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Predicting people with stroke at risk of falls

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Abstract

Background: falls are common following a stroke, but knowledge about predicting future fallers is lacking.
Objective: to identify, at discharge from hospital, those who are most at risk of repeated falls.
Methods: consecutively hospitalised people with stroke (independently mobile prior to stroke and with intact gross cognitive function) were recruited. Subjects completed a battery of tests (balance, function, mood and attention) within 2 weeks of leaving hospital and at 12 months post hospital discharge.
Results: 122 participants (mean age 70.2 years) were recruited. Fall status at 12 months was available for 115 participants and of those, 63 [55%; 95% confidence interval (CI) 46–64] experienced one or more falls, 48 (42%; 95% CI 33–51) experienced repeated falls, and 62 (54%) experienced near-falls. All variables available at discharge were screened as potential predictors of falling. Six variables emerged [near-falling in hospital, Rivermead leg and trunk score, Rivermead upper limb score, Berg Balance score, mean functional reach, and the Nottingham extended activities of daily living (NEADL) score]. A score of near-falls in hospital and upper limb function was the best predictor with 70% specificity and 60% sensitivity.
Conclusion: participants who were unstable (near-falls) in hospital with poor upper limb function (unable to save themselves) were most at risk of falls.

Keywords: *stroke, falls, prediction, elderly*

Background

Although widely reported that one-third of the general older population will fall in any 1 year [1], predicting falls among the elderly has been demonstrated as complex, and no single tool is suitable for all situations [2]. People who have suffered a stroke are at an even higher risk of falling than people among the general population [3–6] but fewer researchers have attempted to develop specific predictive tools. Estimates of fall frequency among the stroke population vary but Tutuarima *et al.* [3, 7] and Nyberg and Gustafson [8, 9] suggested that between 14 and 39% of people with stroke have had one or more falls during their hospital stay and approximately three-fourths of individuals with stroke have fallen in the 6 months following discharge from hospital [4]. Findings from a more recent study have shown that fall rates remained as high as 50% among community dwelling people with stroke [10]. Minor injuries (cuts and bruises) have been found to occur in about 20% of falls [11] and approximately 37 hip fractures have been reported per 1,000 stroke person-years; 84% of which would have resulted from a fall [12]. Interestingly, only a small number of fallers seek professional assistance after an event [13].

In contrast to the general older population, previous falls and multiple medications are less important in predicting falls among people with acute strokes, as a stroke itself changes the individual's state dramatically [9]. Factors such as greater body sway, inability to walk, visuo-spatial deficits and apraxia and use of sedatives [9, 14–16], have been associated with falls in the acute stage. In community dwelling people, the number of impairments has not been related to falls [17] but balance problems, particularly while performing complex tasks such as dressing, have been strongly linked [18]. Hyndman *et al.* [10] found no significant difference between the characteristics of their community-based faller and non-faller groups with stroke, but subgroup analysis of repeat fallers showed a trend to greater mobility deficits, and statistically significant reduced arm function and ADL abilities in comparison to those who did not report any instability. Mackintosh *et al.* [6] also reported reduced mobility and poorer balance among recurrent fallers with stroke in the community. Based on these and other studies, it has now been well established that fall prediction should focus on repeat fallers, as recurrent falls are more likely to lead to injury, and exploration of fall risk among one-off fallers can be misleading [4, 6, 10].

Despite the knowledge that fall risk following a stroke increases significantly after discharge from hospital, researchers have only recently started focusing their attention on the community [6, 16]. The few researchers who have assessed risk at the point of leaving hospital have recruited participants from specialist stroke rehabilitation units with strict entry criteria, thereby excluding a large proportion who were older or more severely affected [6, 16]. Small sample sizes [6], the retrospective nature of the fall report and the inclusion of single fallers in the analysis [16] have further limited the generalisablity of these study findings. Hence, there is still a lack of knowledge about predicting future fallers with a stroke at the point of discharge from hospital. The purpose of this study was to address that knowledge gap.

