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ORIGINAL ARTICLE

Validity, Responsiveness, and Predictive Ability of the Japanese Version of the Cumulated Ambulation Score in Patients with Hip Fracture

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Objectives: The aim of the current study was to investigate the validity, the responsiveness, and the predictive ability for discharge to own home of the Japanese version of the Cumulated Ambulation Score (CAS-JP). This was achieved by analyzing the CAS-JP after hip fracture surgery at multiple time points until patient discharge. **Methods:** Patients who underwent hip fracture surgery were evaluated using CAS-JP, the Barthel Index, and walking ability on postoperative day (POD) 1, 7, and 14 and at discharge. Floor and ceiling effects, responsiveness, and correlations between CAS-JP and other functional outcomes were assessed at each time point. The predictive ability of CAS-JP for discharge to own home was also analyzed using the area under the curve (AUC) of the receiver operating characteristic. **Results:** A total of 121 patients were included in this study. On POD7, POD14, and at discharge, strong correlations were observed between CAS-JP and the Barthel Index (r=0.81, 0.82, and 0.87, respectively), and between CAS-JP and walking status (r=0.82, 0.81, and 0.76, respectively). CAS-JP had a large effect size (1.64–2.25) and standardized response mean (1.49–1.81). The predictive ability of CAS-JP for discharge to own home, as indicated by the AUCs, were 0.73 (95% CI: 0.62–0.83) on POD7 and 0.74 (95% CI: 0.62–0.86) on POD14. **Conclusions:** CAS-JP has sufficient validity and responsiveness as a mobility assessment tool in postoperative hip fracture patients. Furthermore, this study showed that early postoperative mobility status evaluation using CAS-JP can sufficiently predict discharge to own home.

Key Words: hip fracture; psychometric properties; mobility score; rehabilitation

INTRODUCTION

Hip fracture has a high impact on functional impairment, activity limitation, and life expectancy,[1–4] as well as on the cost of medical and nursing care.[5,6] Moreover, with the recent aging of the population, the number of patients with hip fracture is increasing and these patients are also becoming older.[7,8] Older patients often have multiple comorbidities, and the number of comorbidities has been shown to affect postoperative mortality and functional recovery.[9] Therefore, optimal rehabilitation treatments are important in the perioperative period, and many guidelines recommend early physical therapy intervention and early ambulation.[10–13] In addition to rehabilitation interventions, it has been reported

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that the assessment of mobility status and functional recovery in the early postoperative period can be used to predict the discharge destination, the functional outcome, and mortality. Therefore, early postoperative assessment and prediction of mobility recovery is important for appropriate treatment planning and rehabilitation progression. While gait speed measurement and the Timed Up-and-Go test (TUG) are frequently used as measures of walking ability,[14] the Cumulated Ambulation Score (CAS) is recommended for use as a performance assessment of basic mobility, especially to evaluate hospitalized patients soon after surgery.[15]

The CAS was developed in Denmark to evaluate mobility function after hip fracture surgery[16] and is used as a functional outcome not only in patients with hip fracture[17–19] but also in patients after total knee arthroplasty[20,21] or with various diseases.[22–24] The CAS has been translated into more than ten languages, including English,[25] Spanish,[26] Turkish,[27] and French,[28] and is recorded in the nationwide Danish Multidisciplinary Hip Fracture Registry[17,29] and the Irish Hip Fracture Database.[13] The CAS is a simple evaluation of three basic mobility activities on a three-point score, and many studies have reported its reliability, validity, responsiveness, and predictive ability for prognosis.[30] Also, because the CAS is quick to perform and does not require tools or questionnaires, it has been reported that the CAS can be used by different medical professionals, such as physical therapists, occupational therapists, and physicians.[25–27,31] Furthermore, in Japan, the CAS has been used as a functional outcome,[32] and high inter-rater reliability has also been reported for the Japanese version of the CAS (CAS-JP).[31] However, the validity, responsiveness, and predictive ability of the CAS-JP in patients with hip fracture have not been clarified. Moreover, most studies have examined psychometric properties by analyzing the CAS at one or two time points, whereas few have reported analyses with multiple time points.

The aim of this study was (1) to investigate the validity and responsiveness of the CAS-JP scale and (2) to evaluate its ability to predict discharge to own home by investigating the trajectory of the CAS-JP after hip fracture surgery at multiple time points until discharge.

MATERIALS AND METHODS

Design and Ethics

This was a retrospective observational study conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[33] The data used in this study were extracted from the hip fracture dataset of the Department of Rehabilitation, St. Luke's International Hospital, which is an acute general hospital in Tokyo, Japan. This study was approved by the institutional review board of St. Luke's International University (20-R234).

