OPEN

A formula for predicting postoperative functional decline using routine medical data in elderly patients after hip fracture surgery

Taeko Fukuda, MD, PhD[ab], Shinobu Imai, PhD, MHA, RPh[cd], Kazushi Maruo, PhD[e] and Hiromasa Horiguchi, PhD[c]

[a]Department of Anesthesiology, Faculty of Medicine, University of Tsukuba, Tsukuba, Japan
[b]Kasumigaura Medical Center Hospital (Tsuchiura Clinical Education and Training Center), National Hospital Organization, Tsuchiura, Japan
[c]Department of Clinical Data Management and Research, National Hospital Organization Headquarters, Tokyo, Japan
[d]Department of Drug Safety and Risk Management, School of Pharmacy, Tokyo University of Pharmacy and Life Sciences, Tokyo, Japan
[e]Department of Biostatistics, Faculty of Medicine, University of Tsukuba, Tsukuba, Japan

ABSTRACT

Background:

If functional decline after hip surgery can be predicted without special assessment, the effects of new treatments and rehabilitation practices can be easily compared with previous cases or those in other countries. The purpose of this study was to develop and examine a formula for such prediction.

Methods:

Data of 3,120 patients older than 65 yr with hip fracture were analyzed. The Barthel Index was used for evaluating activities of daily living (ADL). Low ADL was defined as patients with a lower score at discharge than the score at admission and patients with complete dependence at admission that did not change until discharge. Three models were developed in a training sample: Basic, Comorbidity, and Laboratory & Vital Signs models were created by inputting basic patient data, the basic data plus comorbidities, the basic data and comorbidities plus 8 laboratory test results and 5 vital signs, respectively. All potential variables with statistical significance < 0.2 on univariate analyses and some variables that may be clinically meaningful were included in multivariable models. The final model was developed by stepwise logistic regression.

Results:

The c-statistic of the Laboratory & Vital Signs formula was 0.701 and the predictive value was 76.9%. The c-statistics of the Basic and Comorbidity formulas were 0.643 and 0.664, respectively. Applying the Laboratory & Vital Signs formula to the validation sample, the c-statistic was 0.663.

Conclusions:

The formula developed from the medical data collected routinely before surgery could predict low ADL following hip fracture surgery in elderly patients.

Level of Evidence:

IVb

Key Words

activities of daily living, elderly, hip fracture, prediction, surgery

The study was approved by the ethical review boards of National Hospital Organization Kasumigaura Medical Center (IRB No. 2019-1).

TF designed the research, analyzed the data, and wrote the manuscript. SI contributed to interpretation of the findings. KM contributed to statistical analyses. HH supervised data collection.

Financial Disclosure: This study was supported by Japan Society for the Promotion of Science (20K10311). The authors report no conflicts of interest.

Correspondence to Taeko Fukuda, MD, PhD, Department of Anesthesiology, Faculty of Medicine, University of Tsukuba, 1-1-1 Tennodai, Tsukuba City, Ibaraki 305-8575, Japan
Tel: +81-29-822-5050; fax: +81-29-824-0494;
e-mail: taekof@md.tsukuba.ac.jp.

With the aging of the population and advances in medical care, the frequency of surgery for the elderly is increasing.[1,2] The frequency of postoperative functional decline in the elderly is higher than that in younger generations.[3] Decreased patient function leads to increased caregiver burden and social costs.[4–7] In addition, an interview survey of elderly people suffering from serious illnesses reported that about 75% of patients who are expected to have severe functional deterioration do not want treatment even if the burden is light.[8] Preventing postoperative functional decline in the elderly is very important for patients, caregivers, and society.

Many studies have investigated factors that affect postoperative mortality and complication rates.[9–13] However, postoperative functional decline in elderly patients has not received much attention yet.[14,15] There are large individual differences in the physical abilities of the elderly.[16] The number of elderly patients in whom postoperative functional decline can be prevented may be higher than expected. Predictors of functional decline that have already been reported often include factors that are laborious and time-consuming to measure.[17,18] For example, frailty is a major factor in postoperative functional decline in the elderly, but it cannot be evaluated without special tests such as of grip strength and walking speed.[11,19] These difficulties obstruct the performance of large-scale or retrospective studies. If predictors of functional decline that can be applied to almost all surgical operations can be identified, it will be possible to compare data with previous studies or studies performed in other geographical regions, which will be useful for improving rehabilitation and preventing postoperative functional decline.

Against this background, we developed formulas for predicting elderly patients with low activities of daily living (ADL) after hip fracture surgery. These formulas were created using basic patient data, information on comorbidities, preoperative vital signs, and the results of routine laboratory tests. Subsequently, the usefulness and accuracy of the predictive formulas were examined in a validation sample. The purpose of this study is to create a predictive measure to prevent postoperative functional decline in the elderly. We hypothesized that data available in routine practice could be used to develop a predictive formula for low ADL after hip fracture surgery.

