programmes. Another concern of this line of research has to do with the methodology used to identify potential predictors of post-discharge fallers. Both Ashburn et al.[10] and Mackintosh et al.[19] took the baseline measurements used to predict fallers in the period from discharge to two weeks after discharge, a period during which some patients had already experienced falls.[19] It is thus possible that some measurements of potential predictors in the above studies can have been confounded by post-discharge falls.

The first aim of this preliminary study was to identify the immediate mechanisms of early post-discharge falls. We gathered information regarding the contextual characteristics of each fall, particularly the subject's familiarity with the activity and the environment where the fall occurred. To provide a framework for examining the impaired balance control mechanisms which were potentially associated with each individual fall, we also categorized the falls from a biomechanical perspective. The second aim was to identify subject-related cognitive and physical factors at hospital discharge that could predict post-discharge fallers.

METHODS

Subjects

A convenient sample of nineteen patients with stroke with hemiplegia or hemiparesis was recruited from a medical centre in Taipei, Taiwan over a one-year period. All of them had been admitted to the Department of Neurology or Department of Rehabilitation for stroke care. All subjects met the following criteria: admitted to the hospital within one month after stroke onset, unilaterally affected, and returning to live in a community home setting in Taipei City or County after hospital discharge. Subjects with unstable medical conditions or uncontrolled systemic diseases, bedridden mobility status, or other neurological diseases were excluded. All of the subjects signed an informed consent form approved by the institutional review board. Table 1. summarises the basic characteristics of the subjects categorized into non-fallers and fallers. A faller was defined as having at least one accidental fall in the first three months after hospital discharge. An accidental fall was defined as "an event which results in a person coming to rest inadvertently on the ground or other lower level and other than a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis such as an epileptic seizure."[23]

Measures

To examine potential predictors of early post-discharge fallers, cognitive and physical assessments were conducted. Cognitive function was assessed by the Mini-Mental State Examination (MMSE).[24] The Fugl-Meyer Assessment (FMA)[25] was used to evaluate the motor functions of the affected upper and lower extremities. The Performance-Oriented Assessments of Balance and of Gait (POAB and POAG, respectively) developed by Tinetti[26] were used to measure control of activity-based balance ability and functional mobility. This scale was

Table 1. Comparison of basic characteristics between non-fallers and fallers.

Variable	Non-fallers (n=9)	Fallers (n=10)	*p* value
Age (years)	62.7 ± 12.6	63.3 ± 13.6	0.918
Sex (male/female)	5/4	7/3	0.515
Etiology (infarction/hemorrhage)	7/2	8/2	0.906
Hemiplegic side (left/right)	6/3	6/4	0.764
Number of stroke attacks (one time/recurrent)	9/0	9/1	0.343
Lesion Site (n)			
Primary motor cortex	3	5	0.463
Supplementary/premotor areas	2	5	0.210
Parietal cortex	2	5	0.210
Basal ganglia	6	3	0.110
Thalamus	0	3	0.073
Brain stem	0	1	0.330
Hemineglect or hemianopsia (yes/no)	2/7	4/6	0.405
Aphasia or dysphasia (yes/no)	4/5	6/4	0.498
Number of medications	2.0 ± 0.7	2.1 ± 0.7	0.754
Number of co-morbidities	1.9 ± 1.1	2.0 ± 1.4	0.850
Time from stroke onset to discharge (days)	33.1 ± 26.6	58.3 ± 20.7	0.041*

Values are presented as numbers or means ± SD.
*Variables showing group differences ($p<0.05$).

developed for screening the fall risk among elderly, and has been shown to be among the most used fall risk assessments by physiotherapists.[27] Higher scores on the MMSE, FMA, POAB and POAG indicated better performance. In addition, the number and types of walking devices, such as a regular cane, quadruped cane, walker, wheelchair or long leg brace, prescribed by the subject's physicians or therapists were also documented.

Procedures

At the time of recruitment, demographic data and medical history were collected from each subject's medical records. The brain lesion sites of all subjects were determined by a radiologist (YHW) reading the CT/MRI images. The examinations for cognitive and physical impairments were conducted within one week prior to the subject's hospital discharge by a physiotherapist (HYC).

