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...
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, 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.

### 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 objec-
tively 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; 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.

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.

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. 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. 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.

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. 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.
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 ($r=0.81, 0.82, \text{ and } 0.87$, respectively) and between the CAS-JP and the walking status on POD7, POD14, and at discharge ($r=0.82, 0.81, \text{ and } 0.76$, 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 ($r=-0.46, -0.32, \text{ and } -0.37$, 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 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)                                                   |

| Table 2. CAS-JP, BI, and m-TUG results on POD1, POD7, POD14, and at discharge |
|--------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| POD1 n=121                          | POD7 n=121      | POD14 n=119     | Discharge n=121 |
| CAS-JP (0–6 points)                 | 1.4 (1.0)       | 3.0 (1.2)       | 3.6 (1.3)       | 3.9 (1.4)       |
| BI (0–100 points)                   | 28.1 (16.4)     | 45.1 (20.9)     | 51.4 (20.3)     | 56.8 (22.9)     |
| m-TUG (s)                           | –               | 51.6 (43.7)     | 40.8 (28.5)     | 35.6 (19.7)     |

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

Data are presented as mean (SD).
between 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-

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

|       | POD1 % Floor | POD1 % Ceiling | POD7 % Floor | POD7 % Ceiling | POD14 % Floor | POD14 % Ceiling | Discharge % Floor | Discharge % 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     | CAS-JP   | BI          | 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 ES | POD7 SRM | POD7 MCID | POD14 ES | POD14 SRM | POD14 MCID | Discharge ES | Discharge SRM | Discharge 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 AUC | 95% CI | POD7 AUC | 95% CI | POD14 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.
The effect sizes on POD14 and discharge in the current study were higher than those reported in previous studies, 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. Ogawa et al. 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. 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. 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. 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. 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 na-

| Cutoff | POD1   | POD7   | POD14  |
|--------|--------|--------|--------|
|        | 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     |

Table 7. Cutoff values, sensitivities, and specificities of the CAS-JP for predicting discharge to own home on POD1, POD7, and POD14

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

| POD1     | AUC   | 95% CI     | POD7     | AUC   | 95% CI     | POD14    | 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 |

NA, not applicable.
ture, 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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