MATERIALS AND METHODS

This study was approved by the ethical review boards of our hospital (2020-8; principal investigator, T.F.; date of approval, June 2020) and the National Hospital Organization (NHO). Following our ethical guidelines for human medical research, which are based on the Declaration of Helsinki, the study protocol was open to the general public via websites in order to obtain patient objections. To protect patient privacy, all personal identification data were encrypted in a security room at the NHO Headquarters. The requirement for written informed consent was waived by the ethical review boards.

Data Sources

This retrospective cohort study was conducted using data from an administrative database. The research period was from January 1, 2016, to December 31, 2019. Data from 80 NHO hospitals were used. The data were obtained from the Diagnosis Procedure Combination (DPC) administrative claims database. The DPC database is a diagnosis-dominant, case-mix system administered by Ministry of Health, Labour and Welfare, and it is linked with a lump-sum payment system.[20]

Selection of Patients and Variables

The inclusion criteria were: (1) male and female patients who are older than 65 yr old; and (2) patients who underwent surgery for a hip fracture during the research period. The patients who died during hospitalization, for whom incomplete data were available, or who were transferred to another hospital at an early stage after surgery (< 7 days) were excluded. The data on the remaining 3,120 patients of the initial 15,744 were analyzed. The training sample was created by randomly selecting approximately 80% of the final dataset, resulting in 2,497 observations in the training sample and 623 in the validation sample (Figure 1).

The data from the DPC database included age, sex, height, weight, main diagnosis, surgery date, surgical procedure, treatments before surgery, information of dwelling place before admission, comorbidities and consciousness level data on admission, and functional status, which was based on the patient's ability to perform tasks related to ADL before admission and at discharge.

Body mass index (BMI) was calculated from height and weight. Overweight is associated with ADL decline.[21] However, most patients were relatively thin and in this study only 1.4% of subjects had a BMI $\geq$ 30 kg/m^2. Therefore, BMI was divided into two groups: < 18.5 kg/m^2 and $\geq$ 18.5 kg/m^2. Time from admission to surgery was categorized as either less than or more than 48 hr.[22] A modified Charlson Comorbidity Index (CCI) score was calculated for each patient based on Quan *et al.*'s coding algorithms.[23] Functional status of ADL includes the following parameters: (1) eating, (2) transferring, (3) grooming, (4) toileting, (5) bathing, (6) walking on a flat floor, (7) using stairs, (8) dressing, (9) defecating, and (10) micturating.[24] The Low-ADL group was defined as patients with a lower score at discharge than the score at admission and patients with a score of 0 (completely dependent) at admission that did not change until discharge. The High-ADL group was defined as patients with improved discharge scores compared with their scores at admission and patients with high scores (fully independent) at admission and discharge.

In each patient, 16 preoperative routine laboratory parameters and 4 vital signs (systolic and diastolic blood pressure, heart rate, and body temperature) at admission were collected using NHO Clinical Data Archives (NCDA). The laboratory parameters were hemoglobin, hematocrit, white blood cells (WBC), platelets (Plt), total serum protein, albumin, alanine aminotransferase (ALT), aspartate aminotransferase (AST), lactate dehydrogenase (LD), total bilirubin, sodium, potassium, chlorine, creatinine (Cre), blood urea nitrogen (BUN), and estimated glomerular filtration rate (eGFR).

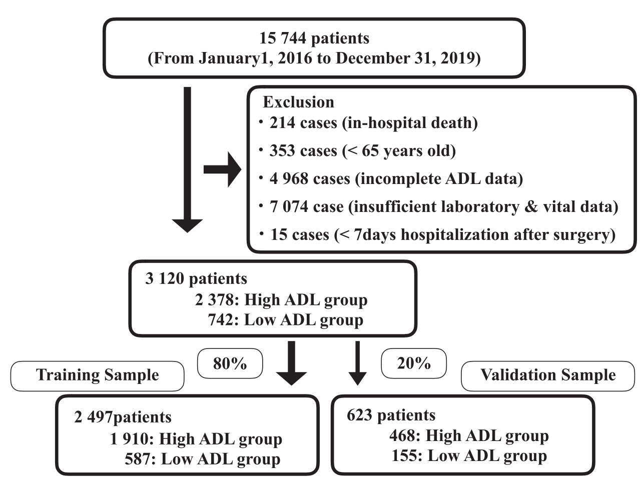

FIGURE 1. Flow diagram of patient inclusion and exclusion for the analysis of postoperative activities of daily living.