Each participant was given a calendar to document accidental falls. Post-discharge phone interviews were performed biweekly to survey the incidence of falls up to three months after discharge. For patients whose MMSE scores were below twenty-four, the main caregivers and/or family members, instead of the patients, were interviewed to ensure accurate reports of fall incidents.

Whenever an accidental fall was confirmed in a phone interview, a face-to-face interview was performed at the patient's residence using a structured fall survey questionnaire. The average time interval between a fall event and the home interview was 4.9 days. The fall survey questionnaire included detailed descriptions regarding the time and place at which the fall occurred, the activity engaged when the fall occurred, and the subject's familiarity with the activity and the environment. When these characteristics were considered together, the patients or the main caregivers were asked to categorize the contextual characteristics of the falls into one of the three types: a usual activity carried out in a familiar and unchanged environment, a usual activity carried out in an unfamiliar or changed environment and an unusual activity. A usual activity was explained as what the patient does almost every day and

the contrary was defined as an unusual activity. A familiar environment was explained here as a place where the patient used to stay in the daily routines, whereas an unchanged environment was explained as a place where no alteration was made to the layout of furniture. On the contrary, an unfamiliar environment was defined as a place where the patient did not often stay during daily routines, and a changed environment was defined as a place where a layout had been changed or furniture was removed or added. In addition, we also recorded whether help was provided or a walking device was properly used when the fall occurred.

To explore the impaired balance control mechanisms underlying the falls registered in the study, all fall events were categorized according to a modified version of Topper and colleagues' classification scheme for falls in older people.[28] In particular, this scheme categorizes falls according to the location at which the destabilising force acts on the body: the centre-of-mass (COM), the base-of-support (BOS), or none. By definition, COM falls indicate that the destabilising force displaces the COM beyond the BOS by an externally applied push or collision, or a self-initiated voluntary movement. BOS falls refer to falls in which the perturbation prevents the BOS (feet or buttocks, for example) from being realigned underneath the COM. In this scheme, where both COM and BOS perturbations are possible, the categorisation of BOS falls is assigned.[28] Falls during walking with no apparent BOS problem were classified in the no apparent perturbation category by Topper et al.,[28] but were placed in the category of COM falls in our study, as the gait of patients with stroke is generally characterised by excessive COM sways compared to healthy older adults.[29] Classification of the falls was performed by one of the authors (HYC), who presented 100% intra-rater agreement and 88% inter-rater agreement with the first author when using this scheme.

Data Analysis

Descriptive analyses were used to analyse the incidence and circumstances of the falls. Differences between non-fallers and fallers in subject-related data were tested by Chi-square tests for categorical variables, independent t-tests for continuous variables that met variance and normality assumptions, and nonparametric Mann-Whitney U tests for ordinal or continuous variables if assumptions of variance and normality were violated.

For cognitive and physical variables showing group differences, univariate logistic regression analyses were performed to identify significant predictors of fallers. The receiver operating characteristics (ROC) curve[30,31] was utilized to determine the cut-off point for each variable with the greatest prediction accuracy in terms of sensitivity and specificity. Univariate logistic regression analyses were selected due to the exploratory nature of this study and the insufficient number of subjects for multivariate logistic regression statistics. SPSS software (12.0) was used for all data management and analyses with alpha value set at 0.05.

RESULTS

Ten of the 19 patients (53%) fell at least once during the investigation period. Seven of the ten fallers fell at least twice. One patient even fell six times. In total, 25 falls were reported, resulting in 2.5 falls per faller on average.

Table 2. summarises the circumstances of the 25 falls. Twelve falls (48%) occurred in the first two weeks after discharge. Most of the falls occurred during the daytime (80%) and in the living room (36%). All 25 falls occurred while the patients were performing basic activities of daily living, among which walking ranked highest (28%), followed by standing up (20%) and reaching for objects (16%). It is important to note that three out of the seven recurrent fallers in our study tended to fall in the same activity. One recurrent faller fell three times when standing up, another one fell twice when transferring and the other one fell twice when walking in a hurry.

