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ORIGINAL REPORT

CLINICAL TESTS PERFORMED IN ACUTE STROKE IDENTIFY THE RISK OF FALLING DURING THE FIRST YEAR: POSTURAL STROKE STUDY IN GOTHENBURG (POSTGOT)*

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Objective: **To assess the likelihood of clinical tests for postural balance, walking and motor skills, performed during the first week after stroke, identifying the risk of falling.**
Design: **Prospective study.**
Subjects: **Patients with first stroke.**
Methods: **Assessments were carried out during the first week, and the occurrence of falls was recorded 3, 6 and 12 months after stroke onset. The tests used were: 10-Metre Walking Test (10MWT), Timed Up & Go, Swedish Postural Assessment Scale for Stroke Patients, Berg Balance Scale and Modified Motor Assessment Scale. Cut-off levels were obtained by receiver operation characteristic curves, and odds ratios were used to assess cut-off levels for falling.**
Results: **The analyses were based on 96 patients. Forty-eight percent had at least one fall during the first year. All tests were associated with the risk of falling. The highest predictive values were found for the 10MWT (positive predictive value 64%, negative predictive value 76%). Those subjects who were unable to perform the 10MWT had the highest odds ratio, 6.06 (95% confidence interval 2.66–13.84, *p*<0.001) of falling.**
Conclusion: **Clinical tests used during the first week after stroke onset can, to some extent, identify those patients at risk of falling during the first year after stroke.**

Key words: outcome assessment; walking; postural balance; prognosis; mobility limitation; stroke; falls.

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INTRODUCTION

Falls after stroke are common. The occurrence of at least one fall has been reported in 15–37% of cases in inpatient stroke rehabilitation units (1, 2). Falls appear to be even more frequent in stroke survivors living in the community, where approximately 40% are reported to have fallen within 6–12 months after stroke (3–5). The consequences of a fall can be serious. A fall can lead to fear of falling and restriction of activity (6, 7), as well as social deprivation and depression (8), which may negatively influence the rehabilitation process. A fall can also lead to a hip fracture, with double the risk of hip fracture reported in persons who had had a stroke (9).

Previous studies have shown that the risk factors for falling are: previous stroke, impaired balance, slow walking speed (10), prior fall, and impaired postural balance in combination with other stroke-related disabilities or deficits (1, 5, 11–13). Recently Rabadi et al. (2) carried out a retrospective study and reported that, in an acute stroke rehabilitation unit, patients with impaired cognition and limited ambulation were at high risk of falling. The use of clinical tests of walking speed and postural balance in order to predict the risk of falling after stroke has been reported previously (1, 5, 12). For walking speed, cut-off values have been proposed for community ambulation (14), and for the Timed Up & Go (TUG) (11, 15) and the Berg Balance Scale (BBS) (5, 16–18), to identify those at risk of falling. However, most of these studies were based on patient examinations several weeks after onset (1), at discharge from hospital/rehabilitation (5, 12), on community-dwelling older adults (17), or on community-dwelling people with stroke (18). A few studies were based, or partly based, on data from the first week after stroke onset (2, 19). To our knowledge, there are no studies that have prospectively assessed walking capacity and postural balance in the acute setting of stroke and validated the prediction of falls occurring in the first year after stroke. The aim of this study was to assess how results from clinical tests of postural balance, walking and motor skills, performed during the first week after stroke, could identify the risk of falling in patients with stroke during the following year.

MATERIAL AND METHODS

Study population

The study was performed at a stroke unit with 14 inpatient beds and the data were gathered over 27 months. Medical approval was given by the patient's physician at the stroke unit prior to inclusion. The inclusion criterion was a first-ever stroke, defined according to the World Health Organization (WHO) criteria (20). Exclusion criteria

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were co-morbidities, e.g. leg amputation, diagnosis of dementia or severe psychiatric diseases. Patients were also excluded if they did not live permanently in the vicinity of Gothenburg, as the study included follow-up procedures. The ischaemic stroke events were classified according to the Trial of Org 10172 in Acute Stroke Treatment (TOAST-criteria) (21). At the time of inclusion demographic and medical data were gathered from the patients' charts. The study was approved by the ethics committee at the University of Gothenburg and written informed consent was obtained. If the patient was not able to understand the information, the next of kin gave informed consent.