Prediction Models

Three models for predicting functional decline were developed using the training sample: Basic, Comorbidity, and Laboratory & Vital Signs. The Basic model was created by inputting the following six variables: age, sex, body mass index, fracture type, time to surgery, and dwelling place before admission. The Comorbidity model was created by inputting the above variables plus comorbidities (cerebrovascular disease and dementia). Finally, the Laboratory & Vital Signs model was created by inputting all of the above variables plus 8 laboratory test results before surgery (hemoglobin, WBC, Plt, total protein, LD, sodium, Cre, and BUN) and 5 vital signs at admission (consciousness level, diastolic blood pressure (dBP), heart rate, body temperature, and oxygen inhalation). For highly correlated pairs of laboratory test variables, either one was selected based on clinical importance (e.g., sodium and chlorine). The hemoglobin threshold of <8 g/dL was used to categorize severe anemia in line with WHO guidelines.[25] Meanwhile, the thresholds for total protein of <6 g/dL and sodium of <135 mmol/L were applied based on previous studies.[26,27] Thresholds for other laboratory data were set based on standard values of our country (WBC > 8,600 10^3/μL, Plt > 34.8 10^4/μL, LD > 222 U/L).[28] Since eGFR of the Low-ADL group was better than that of the High-ADL group, many patients in the Low-ADL group were speculated to have low muscle mass. Therefore, Cre was used as an indicator of sarcopenia when it was lower than the standard value (<0.46 mg/dL). BUN (>20 mg/dL) was considered to be an effective indicator of dehydration and was included in the variables. Since there was no oxygen saturation in our vital signs data, cases in which oxygen inhalation was required before surgery were evaluated as involving a decrease in oxygen saturation. The level of consciousness at the time of admission was evaluated by a local coma scale ("alert" plus nine other grades of lower alertness).[29] All cases other than those with an alert status were evaluated as having impaired consciousness.

Statistical Analysis

No power analysis was performed prior to the research because all available data on the existing database were used. All potential variables with statistical significance < 0.2 on univariable analyses and some variables that may be clinically meaningful were included in multivariable models to identify independent factors associated with low ADL. The final model was developed by stepwise logistic regression. The predictive performance of the models was evaluated by receiver operating characteristic (ROC) analyses and c-statistics; the Hosmer-Lemeshow goodness of fit test was used to assess model performance. Three developed prediction formulas were applied to the validation sample and it was calculated how accurately low ADL can be predicted.

Basic data of the training and validation samples were analyzed by the chi-square test and patient characteristics of the training sample were analyzed by univariable logistic regression analysis. Multivariable analysis was conducted by a logistic regression model with ADL as a dependent variable. An odds ratio (OR) with 95% confidence interval for each predictive factor of low ADL was estimated. Predictive probabilities for logistic models are given by exp(1/[1+exp{-h(x)}]), where h is a linear function and x is a covariate vector. Therefore, we provide h(x) as the formula in this manuscript.

A two-sided *P*-value < 0.05 was considered significant for all statistical tests. Statistical analyses were performed using SPSS software version 26 (IBM, Armonk, New York, USA).

RESULTS

Of the 15,744 elderly patients who underwent hip fracture surgery, 12,624 were excluded from the study. Of these, 214 died in hospital, 353 were under the age of 65, 4,968 had incomplete ADL data, 7,074 lacked necessary laboratory and vital signs data, and 15 had been transferred to other hospitals less than 7 days after surgery. Of the 2,497 patients in the training sample, 587 (23.5%) had low ADL, while of the 623 patients in the validation sample, 155 (24.9%) had low ADL (Figure 1). There were no significant differences in age, sex, BMI, fracture type, or dwelling place between the two samples (Table 1).

Table 2 shows the characteristics of the patients with low ADL and high ADL in the training sample. Compared with the patients with high ADL, the patients with low ADL were older, had a lower BMI, and were more likely to be men, to have trochanteric fractures, and to live in an institution such as a nursing home. Patients with low ADL had higher diastolic blood pressure, heart rate, and body temperature than those with high ADL. Among the low-ADL patients, the proportions with impaired consciousness at admission, requiring oxygen inhalation before surgery, and having dementia were higher than those of high-ADL patients. Patients with low ADL had lower hemoglobin, total protein, albumin, and sodium than those with high ADL.

Table 3 shows the three formulas' characteristics in the training sample. The c-statistic of the Laboratory & Vital Signs formula was 0.701 and the predictive value was 76.9%. When 0.215 was used as a cut-off value for the Laboratory & Vital Signs formula, its sensitivity and specificity were 68.7% and 62.4%, respectively. The ROC curves of the three formulas are shown in Figure 2. The c-statistics of the Basic, Comorbidity, Laboratory & Vital Signs formulas were 0.643, 0.664, and 0.701, respectively.