Setting and Participants

Adult hip fracture patients consecutively admitted to the Department of Orthopedic Surgery between April 2019 and December 2020 were included in the study. Informed consent was obtained in the form of opt-out on the website. No cases were excluded due to refusal to consent or missing data. Seven patients with pathological fracture due to bone metastasis, trauma patients with complications of major organ injury, and patients undergoing revision surgery were excluded.

The mobilization of patients was started on the day after surgery, and rehabilitation by physical therapists specializing in musculoskeletal disorder was performed in all cases. Physical therapy was provided 6 days a week with a focus on mobilization and exercises to improve physical function and walking ability.

Measurements

Postoperative mobility assessments using the CAS-JP and the Barthel Index (BI) were performed by physical therapists on postoperative day 1 (POD1), day 7 (POD7), day 14 (POD14), and at discharge. Walking ability evaluations, i.e., the modified TUG (m-TUG) and walking status, were performed by physical therapists on POD7, POD14, and at discharge.

The CAS-JP was used to assess the patient's independence in three basic mobility activities: (1) getting in and out of bed, (2) sitting to standing to sitting from a chair with armrests, and (3) walking indoors with or without an appropriate device. Each activity was evaluated on a scale from 0 (no ability), 1 (able to perform with human assistance or guiding), to 2 (able to perform independently), resulting in a total 1-day score between 0 and 6, with 6 meaning that the patient is independent in the three activities.[31]

Independence in activities of daily living was evaluated using the BI,[34] which is a 10-item activity assessment: eating, transfer from bed to chair, personal hygiene, toileting, bathing, mobility (walking or wheelchair), climbing stairs, dressing, bowel control, and bladder control. The total score ranges from 0 to 100, with a higher score indicating greater independence in activities of daily living.

The m-TUG was used to assess walking ability objectively and quantitatively in the early postoperative period. The original TUG is effective as a clinical and prognostic measure of walking ability, activity level, and new falls after hip fracture surgery[35–37]; however, many patients have difficulty performing the TUG in the early postoperative period. Therefore, in this study, walking ability was measured using the m-TUG. The m-TUG was performed from a seated position in a wheelchair, and the time to stand up, walk 3 m in parallel bars, turn around, walk back at a comfortable speed, and sit down was recorded. Two measurements were taken, and the shortest time was recorded. Additionally, the postoperative walking status was classified into six levels (i.e., a score from 0–5): independent gait (5), with a cane (4), with a walker (3), with parallel bars (2), wheelchair transfer (1), and bedridden (0).

Patient information before admission and on discharge was extracted from medical records and recorded in the database by a physical therapist. Patient information consisted of the following parameters: age, sex, body mass index, residence before admission, prefracture walking status, prefracture dementia, fracture side, fracture type, surgical procedure, days from surgery to discharge, and discharge destination. The prefracture walking status was classified into five levels: independent gait, with a cane, with a walker, wheelchair transfer, and bedridden. The discharge destination was categorized as the patient's own home, a rehabilitation facility, or death.

Statistical Analysis

Continuous variables are presented as means with standard deviations (SD), and categorical variables are described as numbers with percentages. Floor and ceiling effects of the CAS-JP and the BI were estimated on POD1, POD7, POD14, and at discharge. A floor effect or ceiling effect was deemed to be present if 15% or more of patients scored the lowest or highest value, respectively.[38]

The construct validity of the CAS-JP was analyzed using its correlation coefficients with BI, m-TUG, and walking status. The correlation coefficients between the CAS-JP and the BI at four time points (POD1, POD7, POD14, and discharge) and the m-TUG at three time points (POD7, POD14, and discharge) were analyzed using Pearson's correlation coefficient, whereas the correlation between CAS-JP and the walking status at three time points (POD7, POD14, and discharge) was analyzed using Spearman's rank correlation coefficient. We chose the analytical method to evaluate correlations based on the distributions of the variables. Correlation coefficients of 0.1–0.4 were considered weak; 0.4–0.7 moderate; 0.7–0.9 strong; and 0.9–1.0 very strong.[39]

The effect size (ES) and the standardized response mean (SRM) were used to analyze the responsiveness of the CAS-JP and the BI for evaluating changes over time between POD1 and POD7, POD14, and discharge.[40] The ES was calculated as the mean change in the patient score divided by the SD of the POD1 score. The SRM was calculated as the mean change in the patient score divided by the SD of the changed scores. The ES was interpreted according to Cohen, as follows: ES of 0.2–0.4 was considered small, 0.5–0.7 moderate, and >0.8 large.[41] Additionally, the minimal clinically important difference (MCID) of the CAS-JP and the BI were estimated using a distribution-based approach and were calculated as 0.5 SD of the changed scores.[42]