Methods

Ethical approval for the study was obtained from the Southampton and South West Hampshire Local Research Ethics Committee, Ethical approval No: 095/02.

Consecutively hospitalised patients with a stroke in the Southampton area were identified and recruited at the point of discharge from hospital. Those who were independently mobile prior to the stroke and were able to give informed consent (passed a test of gross cognitive function) [19] were eligible for recruitment. Demographic data (age, gender, time in hospital, side of lesion and Oxford Stroke Classification of cerebral infarct [20]) were documented for each participant. Information on impaired vision, hearing, and musculoskeletal and vestibular deficits, history of previous strokes and other neurological conditions was also recorded.

Study participants completed tests of balance, function, mood and attention in their homes within 2 weeks of being discharged from hospital to the community and at 12 months post-discharge from hospital. The teststhat were identified as important in a previous study by the authors [10] were: Berg Balance Scale, Nottingham Extended ADL Scale, Rivermead Motor Assessment, a screen for unilateral visual neglect, four subtests of the Test for Every day Attention (TEA),0 test of attention, and the Hospital Anxiety and Depression Scale. The tests were carried out in participants' homes by the main assessor who was kept blind to their fall status.

A second independent assessor collected information about falls using more than one procedure. Retrospective fall data was collected from participants and their relatives within the first 2 weeks of admission to hospital (recall about fall history prior to hospital admission), within 2 weeks of discharge from hospital to community (recall about falls in hospital) and at 12 months post-discharge from hospital to the community using questions about fall events based on the interview schedule developed by Stack and Ashburn [21]. Information about falls experienced in hospital was also sought from staff and accident records. Prospective fall data were collected when participants had returned to the community by asking them to keep a diary of falls events (recording falls as and when they occurred) in addition to regular reminder telephone calls and letters. We defined a fall as an event that results in a person coming to rest unintentionally on the ground or other lower level, not as a result of a major intrinsic event or overwhelming hazard [22]. Participants were classed as repeat fallers if they experienced two or more falls during the 12-month follow up period, and as single fallers if they experienced one fall. A near-fall was defined as an occasion on which an individual felt that they were about to fall, but did not actually fall [21].

Descriptive statistics were used to describe the recruited sample, and falling rates were estimated with 95% confidence intervals (95% CI) produced using the Wilson method within CIA [23]. The statistical analysis of prediction was carried out in SPSS. In an initial screening all potential predictors available at or before the time of discharge to the community were compared between groups reporting repeat and non-repeat falling at the 12-month follow up. Continuous variables were compared using t-tests; ordinal scales and non-normally distributed variables using Mann–Whitney U tests; and binary and categorical variables using chi-squared tests. Variables that achieved significance at the 10% level were examined in a logistic regression of repeat falling on their own and controlled for the other variables. The importance of each variable was assessed with likelihood ratio tests, and odds ratios (OR) are presented with 95% CI. Forwards selection was used to select the most important predictors of repeat falling. Variables were selected if they contributed significantly (up to the 15% level—though in practice the selected variables were also significant at the 5% level). Predictive scores based on the selected variables and on all variables emerging from the initial screening were created using regression estimates. The accuracy of individual variables and the two predictive scores was examined using sensitivity, specificity, positive and negative predictive values at cut-points chosen to optimise sensitivity and specificity, and 95% CI were presented. Receiver operating characteristic (ROC) curves and area under the curve (AUC) statistics are presented, the closer an ROC curve is to the top left hand corner representing 100% accurate prediction, the better the prediction attainable from the variable in question.