Applying the Basic, Comorbidity, and Laboratory & Vital Signs formulas to the validation sample, the c-statistics were 0.624, 0.642, and 0.663, respectively. The predictive scores of

TABLE 1. Basic data of training and validation samples

Variables	Training sample	Validation sample	*P*
N	2,497	623	
Age 85+	1,285 (51.5%)	305 (49.0%)	0.263
Male	564 (22.6%)	144 (23.1%)	0.779
BMI < 18.5 or unknown	871 (34.9%)	220 (35.3%)	0.840
Trochanteric Fracture	1,155 (46.3%)	285 (45.7%)	0.820
Institution	931 (37.3%)	244 (39.2%)	0.386

BMI, body mass index.

TABLE 2. Patient characteristics of the training sample

Variables	Low ADL	High ADL	OR	95%CI	*P*
N	587	1,910			
Age	85.4 ± 7.4	83.6 ± 7.6	1.033	1.020-1.046	< 0.001
85+	339 (57.8%)	946 (49.5%)	1.393	1.156-1.679	0.001
Sex (M/F) (Male%)	136 / 451 (23.2%)	428 / 1,482 (22.4%)	1.044	0.838-1.301	0.700
Body Mass Index (kg/m^2)	19.9 ± 4.0	20.8 ± 4.0	0.949	0.926-0.973	< 0.001
< 18.5 or unknown	253 (43.1%)	618 (32.4%)	1.584	1.310-1.914	< 0.001
Fracture Type (trochanteric / cervical)	300 / 287 (51.1%)	855 / 1,055 (44.8%)	1.290	1.072-1.552	0.007
Time to surgery (days)	5.2 ± 3.8	5.0 ± 3.9	1.010	0.987-1.033	0.411
> 48 hr	330 (56.2%)	1,099 (57.5%)	0.948	0.786-1.142	0.572
Dwelling place (Institution / Home)	310 / 277 (52.8%)	621 / 1,289 (32.5%)	2.323	1.924-2.804	< 0.001
Vital sighns					
Disturbance of consciousness at admission	181 (30.8%)	291 (15.2%)	2.480	2.000-3.075	< 0.001
Systolic BP (mmHg) at admission	145 ± 27	145 ± 25	0.999	0.996-1.003	0.705
Diastolic BP (mmHg) at admission	80 ± 15	78 ± 14	1.009	1.003-1.016	0.005
Heart Rate (/min) at admission	86 ± 15	83 ± 14	1.014	1.008-1.020	< 0.001
Body Temperature (°C) at admission	37.3 ± 0.6	37.2 ± 0.6	1.286	1.104-1.498	0.001
Oxygen inhalation before surgery	130 (22.1%)	284 (14.9%)	1.629	1.291-2.054	< 0.001
Comorbidity (Charlson Comorbidity Index)					
CCI 1 Myocardial Infarction	5 (0.9%)	27 (1.4%)	0.599	0.230-1.563	0.295
CCI 2 Cerebrovascular Disease	62 (10.6%)	161 (8.4%)	1.283	0.942-1.747	0.114
CCI 3 Congestive Heart Failure	66 (11.2%)	217 (11.4%)	0.988	0.738-1.324	0.937
CCI 4 Rheumatoid arthritis	11 (1.9%)	58 (3.0%)	0.610	0.318-1.170	0.137
CCI 5 Dementia	239 (40.7%)	427 (22.4%)	2.385	1.959 -2.904	< 0.001
CCI 6 Diabetes uncomplicated	91 (15.5%)	345 (18.1%)	0.832	0.647-1.071	0.153
CCI 7 Mild Liver Disease	28 (4.8%)	84 (4.4%)	1.089	0.703-1.687	0.703
CCI 8 Peptic ulcer disease	12 (2.0%)	48 (2.5%)	0.810	0.427-1.534	0.517
CCI 9 Peripheral vascular disorders	10 (1.7%)	34 (1.8%)	1.046	0.514-2.130	0.902
CCI 10 Chronic pulmonary disorders	22 (3.7%)	86 (4.5%)	0.826	0.512- 1.332	0.432
CCI 11 Any malignancy	28 (4.8%)	115 (6.0%)	0.782	0.512-1.194	0.255
CCI 12 Diabetes complicated	14 (2.4%)	62 (3.2%)	0.728	0.405-1.310	0.290
CCI 13 Hemiplegia or paraplegia	0 (0%)	3 (0.2%)	0	–	0.999
CCI 14 Renal diseasse	34 (5.8%)	126 (6.6%)	0.871	0.589-1.287	0.487
CCI 15 Metastatic solid tumor	0 (0.0%)	13 (0.7%)	0		0.999
CCI 16 Moderate or severe liver disease	4 (0.7%)	9 (0.5%)	1.449	0.445-4.723	0.538
CCI 17 AIDS/HIV	0 (0%)	2 (0.1%)	0	–	0.999
Hb: hemoglobin (g/dL)	10.8 ± 1.8	11.2 ± 1.8	0.901	0.856-0.949	< 0.001
Ht: hematocrit (%)	32.6 ± 5.4	33.6 ± 5.1	0.964	0.947-0.982	< 0.001
WBC: white blood cell (10^3/μL)	8,189 ± 2,893	7,979 ± 2,950	1.000	1.000-1.000	0.131
Plt: platelet (10^4/μL)	20.6 ± 8.1	20.0 ± 7.1	1.011	0.998-1.023	0.087
Total protein (g/dL)	6.3 ± 0.7	6.5 ± 0.7	0.794	0.700-0.901	< 0.001
Albumin (g/dL)	3.2 ± 0.6	3.4 ± 0.6	0.640	0.545-0.752	< 0.001
ALT: alanine aminotransferase (U/L)	18.1 ± 12.3	17.4 ± 14.8	1.003	0.997-1.009	0.302
AST: asparate aminotransferase (U/L)	25.0 ± 13.3	24.6 ± 15.8	1.001	0.995-1.007	0.658
LD: lactate dehydrogenase (U/L)	248 ± 74	242 ± 65	1.001	1.000-1.003	0.059
Total-bilirubin (mg/dL)	0.8 ± 0.4	0.8 ± 0.5	0.875	0.704-1.087	0.229
Na: sodium (mmol/L)	138 ± 5	139 ± 4	0.967	0.946-0.989	0.004
Cl: chloride (mmol/L)	103 ± 4	104 ± 4	0.969	0.948-0.990	0.005
K: potassium (mmol/L)	4.1 ± 0.6	4.1 ± 0.5	1.015	0.856-1.202	0.868
Cre: creatinine (mg/dL)	0.9 ± 1.0	1.0 ± 1.2	0.954	0.875-1.040	0.284
BUN: blood urea nitrogen (mg/dL)	21.8 ± 12.4	21.3 ± 11.3	1.003	0.995-1.011	0.445
eGFR: estimated glemerular filtration rate (mL/min/1.73m^2)	69.0 ± 32.8	66.0 ± 28.2	1.003	1.000-1.007	0.031