Table 2. also shows the contextual characteristics of falls. The majority of falls (76%) occurred while patients were performing usual activities in familiar and unchanged environments. In nearly half (48%) of the falls, the patients lacked the regular help they needed for carrying out the activities. Regarding device use, 28% of the falls occurred while the patients did not use or improperly used the walking devices normally needed for performance of the activities.

Biomechanical categorisation of the immediate mechanisms leading to the falls revealed that nineteen falls (76%) were resulted from COM perturbations (Table 3). Almost all fall events in the COM category occurred during self-initiated movements, except one event resulted from collision with

another person. Twenty percent of the falls were BOS falls in which the patient's foot was tripped by the ground or one leg was tangled by the other leg or by obstacles. The biomechanical mechanism of one fall (4%) was unable to be categorized, as it occurred without a witness in a patient with poor cognition.

There was no significant difference between fallers and non-fallers in most demographic variables or in MMSE (p=0.185) (Tables 1. and 4.). However, fallers stayed in the hospital significantly longer (58.3±20.7 days) than non-fallers (33.1±26.6 days)(p=0.041) for post-stroke care. Fallers performed more poorly on motor functions of the affected upper and lower extremity sections of the FMA (p=0.009 and 0.013, respectively), as well as on the activity-based assessments of POAB (p=0.022) and POAG (p=0.001). Fallers also used more walking devices than non-fallers (p=0.010).

Cognitive and physical variables showing group differences were entered into univariate logistic regression analyses (Table 4.). Results of univariate logistic regression analyses showed that all physical variables had sensitivity and specificity values of greater than 60% in predicting fallers. In particular, the affected upper and lower extremities motor scores of the FMA with cut-off scores of 46 and 28, respectively, showed a sensitivity of 80% and a specificity of ≥ 88% in predicting fallers. These two physical measures thus showed the best overall prediction of fallers among all of the physical assessments used in our study.

DISCUSSION AND CONCLUSIONS

High incidence and high recurrence rate of falls after hospital discharge, especially in the first two weeks

Our finding of high incidence (53%) of post-discharge falls in home-dwelling patients with stroke is in accordance with other studies that showed a higher incidence of falls following discharge (greater than 45%)[10,12,18,19] than during hospitalization (less than 40%).[1,3,4,6-8] Our results also showed a high recurrence rate (70%) of falls. Similarly, Ashburn et al.,[10] Forster and Young[12] and Mackintosh et al.[19] reported recurrence rates of 76%, 65% and 46%, respectively. It is important to

Table 2. Circumstances of falls (n = 25 falls).

Frequency (%)			Frequency (%)		
Week			Time		
1~2	12	(48%)	Day	20	(80%)
3~4	2	(8%)	Night	5	(20%)
5~6	6	(24%)	Location		
7~8	4	(16%)	Living room	9	(36%)
9~10	0	(0%)	Bedroom	6	(24%)
11~12	1	(4%)	Aisle	3	(12%)
Activity			Others (indoor)	4	(16%)
Walking	7	(28%)	Others (community)	3	(12%)
Standing up	5	(20%)	Helper at falls		
Reaching	4	(16%)	Lack of help	12	(48%)
Turning	3	(12%)	No lack of help	13	(52%)
Transferring	3	(12%)	Device at falls		
Sitting down	2	(8%)	Lack of device	7	(28%)
Unknown	1	(4%)	No lack of device	18	(72%)
Contextual Characteristics					
Usual activity carried out in familiar and unchanged environment				19	(76%)
Usual activity carried out in unfamiliar or changed environment				3	(12%)
Unusual activity				3	(12%)

note that three of the seven recurrent fallers in our study tended to fall in the same activity; similar findings were reported by Mackintosh et al.[18] These results suggest that patients with stroke who are at high risk of falls have a tendency to fall in certain types of activities, with individual differences in the type of activity. Early identification of individual-specific risky activities may help reduce the incidence of falls in these patients.