Methods and assessment procedure

Walking was assessed using the 10-Metre Walking Test (10MWT), a valid reliable measure (22). Walking and balance were assessed using the TUG. Postural control was assessed using the Swedish version of the Postural Assessment Scale for Stroke Patients (SwePASS) and the BBS. The SwePASS, developed from the original Postural Assessment Scale for Stroke Patients (PASS) (23), comprises 12 items, scored on an ordinal scale, from 0 to 3, with scores ranging from 0 to 36, with a higher score indicating better postural control. Motor skills, upper extremities, postural balance, transfer and walking were assessed using the Modified Motor Assessment Scale Uppsala Akademiska Sjukhus (M-MAS UAS-95) (24), an ordinal scale, with 11 items scored from 0 to 5.

The BBS and the MAS UAS-95 were performed as soon as possible according to clinical routine. The assessments were carried out in the patient's room by their usual physiotherapist, who was not involved in the research, at a median of 2 days (range 1–7 days) after stroke onset.

Between days 4 and 7 (median day 5) after the onset of stroke symptoms the patients were examined using the 10MWT, the TUG and the SwePASS. The 10MWT and the TUG were performed in the corridor on the ward and the SwePASS was performed in the patient's room, by 1 of 5 physiotherapists who were not involved in the patients' rehabilitation. For the 10MWT the patients, who were asked to walk at a self-selected pace, started just in front of a taped line on the floor when they were ready. The time taken to complete the test was recorded with an analogue stop-watch that was started when the first leg crossed the taped line on the floor, and stopped when the first leg crossed the other taped line 10 m away. Support was allowed and the need for support was noted, as well as the type of shoes. Patients who were unable to perform the 10MWT/the TUG, because of their inability to walk, were included in the analysis of the median, with their surrogate time set to infinity, but were excluded from the presentation of the min–max values. For the TUG, the patients were asked to stand up from a standardized armchair, walk 3 m (marked by a tape), and turn, return and sit down as fast and as safely as possible, while the time taken to complete the test was recorded. Before starting, the patients sat in a chair with their back supported. The tester recorded, with a stop-watch, the time from which the patient's back left the chair back until the patient sat in the chair again, after walking, with their back supported by the chair back. For safety reasons, the tester stood in close proximity to the subject while observing and timing, without interfering with the test.

Follow-up assessments were carried out at 3, 6 and 12 months after stroke onset. A time-window of 14 days before or after was allowed for the follow-ups. At every follow-up the patients were asked structured questions about any fall since their last visit and new tests were performed. A fall was defined as an event in which the person unintentionally found himself or herself below sitting-level or on the ground. On occasions, when the patient was unable to attend the follow-up, the structured questions about eventual fall/falls were sent by post.

Statistics

All analyses were performed using the Statistical Package for Social Services (SPSS©) computer program (Version 17 SPSS Inc., Chicago, IL, USA). Comparisons of proportions were analysed using the χ^2 test. Univariate logistic regression analyses were performed to explore whether falling was associated with the age and length of stay (LOS) in a comparison between fallers and non-fallers (Table I).

To assess how well a clinical test predicts falling we used the receiver operating characteristic (ROC) curves. An optimal cut-off level was considered to be that cut-off that maximizes the sum of sensitivity and specificity, with the condition that a high sensitivity was the most important factor (should be the highest), since the focus was on the risk of falling. Patients who were unable to perform the 10MWT/the TUG, because of their inability to walk, were included in the ROC analysis, with their surrogate time set to infinity. The p-values presented in Table III are based on the statistical hypotheses that AUC = 0.5, which is considered to represent a result by chance.

To assess the relationship between a test result and the probability of falling, while controlling for age and sex differences, we used the logistic regression model, where fall was the outcome, and clinical test, sex and age were the covariates. To account for the correlation of observations within individuals we used the methodology of generalized estimated equations (GEE) with the empirical variance estimator.

Table I. *Characteristics of the study population*

Characteristics	All participants $n=96$	Fallers $n=46$	Non-fallers $n=50$	p	Lost to follow-up $n=20$
Age, years, median (range)	73 (47–94)	74 (49–94)	72 (47–94)	0.075	82
Patients, n (%)					
Female	40 (42)	21 (46)	19 (38)	0.447	8 (40)
Male	56 (58)	25 (54)	31 (62)		12 (60)
Side of lesion, n (%)					
Right side lesion	45 (47)	20 (44)	25 (50)	0.522	10 (50)
Left side lesion	51 (53)	26 (56)	25 (50)		10 (50)
Stroke classification				0.324	
Large vessel disease	24 (25)	15 (32)	9 (18)		6 (30)
Small vessel disease	25 (26)	12 (26)	13 (26)		6 (30)
Cardioembolic stroke	20 (21)	10 (22)	10 (20)		3 (15)
Cryptogenic stroke	17 (18)	5 (11)	12 (24)		1 (5)
Intracerebral haemorrhage	10 (10)	4 (9)	6 (12)		3 (15)
Hypertension	61 (64)	31 (67)	30 (60)	0.452	13 (65)
Diabetes mellitus	22 (23)	13 (28)	9 (18)	0.232	6 (30)
Current smoking	21 (22)	9 (20)	12 (24)	0.600	3 (15)
Diuretic medication	26 (27)	13 (28)	13 (26)	0.803	7 (35)
LOS, days, median (range)	14 (4–79)	20 (5–79)	10 (4–37)	<0.001	19

p-values for comparison between fallers and non-fallers.
LOS: length of stay.