ADL, activities of daily living; BP, blood pressure; CI, confidence interval; OR, odds ratio.

the Laboratory & Vital Signs formula in the validation sample were sorted in ascending order and the proportion of low-ADL patients was examined at 10% (62 or 63 patients) sample size intervals. The percentage of low-ADL patients increased in proportion to the increase in predictive score (Figure 3).

DISCUSSION

Although the Basic and Comorbidity formulas developed in this study had difficulty predicting low ADL after hip fracture surgery, the Laboratory & Vital Signs formula predicted the occurrence of low ADL in elderly patients with a probability of 76.9% and its c-statistic was 0.701. When this formula was applied to the validation sample, the predictive rate was 75.6% and the predictive score, which was calculated based on the Laboratory & Vital Signs formula, was proportional to the probability of occurrence of low ADL. Along with impaired consciousness at admission, dementia, and hospitalization from a location other than home, severe anemia and low Cre were major predictive factors of low ADL.

TABLE 3. Three formulas' characteristics in the training sample

Nomogram	c-statistics	95%CI	Hosmer-Lemeshow
Basic	0.643	0.618-0.669	0.460
Comorbidity	0.664	0.639-0.689	0.594
Laboratory & Vital Sign	0.701	0.677-0.725	0.519

Basic formula: Age × 0.024 + BMI (<18.5) × 0.379 + Trochanteric Fracture × 0.168 + Institution × 0.785 - 3.751.
Comorbidity formula: Age × 0.017 + Male × 0.167 + BMI (<18.5) × 0.373 + Trochanteric Fracture × 0.16 + Institution × 0.661 + Dementia × 0.627 - 3.387.
Laboratory & Vital Sign formula: Age × 0.014 + Male × 0.172 + BMI (<18.5) × 0.321 + Trochanteric Fracture × 0.205 + Institution × 0.623 - Surgery Delay (> 48 hr) × 0.141 + Cerebrovascular Disease × 0.230 + Dementia × 0.550 + Hb (< 8) × 0.642 - Total Protein (< 6) × 0.269 + Na (<135) × 0.317 + BUN (> 20) × 0.152 + Cre (< 0.46) × 0.626 + Consciousness Disturbance × 0.541 + dBP × 0.011 + Heart Rate × 0.007 + Oxygen Inhalation × 0.328 - 4.831.