The area under the curve (AUC) of the receiver operating characteristic (ROC) curve was used to examine the predictive ability for discharge to own home of the CAS-JP and the BI at three time points (POD1, POD7, and POD14). The AUCs were calculated with 95% confidence intervals (CIs). An AUC of >0.7 was considered fair and >0.8 was considered good.[43] The sensitivity and specificity of the cutoff values of the CAS-JP at each time point were calculated. Additionally, as a sensitivity analysis, the predictive ability was analyzed only for cases admitted directly from home, thereby ensuring that only patients who were independent before injury were evaluated.

Data analyses were performed using SPSS Statistics version 25 (SPSS, Chicago, IL, USA), and the statistical significance level was set at $P<0.05$.

RESULTS

A total of 121 patients with a mean (SD) age of 83.9 (11.4) were included in this study and the majority were women (n=99, 82%). Demographic, preoperative, and postoperative information is shown in **Table 1**. Twenty-nine of 99 patients (29%) who were admitted from their own home were discharged directly to their own home from the acute hospital

Floor and Ceiling Effects

Both the CAS-JP and the BI scores improved with time (**Table 2**). Floor and ceiling effects of both assessment scales at each time point are also shown in **Table 3**. No floor or ceiling effect was found for the BI at any time point, whereas the CAS-JP had a minor floor effect on POD1 (20%) and a minor ceiling effect (18%) at discharge.

Table 1. Demographics and preoperative and postoperative values

	Total n=121
Age	83.9 (11.4)
Sex	
Female	99 (82)
Male	22 (18)
Body mass index	20.3 (3.6)
Admitted from:	
Own home	99 (82)
Nursing home	22 (18)
Pre-fracture walking status:	
Independent gait	50 (41)
With cane	32 (26)
With walker	30 (25)
Wheel chair	8 (7)
Bedridden	1 (1)
Pre-fracture dementia	25 (21)
Fracture side:	
Right	53 (44)
Left	67 (55)
Bilateral	1 (1)
Fracture type:	
Femoral neck	73 (60)
Trochanteric	48 (40)
Surgical procedure:	
Open reduction and internal fixation	59 (49)
Stable reduction	56 (95)
Unstable reduction	3 (5)
Hemiarthroplasty	61 (50)
Total hip arthroplasty	1 (1)
Days from surgery to discharge	25.2 (15.2)
Discharge destination:	
Home	29 (24)
Rehabilitation Facility	91 (75)
Death	1 (1)

Data are presented as number (percentage) or as mean (SD) for age, body mass index, and days from surgery to discharge.

Validity

The correlations between the CAS-JP and other mobility assessments at each time point are shown in **Table 4**. Strong correlations were observed between the CAS-JP and the BI on POD7, POD14, and at discharge (r=0.81, 0.82, and 0.87, respectively) and between the CAS-JP and the walking status on POD7, POD14, and at discharge (r=0.82, 0.81, and 0.76, respectively). However, only weak correlations were identified between the CAS-JP and the BI at POD1 (r=0.46), and between the CAS-JP and the m-TUG on POD7, POD14, and at discharge (r=−0.46, −0.32, and −0.37, respectively).

Responsiveness and MCID

The responsiveness and MCID of CAS-JP and BI at each time point are shown in **Table 5**. Both assessments at each time point had large effect sizes, i.e., in the range 1.64–2.25 for CAS-JP and in the range 1.03–1.74 for BI.

Predictive Ability for Discharge to Own Home

The AUCs of the CAS-JP and the BI ROCs at each time point for predicting discharge to own home are shown in **Table 6**. The predictive abilities of CAS-JP on POD7 and POD14 and those of BI on POD1, POD7, and POD14 were found to be fair. Additionally, the cutoff values and the sensitivities and specificities are shown in **Table 7**. Sensitivity analysis showed similar AUCs for the subgroup of patients admitted from their own home, as presented in **Table 8**.

DISCUSSION

This study confirmed that the CAS-JP has sufficient validity and responsiveness as a mobility assessment when used in patients with hip fracture during acute care hospitalization. Furthermore, it was shown that early postoperative mobility status evaluation using the CAS-JP can sufficiently predict discharge to own home. In particular, the absence of floor or ceiling effects, strong correlation with the BI and walking status, and fair predictive ability suggest the usefulness of the CAS-JP when evaluated on POD7 and POD14.