Results

Out of 512 people identified for the study, 323 (63%) were ineligible for a variety of reasons including death, unconfirmed diagnosis, withholding of medical consent, cognitive impairment, not discharged from hospital in time, and discharged from hospital to a nursing home. Of the 189 eligible people approached to enter the study, 64 (34%) failed to reply or declined the invitation, 3 withdrew shortly after enrollment, leaving 122 data sets for analysis. Information about fall status at the 12-months follow up was available for 115 participants and of them, 63 (55%; 95% CI 46–64) experienced one or more falls; 48 (42%; 95% CI 33–51) experienced repeated falls; and 62 (54%) experienced near-falls. We defined stroke types in our sample using the Oxford Community Stroke Project Classification (OCSP) (Table 1). Partial anterior circulation infarct (PACI) was the most frequently occurring lesion; only six people with a total anterior circulation infarct (TACI) took part; and three were not classified. No major differences were apparent between repeat and non-repeat fallers (Table 1): there was a wide age range (21–92); more male than female participants; an even distribution of left and right hemisphere infarctions (one participant had both hemispheres affected); the majority of participants had a first ever stroke; and a large range of time between onset of stroke and the visit at the time of discharge from hospital of 10–330 days (Table 1).

All variables available at the time of discharge were considered in the screening for predictors of repeat falling, and seven potential predictors emerged (a history of near-falling in hospital, and six tests of movement or function: Rivermead leg and trunk score, Rivermead upper limb score, Rivermead total score, Berg Balance score, mean functional reach, and Nottingham extended ADL score—see Table 1 for selected results from the screening). Rivermead total score was not included in the logistic regression modelling as it duplicates information in the leg and trunk and upper

Table 1. Characteristics of the sample at point of discharge to the community figures are number (%) unless stated otherwise

Variable		Non-repeat faller ($n = 67^a$)	Repeat faller ($n = 48^a$)	P^b
Age in years	Mean (SD)	69.7 (13.3)	70.7 (11.0)	0.696 (*t*)
	Minimum to maximum	21–92	46–91	
Gender	Male (%)	46 (69%)	31 (65%)	0.210 (χ^2)
	Female (%)	21 (31%)	17 (35%)	
Previous stroke		11 (16%)	8 (17%)	0.972 (χ^2)
OCSP classification[c]	TACI (%)	4 (6%)	2 (4%)	0.389 (χ^2)
	PACI (%)	31 (46%)	15 (31%)	
	POCI (%)	13 (19%	12 (25%)	
	LACI (%)	11 (16%)	15 (31%)	
	PICH (%)	6 (9%)	3 (6%)	
	Not classified (%)	2 (3%)	1 (2%)	
Side of infarction	Right (%)	35 (52%)	22 (46%)	0.448 (χ^2)
	Left (%)	31 (46%)	26 (54%)	
	Both (%)	1 (2%)	0	
Time since stroke in days	Mean (SD)	75.7 (54.6)	83.4 (59.7)	0.384 (MW)
	Median (minimum to maximum)	59.0 (10–268)	69.5 (23–330)	
Living status before the stroke	Alone	17 (25%)	12 (25%)	0.815 (χ^2)
	Partner	45 (67%)	32 (67%)	
	Family friends	4 (6%)	4 (8%)	
	Residential home	1 (1%)	0	
Number of falls in year before onset	Mean (median)	0.4 (0)	0.6 (0)	0.119 (MW)
	Minimum to maximum	0–6	0–6	
Number of falls in hospital	Mean (median)	0.5 (0)	0.9 (0)	0.225 (MW)
	Minimum to maximum	0–6	0–6	
History of near-falls in hospital		11 (16%)	19 (40%)	0.005 (χ^2)
Rivermead leg and trunk	Mean (SD)	7.8 (2.6)	7.2 (2.3)	0.054 (MW)
	Minimum to maximum	0–10	1–10	
Rivermead upper limb	Mean (SD)	11.2 (4.6)	9.6 (4.2)	0.012 (MW)
	Minimum to maximum	0–15	1–15	
Rivermead gross function	Mean (SD)	9.0 (2.8)	8.4 (2.3)	0.175 (MW)
	Minimum to maximum	1–13	1–13	
Rivermead total score	Mean (SD)	28.0 (8.6)	25.2 (7.6)	0.020 (MW)
	Minimum to maximum	1–38	3–38	
Berg Balance	Mean (SD)	41.2 (15.2)	37.5 (11.7)	0.016 (MW)
	Minimum to maximum	5–56	7–56	
Mean functional reach (cm)	Mean (SD)	20.7 (12.8)	16.8 (9.3)	0.055 (MW)
	Minimum to maximum	0–53	0–35	
Nottingham extended ADL	Mean (SD)	26.3 (15.6)	12.0 (11.8)	0.074 (MW)
	Minimum to maximum	1–63	2–49	