Table II. *Results from clinical tests for walking, postural balance and motor skills during the first week after stroke onset*

	All participants (*n*=96)				Fallers (*n*=46)				Non-fallers (*n*=50)			
Clinical tests	*n*	Median	Min–Max	Unable to perform the test *n*	*n*	Median	Min–Max	Unable to perform the test *n*	*n*	Median	Min–Max	Unable to perform the test *n*
10MWT, s	96	14[a]	6–95	18	46	23.5[a]	8–95	14	50	11[a]	6–29	4
TUG, s	96	15[a]	8–59	28	46	43[a]	9–50	22	50	14[a]	8–59	6
SwePASS (0–36)	95	30	3–36	0	45	29	3–36	0	50	32	5–36	0
BBS (0–56)	88	42	0–56	0	42	28	0–56	0	46	46	0–56	0
M-MAS UAS-95 (0–55)	83	47	0–55	0	42	40	0–55	0	41	52	28–55	0

[a]Patients unable to perform the test are included in the analysis for the median.
10MWT: Ten Metre Walking Test; TUG: Timed Up & Go; SwePASS: Swedish Postural Assessment Scale for Stroke Patients; BBS: Berg Balance Scale; M-MAS UAS-95: Modified Motor Assessment Scale, Uppsala Akademiska Sjukhus.

For each test we used separate models to avoid colinearity problems, since Spearman's correlation coefficients were high between the results of the different clinical tests. The estimated parameters from the above-mentioned models are presented as odds ratios (ORs) with the 95% confidence interval and *p*-values. In addition, GEE-analyses length of stay was added, as a covariate, to sex and age.

RESULTS

We aimed to carry out a prospective study with 120 patients. According to medical information obtained later, 4 of these 120 patients did not meet the inclusion criteria and were thus excluded. Of the correctly included 116 patients, 96 (83%) participated in at least 1 follow-up visit at 3, 6 and 12 months after stroke onset. This study is therefore based on data obtained from those 96 patients. Of the 20 patients who were lost to follow-up, 1 patient died within 3 months after inclusion, 2 had a recurrent stroke, 1 moved away, and 16 withdrew their consent (did not wish to continue the study, mainly due to severe disability). During the study there were another 56 patients who met the inclusion criteria that we failed to include. The median age of these non-included patients was 76 years, and 52% were females.

At the first follow-up 90 patients were assessed, at 6 months 80 patients were assessed, and at 12 months 81 were assessed; a total of 96 individuals participated in at least at 1 follow-up. Forty-six (48%) of the 96 patients had at least 1 recorded fall during the first year. Thirty-two patients experienced a fall within 3 months after stroke onset, 23 patients experienced a fall within 3–6 months after stroke onset and 16 had fallen 6–12 months after stroke onset. The characteristics of the study population comparing fallers with non-fallers are presented in Table I. Those who fell had had twice as long a stay (LOS) in the hospital compared with the non-fallers. Those who refrained from follow-up were older (median 82 years) than those who participated (median 73 years) ($p=0.002$). Those who were discharged to nursing homes were at high risk of falling (11 out of 15 fell).

The results from the clinical tests of postural balance, walking and motor performance for all participants, the fallers and the non-fallers, are shown in Table II. Incomplete test data (1 for the SwePASS, 3 for the BBS, 11 for the M-MAS UAS-95), or data collected after the accepted time-window of 7 days post-stroke (5 for the BBS, 2 for the M-MAS UAS-95), were excluded from the analysis. The fallers seemed to be slower on the 10MWT and the TUG and scored lower on the SwePASS, the M-MAS UAS-95 and the BBS compared with the non-fallers.

The optimal cut-off level to predict the risk of falling was, according to the ROC analysis, ≥ 12 s for the 10MWT, ≥ 15 s for the TUG, ≤ 32 s for the SwePASS, ≤ 42 s for the BBS and ≤ 50 s for the M-MAS UAS-95. The sensitivity, specificity, positive predictive value and negative predictive values for all 5 tests are shown in Table III. All assessment scales, apart from the BBS, had an area under the curve of at least 0.70 (70%). The best positive predictive value was noted for the M-MAS UAS-99 (65%) and for the 10MWT and the BBS (64%).