Previous studies have reported correlation coefficients be-

Table 2. CAS-JP, BI, and m-TUG results on POD1, POD7, POD14, and at discharge

	POD1	n	POD7	n	POD14	n	Discharge	n
CAS-JP (0–6 points)	1.4 (1.0)	121	3.0 (1.2)	121	3.6 (1.3)	119	3.9 (1.4)	121
BI (0–100 points)	28.1 (16.4)	119	45.1 (20.9)	121	51.4 (20.3)	119	56.8 (22.9)	121
m-TUG (s)	–		51.6 (43.7)	39	40.8 (28.5)	41	35.6 (19.7)	45

Data are presented as mean (SD).

Table 3. Floor and ceiling effects of the CAS-JP and the BI on POD1, POD7, POD14, and at discharge

	POD1		POD7		POD14		Discharge	
	% Floor	% Ceiling	% Floor	% Ceiling	% Floor	% Ceiling	% Floor	% Ceiling
CAS-JP	20	0	1	4	0	8	1	18
BI	5	0	1	0	1	1	1	0

Data are presented as the percentage of patients with maximum or minimum scores.

Table 4. Correlations between the CAS-JP and the BI score, m-TUG time, and walking status

Day			r	P-value
POD1	CAS-JP	BI (n=119)	0.46[a]	<0.001
POD7	CAS-JP	BI (n=120)	0.81[a]	<0.001
		m-TUG (n=39)	–0.46[a]	0.004
		Walking status (n=120)	0.82[b]	<0.001
POD14	CAS-JP	BI (n=106)	0.82[a]	<0.001
		m-TUG (n=41)	–0.32[a]	0.045
		Walking status (n=107)	0.81[b]	<0.001
Discharge	CAS-JP	BI (n=121)	0.87[a]	<0.001
		m-TUG (n=45)	–0.37[a]	0.015
		Walking status (n=121)	0.76[b]	<0.001

[a] Pearson's correlation coefficient.
[b] Spearman's rank correlation coefficient.

Table 5. Responsiveness of the CAS-JP and the BI from POD1 to POD 7, POD14, and discharge

	POD7			POD14			Discharge		
	ES	SRM	MCID	ES	SRM	MCID	ES	SRM	MCID
CAS-JP	1.64	1.54	0.51	2.22	1.81	0.59	2.55	1.49	0.69
BI	1.03	1.26	6.75	1.42	1.55	7.54	1.74	1.63	8.81

ES, effect size; SRM, standardized response mean; MCID, minimal clinically important difference.

Table 6. Predictive ability of CAS-JP and BI for discharge to own home

	POD1		POD7		POD14	
	AUC	95% CI	AUC	95% CI	AUC	95% CI
CAS-JP	0.64	0.51–0.76	0.73	0.62–0.83	0.74	0.62–0.86
BI	0.71	0.59–0.83	0.71	0.59–0.83	0.75	0.63–0.86

AUC, area under the ROC curve; CI, confidence interval.

tween CAS and BI of 0.33–0.60[19,24,27)] and between CAS and other mobility outcomes of 0.56–0.90[19,24,28,30)]; the CAS-JP in this study showed the same or higher associations. However, there was a weaker correlation between CAS-JP and BI on POD1, a finding that corresponds to those of a previous study.[19)] This may be because CAS-JP assesses only three basic mobility activities, whereas BI assesses a wider range of activities, such as eating and personal hygiene, in addition to some of the basic mobility activities included in the CAS. On POD1, some patients were able to use their upper extremity for eating or personal hygiene, which improves the BI score; however, these upper extremity functions are not evaluated by the CAS.

The CAS-JP effect size in the present study was large at all time points and was even higher than that previously reported by Hulsbæk et al.[19)] They also reported a large CAS effect size (1.04) when used from POD1 to the time of discharge (mean length of stay: 8 days) in a Danish setting. The ef-

Table 7. Cutoff values, sensitivities, and specificities of the CAS-JP for predicting discharge to own home on POD1, POD 7, and POD14

	POD1		POD7		POD14	
Cutoff	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
≥1	0.86	0.22	1.00	0.01	NA	NA
≥2	0.69	0.51	1.00	0.07	1.00	0.02
≥3	0.21	0.97	0.86	0.40	0.90	0.22
≥4	0.07	1.00	0.45	0.84	0.79	0.62
≥5	0.03	1.00	0.38	0.93	0.62	0.69
≥6	NA	NA	0.17	0.99	0.38	0.87

NA, not applicable.