[a] Upto three missing values on some of the variables in the table.
[b] *P* values from several tests (*t*, from *t*-test; MW, from Mann–Whitney U test; χ^2, from chi-squared test).
[c] OCSP, Oxford Community Stroke Project Classification; TACI, total anterior circulation infarcts; PACI, partial anterior circulation infarcts; POCI, posterior circulation infarcts; LACI, lacunar infarcts; PICH, primary intracerebral haemorrhage.

limb sub-scores, although its accuracy of prediction of repeat falling on its own is considered in Table 3. The logistic models were fitted to the 110 participants who had known fall status and information on the six remaining variables emerging from the screening. In Table 2 it can be seen that a history of near-falling in hospital achieved highest significance of these, and the Rivermead upper limb score, mean functional reach and the Nottingham extended ADL were also close to significance when considered on their own. In the presence of the other selected variables, a history of near-falling in hospital remained highly significant, with Rivermead upper limb score also close to significance. The OR for history of near-falling in hospital (unadjusted OR = 3.27, adjusted OR = 4.14) is a measure of the increased risk of repeated falling in this group. For the other variables the OR indicate that when considered on their own with unit improvement in the test in question, the risk of repeat falling decreases since all are scaled in the direction of higher values indicating better function. Two of the OR (those for the Rivermead leg and trunk and Berg Balance scores) became greater than 1.0 after adjusting for the other selected variables, indicating greater risk of falling with better movement. This reflects the fact that these variables were not important in the controlled analysis or they duplicated predictive power obtainable from other variables.

Forwards selection amongst the six variables resulted in a predictive score based on a history of near-falling in hospital and Rivermead upper limb score (predictive score: $0.293 + 1.290 \times$ hospital near falls [Yes] $-0.094 \times$ Rivermead upper limb). By choosing an optimal cut-point of -0.4114, sensitivity—the proportion of participants who fell repeatedly and were predicted to do so—was 60%; and specificity—the proportion of participants who had zero or one fall and were predicted not to repeat fall—was 70% (Table 3). These were achieved with positive predictive value—the proportion of those who were predicted to fall repeatedly and actually did so—of 59%; and negative predictive value—the proportion of those who were predicted not to fall repeatedly and did not do so—of 71%. All six selected variables were also included in a logistic regression to see whether the other variables, though not statistically significant, might improve prediction (predictive score: $-0.455 + 1.421 \times$ hospital near falls [Yes] $+ 0.149 \times$ Rivermead leg and trunk $-0.119 \times$ Rivermead upper limb $+ 0.024 \times$ Berg Balance $-0.046 \times$ mean functional reach $-0.012 \times$ Nottingham extended ADL). Including all six,

Table 2. Adjusted and unadjusted odds ratios of repeat falling for variables selected from screening. Models fitted to patients with data available for the six variables ($n = 110$)

	Unadjusted		Adjusted[a]	
Variable	Odds ratio (95% CI)	*P*	Odds ratio (95% CI)	*P*
History of near-falling in hospital	3.27 (1.36, 7.90)	0.007	4.14 (1.57, 10.91)	0.003
Rivermead leg and trunk[b]	0.90 (0.77, 1.06)	0.209	1.16 (0.85, 1.59)	0.345
Rivermead upper limb[b]	0.92 (0.84, 1.00)	0.052	0.89 (0.78, 1.01)	0.059
Berg Balance[b]	0.98 (0.95, 1.01)	0.199	1.02 (0.95, 1.10)	0.507
Mean functional reach[b]	0.97 (0.94, 1.01)	0.085	0.96 (0.89, 1.03)	0.202
Nottingham extended ADL[b]	0.97 (0.95, 1.00)	0.063	0.99 (0.95, 1.03)	0.558

[a] Adjusted for all of the other variables in the table.
[b] Odds ratio represents the increase in risk per unit increase in the variable.