Forty-eight percent of the falls registered in this study occurred in the first two weeks after discharge, suggesting that most of the falls were clustered in the very early period after discharge. Our biweekly fall survey and the provision of a calendar to document fall incidents allowed us to capture these early post-discharge falls. Forster and Young[12] and Mackintosh et al.[18] reported that among patients with stroke followed up to six months after discharge, 54% to 61% of the recorded falls occurred in the first eight weeks. Mackintosh et al., in another study,[19] reported that 25% of patients who fell during the first six months after hospital discharge indeed fell in the first two weeks post-discharge. It might be possible that with stroke-related disabilities, these patients face the challenges of adapting their behaviours to navigate through the seemingly familiar

Table 3. Biomechanical categorisation of fall mechanisms (n = 25 falls).

Category	Frequency (%)		Subtotal (%)
COM falls			19 (76%)
Pushed	0	(0%)	
Collision (during walking)	1	(4%)	
Upper extremity movement	2	(8%)	
Bending	2	(8%)	
Turning with no apparent BOS problem	1	(4%)	
Transfer with no apparent BOS problem (include transferring between sitting and standing)	10	(40%)	
Walking with no apparent BOS problem	3	(12%)	
BOS falls			5 (20%)
Transfer with BOS problem	0	(0%)	
Trip or tangle of foot or leg (during turning or walking)	5	(20%)	
Slip	0	(0%)	
Overstep curb or step	0	(0%)	
Insufficient information	1	(4%)	1 (4%)

COM = Centre-of-mass; BOS = Base-of-support.

Table 4. Clinical characteristics before discharge and their accuracy as predictors of post-discharge fallers.

Variable (possible scoring range)	Non-fallers (n=9)	Fallers (n=10)	Cut-off Point	Sensitivity (%)	Specificity (%)
MMSE (0~30)	24.3 ± 4.4	20.8 ± 4.4			
FMA-affected UE (0~66)	57.1 ± 12.3	23.6 ± 23.7*	≤ 46	80	88
FMA-affected LE (0~34)	31.2 ± 4.0	24.1 ± 6.7*	≤ 28	80	89
POAB (0~26)	22.3 ± 5.7	14.5 ± 8.4*	≤ 16	60	89
POAG (0~9)	7.9 ± 1.5	3.5 ± 3.1*	≤ 7	100	67
Number of walking device	0.3 ± 0.7	1.5 ± 1.0*	≥ 1	90	78

*Variables showing group differences ($p<0.05$).
MMSE = Mini-Mental State Examination; FMA = the Fugl-Meyer Assessment; UE = Upper extremity; LE = Lower extremity; POAB = Performance-Oriented Assessment of Balance; POAG = Performance-Oriented Assessment of Gait.

environment, and the first two weeks after discharge home is the critical transitional period for these patients to re-establish a new behaviour-environment interaction pattern. Our findings that almost half of the falls occurred during this period also imply that many of our patients were not able to adapt their behaviours successfully or that the seemingly familiar home environment lack sufficient modifications to accommodate patients' disability. It is thus recommended that the main caregivers of patients with stroke be educated to pay more attention to the risk of falls in this critical transitional two weeks after discharge and that sufficient modifications of home environment to accommodate patients' disability be done before patient's discharge.

Many falls occurred during unsafe behaviours and were associated with COM perturbation

A significant proportion of the falls registered in the study occurred while the patient lacked necessary help from the caregiver (48%) or did not properly use a walking device (28%). Similarly, Nyberg and Gustafson4 documented that 58% of falls occurred while disobeying instructions during the performance of an activity, e.g. transferring without necessary help. Our finding indicates the importance of re-education of both patients and caregivers on safety behaviours to prevent early post-discharge falls.

Our unique exploration of the biomechanical mechanisms leading to falls could provide insight into the mechanical and motor control causes of falls. Among the nineteen COM falls, eighteen occurred during self-initiated movements such as upper body motions, turning, transferring or walking, suggesting impaired proactive control of the whole body balance while moving. The five BOS falls occurred during turning or walking while patient's feet or leg were moving and got tripped or tangled by obstacles, suggesting impaired control of the distal part of the affected lower extremity. These activities during which the falls occurred are in line with previous studies targeted at community-dwelling patients with stroke.[12,13,15,16,18] Based on these findings, therapists are encouraged to evaluate and train the patient's capability to control the COM or BOS proactively in carrying out daily functional activities prior to patient's discharge.