Each test's ability to predict a fall was also analysed with generalized estimated equations together with gender and age. In this analysis both first and repeated falls were included. The results are

Table III. *The cut-off value specified with area under the curve, and sensitivity, specificity, positive predictive value and negative predictive value for each clinical test*

Variable	*n*	Cut-off s	AUC	*p*	95% CI	Sensitivity	Specificity	PPV	NPV
10MWT, s	96	≥12	0.74	<0.001	0.64–0.81	37/46 (80%)	29/50 (58%)	37/58 (64%)	29/38 (76%)
TUG, s	96	≥15	0.70	0.001	0.60–0.81	29/46 (63%)	29/50 (58%)	29/50 (58%)	29/46 (63%)
SwePASS (0–36)	95	≤32	0.73	<0.001	0.63–0.83	37/45 (82%)	25/50 (50%)	37/62 (60%)	25/33 (76%)
BBS (0–56)	88	≤42	0.69	0.002	0.58–0.80	29/42 (69%)	30/46 (65%)	29/45 (64%)	30/43 (70%)
M-MAS UAS-95 (0–55)	83	≤50	0.72	0.001	0.61–0.83	31/42 (74%)	24/41 (58%)	31/48 (65%)	24/35 (69%)

AUC: area under the curve obtained from receiver operation characteristic curves; PPV: positive predictive value; NPV: negative predictive value; 10MWT: 10-Metre Walking Test; TUG: Timed Up & Go; SwePASS: Swedish Postural Assessment Scale for Stroke Patients; BBS: Berg Balance Scale; M-MAS UAS-95: Modified Motor Assessment Scale, Uppsala Akademiska Sjukhus; CI: confidence interval.

Table IV. *Odds ratio (OR) for the risk of falling according to generalized estimated equations*

Test/variables	*n*	OR	95% CI	*p*
10MWT, s	251			
≤12	119	1		
>12 or unable to perform the 10MWT	132	3.17	1.54–6.54	0.002
TUG, s	251			
≤15	128	1		
>15 or unable to perform the TUG	123	2.44	1.22–4.92	0.012
SwePASS (0–36)	248			
>32	89	1		
≤32	159	4.88	2.02–11.80	<0.001
BBS (0–56)	232			
>42	115	1		
≤42	117	3.14	1.44–6.86	0.004
M-MAS UAS-95 (0–55)	219			
>50	94	1		
≤50	125	3.71	1.67–8.25	0.001

n: assessment occasions; 10MWT: 10-Metre Walking Test; TUG: Timed Up & Go; SwePASS: Swedish Postural Assessment Scale for Stroke Patients; BBS: Berg Balance Scale; M-MAS UAS-95: Modified Motor Assessment Scale, Uppsala, Akademiska Sjukhus; CI: confidence interval.

presented in Table IV, and indicate that all 5 tests' cut-offs were significant for predicting the risk of falling, while gender and age were not. It was found that, when separating those who scored less than the cut-off level and those who were unable to perform the test, patients unable to perform the 10MWT had the highest odds ratio regarding the risk of falling (Table V). Of those 18 patients who were unable to perform the 10MWT in the first week, 14 fell within the first year. When adding LOS, besides gender and age, to the GEE analyses, lower OR for each test was noted. The only significant, and the highest, OR was found in the model with SwePASS (OR 2.984, CI 1.151–7.735, $p=0.024$). Furthermore, the results showed that LOS was significant in all models. The OR for the LOS ranged from 1.033 (CI 1.010–1.056, $p=0.004$ in the model unable to perform the TUG) to 1.050 (CI 1.020–1.082, $p=0.001$ in the model with M-MAS UAS-95).

DISCUSSION

The aim of this study was to assess how results from clinical tests for postural balance, walking and motor skills, performed during the first week after stroke, could identify the risk of falling in patients with stroke during the following year. We found that the results from all 5 tests (the 10MWT, the TUG, the SwePASS, the BBS and the M- MAS UAS-95) could identify those at risk of falling. However, none of the tests are perfect. A negative predictive value of 76%, as for 10MWT, implies that 1 of 4 patients classified as "non-fallers" can be expected to fall during the first year.