Table 3. Sensitivity, specificity, positive and negative predictive values at optimal cut-points for individual variables and predictive scores of repeat falling. Values are numbers (%; 95% CI)

Variable	Cut-point[a]	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Score based on history of near falling in hospital and Rivermead upper limb	≥ -0.4114	29/48 (60%; 46–73)	47/67 (70%; 58–80)	29/49 (59%; 45–72)	47/66 (71%; 59–81)
Score based on the six variables	≥ -0.3731	29/45 (64%; 50–77)	45/65 (69%; 57–79)	29/49 (59%; 45–72)	45/61 (74%; 62–83)
Number of falls in hospital	≥ 2	11/48 (23%; 13–37)	59/67 (88%; 78–94)	11/21 (52%; 32–72)	59/96 (61%; 51–71)
History of near-falling in hospital	Near faller	19/48 (40%; 27–54)	56/67 (84%; 73–91)	19/30 (63%; 46–78)	56/85 (66%; 55–75)
Rivermead leg and trunk	≤ 9.5	43/48 (90%; 78–95)	22/67 (33%; 23–45)	43/88 (49%; 39–59)	22/27 (81%; 63–92)
Rivermead upper limb	≤ 11.5	32/48 (67%; 53–78)	41/67 (61%; 49–72)	32/58 (55%; 42–67)	41/57 (72%; 59–82)
Rivermead total	≤ 28.5	33/48 (69%; 55–80)	36/67 (54%; 42–65)	33/66 (50%; 38–62)	36/51 (71%; 57–81)
Berg balance	≤ 48.5	41/48 (85%; 73–93)	33/67 (49%; 38–61)	41/75 (55%; 43–65)	33/40 (83%; 68–91)
Mean functional reach	≤ 21.5	31/45 (69%; 54–80)	35/65 (54%; 42–65)	31/61 (51%; 39–63)	35/49 (71%; 58–82)
Nottingham extended ADL	≤ 24.5	32/48 (67%; 53–78)	32/67 (48%; 36–60)	32/67 (48%; 36–60)	32/48 (67%; 53–78)

[a] Values in the range predict repeat falling.

sensitivity was increased to 64% at the cost of slightly lower specificity of 69%.

In Table 3 we also examine the predictive power of the variables that emerged from the initial screening individually. No variable gave sensitivity and specificity simultaneously greater than 70% at the cut-points chosen. Near-falling achieved higher specificity (84%) at the cost of lower sensitivity. The Rivermead upper limb score achieved a reasonable level of sensitivity (67%), but with relatively low specificity. Considering all the potential predictors examined in Table 3, the best combinations of sensitivity and specificity was achieved by the two scores with specificity of predicting repeat falling of about 70%, and sensitivity of about 60%.

The ROC curves for the two predictive scores are shown in Figure 1a and b (the optimal cut-points shown in Table 3 are indicated by asterisks). The accuracy of prediction for history of near-falling in hospital is not displayed as an ROC curve because only one cut-point is possible as it is binary. In Figure 1c the sensitivity and specificity for history of near-falling in hospital is indicated by an asterisk superimposed on the ROC curve for the number of actual falls in hospital which is close to the diagonal line indicating no predictive power, an impression confirmed by its low AUC statistic (AUC = 0.556). The number of actual falls in hospital did not emerge from the initial screening, but has been plotted in Figure 1c for comparison with the predictive power of history of near-falling in hospital and because it has recently been suggested as a potential predictor of subsequent falling [6]. In Figure 1d the ROC curve for the Rivermead upper limb score is shown. The points representing the optimal cut-points for the two predictive scores are slightly closer to the upper left hand corner of the plot (the point of perfect prediction) than those for the individual variables; nevertheless, it is clear that it is not possible to predict subsequent falling with high sensitivity and specificity simultaneously.