Similar to previous studies,[4,6,8,12,13,15,16,18] we also found that the majority of falls occurred during daytime while subjects were indoors such as in the living room or bedroom, implying that most falls are associated with the time and places of the most common usages in daily life. Taken together, these findings suggest that it is daily routines performed in unchanged and familiar environments that primarily lead to falls in patients with stroke residing in the community.

Fugl-Meyer Assessment motor scores before discharge showed high sensitivity and specificity in predicting post-discharge fallers

Our study is the first one to show that poorer motor recovery of the affected upper and lower extremities as revealed by the Fugl-Meyer Assessment was the most sensitive (sensitivity $\geq 80\%$) and specific (specificity $\geq 88\%$) predictor of early post-discharge fallers. Although the extent of motor recovery has not been assessed as a potential predictor of early post-discharge fallers in previous studies,[10,12,19] we speculate that with poorer motor recovery, patients would have greater difficulty moving the affected upper and lower extremities or using these affected limbs to maintain balance, which then would inevitably perturb the COM or BOS. Our results further revealed that the POAB had high specificity but moderate sensitivity in predicting fallers, whereas the POAG and the number of walking devices both had high sensitivity but moderate specificity in predicting fallers. Therefore, clinicians are encouraged to choose the proper clinical measures for fall prediction or fall prevention based on their purposes.

One limitation of this study was the small sample size. However, as mentioned earlier, our results are in congruent with other studies using larger sample sizes in terms of the incidence and circumstances of fall events. Furthermore, similar to previous studies,[12,19] we found that neither the use of medications nor deficits of cognition were significant predictors of early post-discharge fallers. The second limitation of this study was that in-hospital fall history was not investigated as a potential predictor, due to the concern of potential confounding factors of in-hospital falls, such as a change in caregivers. Previous studies have commonly reported that in-hospital fall history is a significant predictor of early post-discharge fallers in patients with stroke.[12,19] Since many of our participants showed a tendency to fall in certain types of activities, it is worthy to investigate whether the specific activities in which in-hospital falls occur are also the fall-risky activities after discharge in future research.

In conclusion, our study revealed that most falls in recently discharged patients with stroke were due to COM perturbation while performing daily functional activities. It is recommended that functional training with emphasis on COM control be incorporated into pre-discharge programmes, especially for patients who are at high risk of post-discharge falls.

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中風病患出院返家後三個月內之跌倒立即機轉與預測因子探討

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背景和目的：本研究旨在探討中風病患出院返家後三個月內之跌倒立即機轉，並找出此關鍵轉銜期之跌倒高危險群預測因子。**方法：**十九位中風病患在出院前一週內接受完整的認知與身體檢查評估，以作為可能的跌倒高危險群預測因子。出院後三個月內接受每兩週一次的跌倒情形追蹤，若有跌倒發生則安排家訪，以分析跌倒發生之情境以及生物力學相關之立即機轉（身體質心或支撐底面積之干擾）。**結果：**二十五次跌倒事件中，執行動態功能性活動時之身體質心與支撐底面積之干擾分別佔了76%與20%的立即機轉，並且大部分的跌倒事件（76%）發生在熟悉環境中執行規律活動時。出院前富格梅爾量表之上、下肢動作功能分數分別低於46與28分，最能有效預測出院後跌倒高危險群（敏感度≥80%，特異度≥88%）。**結論：**中風病患出院後之跌倒主要歸因於執行日常規律活動時身體質心受干擾。因此，出院前之治療計畫應針對富格梅爾量表動作功能分數表現差之高危險群病患，評估與訓練其身體質心控制能力。（FJPT 2010;35(4):275-283）

關鍵詞：中風、意外跌倒、出院、敏感度與特異度

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