Table 8. Predictive ability of CAS-JP and BI for discharge to own home for the subset of patients initially admitted from home

	POD1		POD7		POD14	
	AUC	95% CI	AUC	95% CI	AUC	95% CI
CAS-JP	0.68	0.55–0.81	0.75	0.62–0.87	0.76	0.62–0.89
BI	0.77	0.66–0.88	0.78	0.66–0.89	0.77	0.64–0.89

fect sizes on POD14 and discharge in the current study were higher than those reported in previous studies,[19,28] which may be explained by greater mobility recovery with the longer follow-up period in the current study. The MCID of the CAS-JP in this study ranged from 0.51 to 0.69 CAS points, which is similar to the MCID of 0.8 reported in a previous study.[19] Ogawa et al.[31] reported a measurement error of 0.47 for the CAS-JP, suggesting that a 1-point improvement in the CAS-JP may be interpreted as a clinically significant change in patients after hip fracture surgery.

In the current study, we demonstrated the possibility of using the CAS-JP on POD7 and POD14 to predict whether patients can be discharged to their own home. The AUCs of the CAS-JP ROC curves in the present study were 0.73 on POD7 and 0.74 on POD14, which were similar to those of the BI at the same time points and also similar to those reported in a previous study in which the CAS AUC was 0.74.[22] At both time points, a cutoff score of 4 would be a good estimate, as shown in **Table 7**. In contrast, the predictive ability of the CAS-JP on POD1 was low. This was likely due to the high value of the floor effect, 20%, and a low mean. The CAS-JP on POD1 was 1.4, which indicates that most patients were able to perform only one activity with assistance. However, the CAS-JP improved by a mean of 2.4 points from POD1 to POD7. Before this large change in functional status, it is likely that sufficient AUC was not obtained. The finding of similar sensitivity analysis results for the subset of patients who had preserved mobility before injury also suggests the robustness of the fair prediction ability of CAS

One of the limitations of this study was that the CAS-JP had a minor floor effect on POD1 and a corresponding ceiling effect at discharge. A previous study also reported a floor effect on the day after surgery and a ceiling effect at discharge.[19] However, the floor effect on POD1 would have been even higher using other objectively assessed measures of mobility such as the TUG. Correspondingly, the ceiling effect at discharge should be considered encouraging, because independent mobility evaluated by the CAS is recommended as a first step rehabilitation goal for this frail patient group.[44] The CAS is an evaluation scale with a range of only 0–6 points; however, further evaluation of mobility and functional recovery will be possible by conducting quantitative mobility assessments, such as the TUG, after the patient becomes independent in basic mobility activities.[44] Because only one-fifth of patients reached an independent CAS level during their acute care stay, the CAS-JP would also seem to be relevant for use in the continuum of care after discharge for the large majority of patients. The second limitation of this study was that only objective assessments of mobility were used, i.e., no patient-reported outcome or quality-of-life rating was included in the assessment. Because patients' subjective outcomes as well as objective outcomes are important in determining treatment outcomes, future studies on the relationship between the CAS-JP and patient-reported outcomes will help clarify the usefulness of the CAS-JP. The third limitation was that this study was retrospective in nature, and our results include potential biases. However, this study included almost all patients who underwent surgery for a hip fracture in the hospital; as a result, the evaluation of the CAS-JP was likely relatively unaffected by selection bias given the completeness of the sample. In contrast with m-TUG, which can be measured in only a limited number of patients during their acute care stay (less than 50% at all time points in the present study), functional assessment using CAS can be performed in all patients, and there were few data deficiencies. In addition, some factors that may be related to the recovery of postoperative activity, such as bone mineral density, were not assessed, and their effects were not considered in this study. Finally, we evaluated only the short-term outcomes during hospitalization. To investigate the potential usage of CAS to help clinical decision making, it would be desirable to study the usefulness of CAS-JP in predicting mid- to long-term prognosis after hip fracture surgery and in the assessment of psychometric properties of CAS-JP in other diseases.

In conclusion, this study demonstrated that the CAS-JP is a valid and responsive outcome measure for assessing the basic mobility level and functional recovery of Japanese patients in acute settings after hip fracture surgery. Furthermore, the ability of the CAS-JP to predict discharge to own home was demonstrated and supports its use in the acute phase to set up an appropriate rehabilitation plan in the early postoperative period. We recommend that CAS-JP be used to monitor the mobility function of patients with hip fracture in acute and subacute Japanese settings until an independent ambulatory status has been reached.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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