Those patients who were unable to perform the 10MWT appeared to have the highest risk of falling, which is of clinical importance. In our population of 96 patients, approximately 20% were unable to perform the 10MWT during the first week after stroke onset, which is similar to the value reported by the Copenhagen Stroke Study (19), in which 15% were unable to walk due to leg paralysis at admission.

Although our optimal cut-off time for the risk of falling (≥15 s for the TUG) is similar to that reported by Andersson et al. (11), there are several differences between the two studies. Their calculations were carried out on assessments performed at a median of 8 days after the stroke event, with 62% examined before the seventh day. Their cut-off value of >14 s gave both a lower sensitivity (50%) and a lower positive predictive value (59%) than in our study, but a higher specificity (78%) as well as a higher negative predictive value (72%). This indicates that the cut-off for the TUG in our study was better for identifying patients at risk of falling, which is clinically essential. One explanation for such variable results may be that we included the patients who were unable to perform the TUG in the ROC curves analysis, while such patients were excluded in the study by Andersson et al. (11).

Our suggested cut-off value for the BBS (score ≤42) based on reported falls is near, but a little lower than, that suggested by others (5, 16–18) with the exception of the cut-off ≤29, with a sensitivity of 80% and a specificity of 78%, reported in a follow-up study of 70 stroke inpatients almost two years after stroke onset, presented by Maeda et al. (25). The differences can be caused by the different selection of study populations.

Even though the M-MAS UAS-95 is not primarily used as a test to identify the risk of falling it had a higher OR compared with the BBS. This finding confirms the results from other studies in which stroke-related impairment (1, 5) and severe disability early after stroke (13) as well as poor upper limb function in people with stroke in hospital (12) and high stroke severity (26) were independently associated with falls. This is in contrast to another study (11) in which stroke severity seemed to be less important. The results from our study that show that those who fall tend to have a longer LOS compared with those who do not fall, confirm the results of Andersson et al. (11). When the LOS was added in the GEEs, the OR was less for all the assessment scales and only the SwePASS had significant value. The results of LOS analyses were not surprising, since LOS is strongly correlated with more severe stroke (27, 28). There can also be a confounding factor, since the LOS depends on the physician's decision, based on the results of the balance assessments and activities of daily living as well as assumptions about ability to manage at home. The aim of this study was to compare the ability to identify patients with

Table V. *Odds ratio (OR) for the risk of falling according to generalized estimated equations with the 10MWT and the TUG classified into 3 groups*

Test/variables	*n*	OR	95% CI	*p*
10MWT, s	251			
≤12	119	1		
>12	89	2.29	1.03–5.09	0.043
Unable to perform the 10MWT	43	6.06	2.66–13.84	<0.001
TUG, s	251			
≤15	128	1		
≥15	55	0.84	0.31–2.27	0.728
Unable to perform the TUG	68	4.44	2.14–9.19	<0.001

n: assessment occasions; 10MWT: 10-Metre Walking Test; TUG: Timed Up & Go; CI: confidence interval.

risk of falling using the different assessment scales, and not to determine whether LOS predicted risk of falling.

In the present study, the risk of falling after a first-ever stroke was high. Almost every second patient in our study fell within the first year. This is similar to the results reported by Andersson et al. (11), who found that 48% of 93 patients fell, and by Ashburn et al. (12), in which 55% of 112 patients fell. In our study the highest fall incidence occurred mainly within the first period after stroke, within 0–3 months. This is in line with other studies (13, 29–31). However, falls are influenced by environmental factors that may differ between different stroke units, communities and countries. There are also differences in the recall methods and in the precision of the recording of falls, which is why we must be careful when we draw conclusions from these data.

The strength of this study is that our results are based on a selection of common clinical tests and that early identification of the risk of falling was confirmed by a longitudinal follow-up of reported falls. A weakness is that neither the presence of neglect (13) nor attention deficits (32) were considered as confounders. Moreover, we cannot ignore the risk of lack of precision, recall bias in self-reports, or that the patients who did not participate in the follow-up assessments should all have been sent the structured questions about falls, which are fundamental to the validity of the results. Not gathering information about falls every week or every month from study participants, as described (33), might also have led to underestimation of the risk of falling.

In conclusion, clinical tests (10MWT, TUG, SwePASS, BBS and M-MAS UAS-95) performed during the first week after stroke onset have moderate predictive values for identifying those patients at risk of falling during the first year after stroke. The 5 different tests all showed similar results in distinguishing patients at risk of falling. SwePASS is a new test, not previously studied, the psychometric properties of which need to be investigated further. Patients who were unable to perform the 10MWT showed the highest risk of falling. Therefore, in clinical practice, the 10MWT should be considered a primary test for identifying persons at risk.

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