To our knowledge, the use of the Rothman Index[30] is the only approach similar to that developed in our study. This index is used to evaluate patient status by inputting seven routine laboratory test results, 7 vital signs, and 12 nursing assessments. McLynn *et al.*[31] reported that this index was associated with postdischarge adverse events in patients with hip fracture surgery. However, this index is not specific to hip fracture. In addition, since the algorithm behind this index was not disclosed, it could not be compared with the formula developed in our study. Recent reviews have listed the following as predictors of poor functional outcome after hip fracture surgery: comorbidities, hypoalbuminemia, malnutrition, anemia, and dehydration, among others.[32,33] However, to the best of our knowledge, no reports of studies examining the combination of multiple laboratory test results and vital signs have been published.

Although several reports cite albumin as a predictor,[26,27,34] total protein was more predictive of postoperative functional decline than albumin in this study. In this study, albumin was lower than the normal range in many patients in the High-ADL group, but total protein was within the normal range in about half of patients in that group. This difference may explain why total protein was a better predictor in this study.

Low creatinine level was more predictive of low ADL than high creatinine level in this study. However, this does not mean that renal dysfunction is not a predictor. Many older people lose muscle mass. As a result, Cre and eGFR do not show poor values even if renal function is reduced. However, when renal function is severely reduced, urine cannot be concentrated or diluted, so hypernatremia and hyponatremia are more likely to occur.[35,36] Hyponatremia was reported to increase bone resorption, decrease bone formation, and decrease bone mineral density.[37] Patients undergoing hip surgery often have hyponatremia.[38] Hyponatremia was suggested to be more effective as an indicator of decreased renal function than Cre and GFR in elderly patients with hip fracture. Regarding BUN, it was not clear whether it was related to low ADL, but it was included as a variable in developing the Laboratory & Vital Signs formula. The obtained results are consistent with a report by Adunsky *et al.*[39] stating that BUN is a better predictor of adverse functional outcome than Cre or GFR.

Moreover, in this study, dBP, but not sBP, was a predictor of low ADL. In clinical practice, if sBP is high, it is often remeasured. There was no significant difference in sBP between the Low-ADL group and the High-ADL group in this study. It may be that dBP correctly represents the degree of hypertension. Furthermore, diastolic hypertension was reported to be associated with increased postoperative mortality.[40] Although some exceptions to this depending on patient age were reported, dBP is an important factor related to organ perfusion.[41]

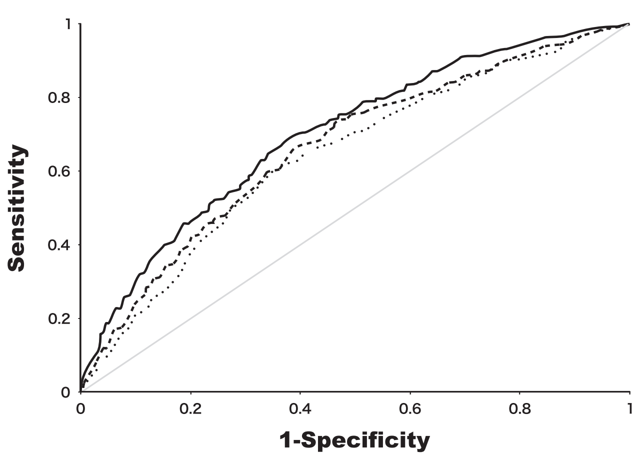

FIGURE 2. Receiver operating characteristic curve of the prediction score. The c-statistics of the Basic, Comorbidity, and Laboratory & Vital Signs formulas were 0.643, 0.664, and 0.701, respectively. Dotted line: Basic formula, dashed line: Comorbidity formula, and solid line: Laboratory & Vital Signs formula.

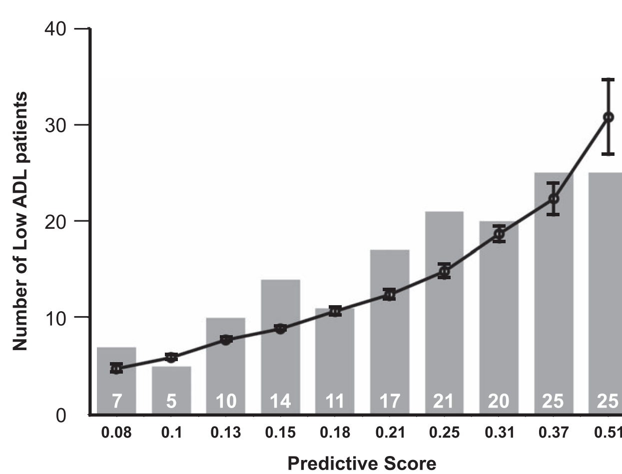

FIGURE 3. Numbers of observed and predicted patients with low ADL in the validation sample. The vertical axis shows the number of patients. The horizontal axis shows cases sorted according to the size of the predictive score, at 10% intervals. Columns: number of observed low-ADL patients. Line graph: number of predicted low-ADL patients (mean ± SD).