Discussion

Previous researchers in falls among the general older population [1] and stroke communities [9, 24] have highlighted the difficulties of developing a single predictive tool

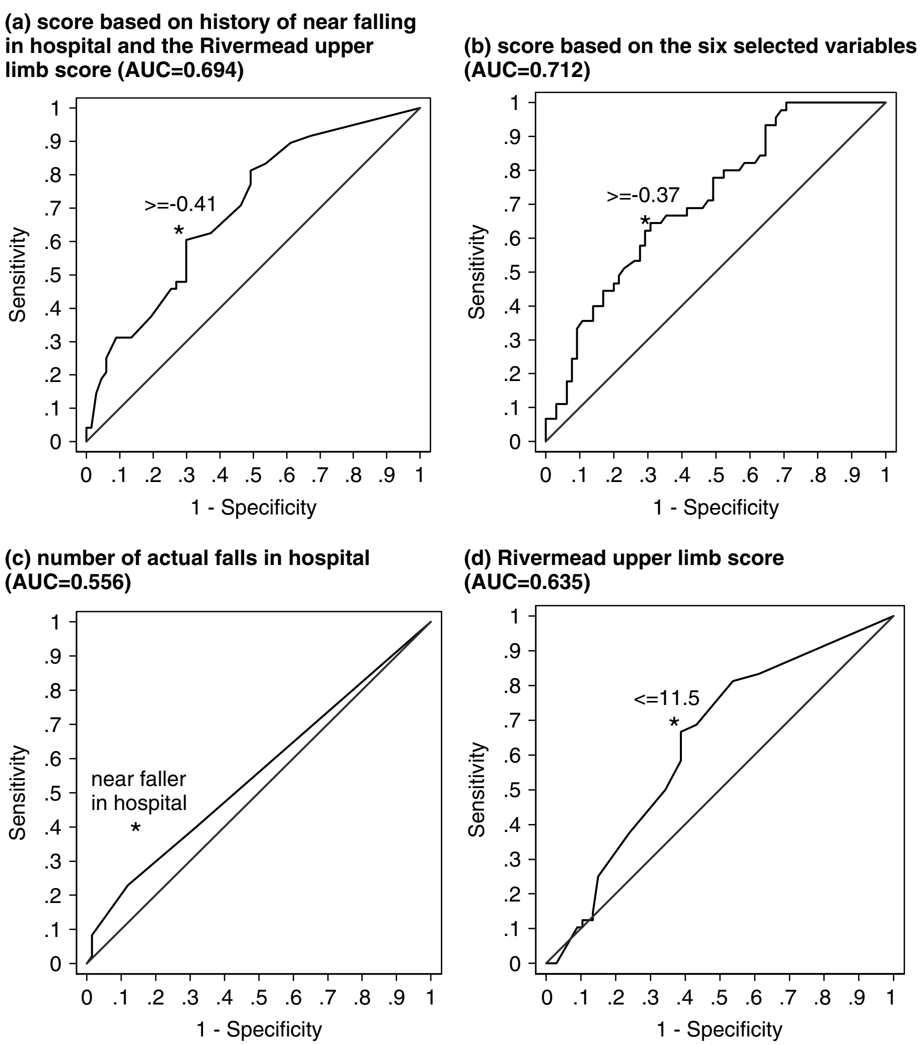

Figure 1. ROC curves of the prediction of repeat falling of scores based on history of near-falling and Rivermead upper limb score, on the six selected variables, actual falls in hospital, and Rivermead upper limb score. Optimal cut-points shown with *.