There is no clear evidence explaining why trochanteric fractures are predictors of low ADL. In a CT analysis study, bone mineral density in the trochanteric area was shown to decrease with age, but was better maintained than that in the cervical area.[42] The reason for this is presumed to be that the muscles attached to the trochanter may prevent bone loss in the trochanter. If this is correct, it is presumed that people with significantly reduced muscle mass are more likely to have trochanteric fractures. Patients with trochanteric fractures may be more prone to low ADL because they originally have lower muscle mass. Delayed surgery of 48 hr or more has been reported as a factor that worsens prognosis,[32,33] but it was not predictive of low ADL in this study. This result is consistent with some previous studies.[43,44]

There are several limitations in this study. For example, this study excluded cases with missing laboratory and vital signs data. The proportion of patients with low ADL increased by 3.6% after excluding such cases compared with the proportion before such exclusion. Given that more tests and measurements are performed on vulnerable patients, there is a need for further verification to determine whether the results of this study apply to all patients. In addition, since no data on oxygen saturation were available in this study, preoperative oxygen inhalation was used instead. Oxygen saturation in patients requiring oxygen inhalation was speculated to be less than 90%, but this needs to be verified. Moreover, a local coma scale was used to evaluate the level of consciousness. However, since the level of consciousness is categorized as simply "normal" or "abnormal" using this scale, this approach can be applied even if other scales are used. It was also reported that parathyroid hormone levels were effective at predicting mortality.[27] Since neither this hormone nor calcium concentration is included in routine laboratory tests in our country, their effects could not be investigated here, which is another limitation of this study. Since most of the patients in this study were from one country, it is unclear whether the results of this study can be applied in other countries.

CONCLUSIONS

In this study, using basic patient data, vital signs, and the results of routine laboratory tests, a formula was created to predict low ADL after hip fracture surgery. The usefulness and accuracy of the prediction formula was confirmed in a validation sample. Disorders of consciousness at admission, dementia, hospitalization from a location other than home, severe anemia, and low Cre values were closely associated with functional decline after hip surgery in the elderly. Further studies are needed to determine whether this formula can help improve the actual prognosis.

ACKNOWLEDGMENTS

The authors thank Chiharu Okada, MD, PhD, MBA (National Hospital Organization Headquarters, Department of Hospital Management Assistance for arranging this study. The data collection and technical support by Mr. Shunji Shimoda and Mr. Masaya Nakadera are highly appreciated.