owing to the wide range of factors associated with falls (e.g. fall history, impaired balance, altered mood and cognition), the varying profiles relating to environmental status (living in the community, hospital or supported housing) and the problems with validating fall events [2, 25, 26]. These features may explain why in this study the sensitivity (60%) and specificity (70%) of the two risk factors we identified for predicting future falls were not simultaneously high. The experience of near-falling in hospital was associated with an increased risk of falling post discharge, surprisingly to a greater extent than experiencing an actual fall in hospital. The other variable that stood out was the Rivermead upper limb score. These findings suggest that individuals who showed signs of instability (near-falls) and were unable to save themselves from falling (poor upper limb function) were most at risk of falls after discharge from hospital. In a previous study Hyndman *et al.* [10] found that repeat fallers had worse upper limb function in comparison to non-repeat fallers, and non-fallers who experienced near-falls saved themselves from actually falling by using their arms. Frequency of actual falls during the hospital stay was not identified as a predictor in this study, possibly due to hospital policies that stipulate careful monitoring to avoid fall events. Instability was therefore identified through near-falls. In contrast, Mackintosh *et al.* [6] from Australia found a link between the recurrent falls of participants during their stay in a rehabilitation hospital, poor balance control and future falls in the community. The nature of rehabilitation is to encourage independence and mobility, opening up situations where fall events can occur [8] and this may also explain why there was a higher percentage of falls (42%) during the hospital stay in Mackintosh's study [6] than this study (34%) which was based in a typical UK District General Hospital.

The findings from this study need to be validated in a new sample before recommendations can be made for clinical practice. Caution should be taken as the sensitivity (60%) and specificity (70%) were below the level recommended by Oliver *et al.* [25] as high predictive value (70% for both simultaneously). Although a systematic review of predictive tools of fall risk among the general older population found some with good validity and reliability, none could be recommended for implementation in all settings or for all sub-populations [26]. Crossing the boundaries into community settings in this study may have added to the difficulties of finding a predictive tool; what influences a fall in the acute setting may be very different to that in the community. We chose to predict those at a risk of falls at the point of leaving hospital as this is the natural time for clinicians to initiate services for individuals with stroke in the community. The interpretation of our findings must also be placed in the context of our non-inclusive sample. We required participants to recall falls and near-falls so we screened individuals for gross cognitive impairment. We selected those who were independently mobile prior to stroke and returning to the community, to avoid the influence of previous immobility and institutional restrictions on subsequent falls.

Our recommendations for clinical practice are that, in the absence of conclusive evidence at the point of discharge, all people with stroke have to be considered as being at a risk of falls but that those who have been unsteady in hospital and have upper limb impairments may be at greater risk. Tests of instability and upper limb movements are part of standard therapy programmes and take a few minutes to administer although this may vary depending on stroke severity. These two assessments could be shared with colleagues following a simple training. Individuals with stroke should be encouraged to report both falls and near-falls (whilst in hospital and in the community) so that management programmes can be implemented. Communication about falls requires careful questioning (using the fall interview schedule) in order to identify fall-related circumstances [21].

Research challenges in the future include the validation of predictive tools for fall risk among people with stroke and a systematic review of quality studies of prediction in this group. Increased understanding is needed of the circumstances surroundings falls and the way individuals save themselves or fall as this will form the basis of the development of interventions (exercises and strategies) and subsequent evaluation of managing safe functional mobility.

Key points

- We were unable to make accurate predictions of falling in the 12 months following discharge to the community from the information available in this study at the time of discharge.
- Near-falls in hospital and poor upper limb function at time of discharge from hospital were the two best predictors of repeated falls in the first 12 months following discharge to the community among people with stroke who had passed a screen for gross cognitive impairment and who were independently mobile prior to their stroke.
- Individuals should be encouraged to report both falls and near-falls.

Conflicts of interest

None

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