REFERENCES

1. Kim TI, Brahmandam A, Skrip L, *et al*. Surgery for the very old: are nonagenarians different? *Am Surg*. 2020; 86:56–64.
2. Etzioni DA, Liu JH, Maggard MA, *et al*. The aging population and its impact on the surgery workforce. *Ann Surg*. 2003; 238:170–177.
3. Fukuda T, Imai S, Nakadera M, *et al*. Deterioration of post-operative daily living activities in elderly patients: incidence and associated factors. *Int J Gerontol*. 2020; 14:124–128.
4. Bakker FC, Persoon A, Bredie SJH, *et al*. The carewell in hospital program to improve the quality of care for frail elderly inpatients: results of a before-after study with focus on surgical patients. *Am J Surg*. 2014; 208:735–746.
5. Wiedl A, Forch S, Otto A, *et al*. Beyond hip fractures: other fragility fractures' associated mortality, functional and economic importance: A 2-year-follow-up. *Geriatr Orthop Surg Rehabil*. 2021; 12:21514593211058969.
6. Lee IY, Shih CY, Wei YT, *et al*. Increasing burden of major trauma in elderly adults during 2003-2015: analysis of real-world data from Taiwan. *J Formos Med Assoc*. 2022; 121:144–151.
7. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury*. 2018; 49:1458–1460.
8. Fried TR, Bradley EH, Towle VR, *et al*. Understanding the treatment preferences of seriously ill patients. *N Engl J Med*. 2002; 346:1061–1066.
9. Eamer G, Al-Amoodi MJH, Holroyd-Leduc J, *et al*. Review of risk assessment tools to predict morbidity and mortality in elderly surgical patients. *Am J Surg*. 2018; 216:585–594.
10. Guerra MTE, Giglio L, Morais JMM, *et al*. The relationship between the Lee score and postoperative mortality in patients with proximal femur fractures. *Rev Bras Ortop*. 2019; 54:387–391.
11. Lin HS, Watts JN, Peel NM, *et al*. Frailty and post-operative outcomes in older surgical patients: a systematic review. *BMC Geriatrics*. 2016; 16:157.
12. Machado AN, Sitta MC, Jacob FW, *et al*. Prognostic factors for mortality among patients above the 6th decade undergoing non-cardiac surgery: cares-clinical assessment and research in elderly surgical patients. *Clinics (Sao Paulo)*. 2008; 63:151–156.
13. Turrentine FE, Wang H, Simpson VB, *et al*. Surgical risk factors, morbidity, and mortality in elderly patients. *J AM Coll Surg*. 2006; 203:865–877.
14. Kwon S, Symons R, Yukawa M, *et al*. Evaluating the association of preoperative functional status and postoperative functional decline in older patients undergoing major surgery. *Am Surg*. 2012; 78:1336–1344.
15. Tan HL, Chia STX, Nadkarni NV, *et al*. Frailty and functional decline after emergency abdominal surgery in the elderly: a prospective cohort study. *World J Emerg Surg*. 2019; 14:62.
16. Whipple MO, Schorr EN, Talley KMC, *et al*. Variability in individual response to aerobic exercise interventions among older adults. *J Aging Phys Act*. 2018; 26:655–670.
17. Konda SR, Dedhia N, Ranson RA, *et al*. Loss of ambulatory level and activities of daily living at 1 year following hip fracture: can we identify patients at risk. *Geriatr Orthop Surg Rehabil*. 2021; 12:21514593211002158.
18. Burgos E, Gomez-Arnau JI, Diez R, *et al*. Predictive value of six risk scores for outcome after surgical repair of hip fracture in elderly patients. *Acta Anaesthesiol Scand*. 2008; 52:125–131.
19. Sioutas G, Tsoulfas G. Frailty assessment and postoperative outcomes among patients undergoing general surgery. *Surgeon*. 2020; 18:e55–e66.
20. Hayashida K, Murakami G, Matsuda S, *et al*. History and profile of diagnosis procedure combination (DPC): development of a real data collection system for acute inpatient care in Japan. *J Epidemiol*. 2021; 31:1–11.
21. Okamoto S, Okamura T, Sugiyama D, *et al*. Overweight or underweight and the risk of decline in activities of daily living in a 22-year cohort study of Japanese sample. *Geriatr Gerontol Int*. 2018; 18:799–805.
22. Le-Wendling L, Bihorac A, Baslanti TO, *et al*. Regional anesthesia as compared with general anesthesia for surgery in geriatric patients with hip fracture: does it decrease morbidity, mortality,

and health care costs? Results of a single-centered study. *Pain Med*. 2012; 13:948–956.
23. Quan H, Sundararajan V, Halfon P, *et al*. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005; 43:1130–1139.
24. Collon C, Wade DT, Davies S, *et al*. The Barthel Index: a relaiability study. *Int Disabil Stud*. 1988; 10:61–63.
25. World Health Organization 2011 Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. https://apps.who.int/iris/handle/10665/85839
26. Howlett S, Rockwood MRH, Rockwood K. Standard laboratory tests to identify older adults at increased risk of death. *BMC Med*. 2014; 12:171.
27. Lizaur-Utrilla A, Gonzalez-Navarro B, Vizcaya-Moreno M, *et al*. Altered seric levels of albumin, sodium and parathyroid hormone may predict early mortality following hip fracture surgery in elderly. *Int Orthop*. 2019; 43:2825–2829.
28. Ichihara K, Yamamoto Y, Hotta T, *et al*. Collaborative derivation of reference intervals for major clinical laboratory tests in Japan. *Ann Clin Biochem*. 2016; 53:347–356.
29. Shigamatsu K, Nakano H, Watanabe Y. The eye response test alone is sufficient to predict stroke outcome-reintroduction of Japan Coma Scale: a cohort study. *BMJ Open*. 2013; 3: e002736.
30. Rothman MJ, Rothman SI, Beals J. Development and validation of a continuous measure of patient condition using the electronic medical. *J Biomed Inform*. 2013; 46:837–848.
31. McLynn RP, Ottesen TD, Ondeck NT, *et al*. The Rothman Index is associated with postdischarge adverse events after hip fracture surgery in geriatric patients. *Clin Orthop Relat Res*. 2018; 476:997–1006.
32. Xu BY, Yan S, Low LL, *et al*. Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. *BMC Musculoskelet Disord*. 2019; 20:568.
33. Sheehan KJ, Williamson L, Alexander J, *et al*. Prognostic factors of functional outcome after hip fracture surgery: a systematic review. *Age Ageing*. 2018; 47:661–670.
34. Sim SD, Sim YE, Tay K, *et al*. Preoperative hypoalbuminemia: poor functional outcomes and quality of life after hip fracture surgery. *Bone*. 2021; 143:115567.
35. Arroyo RA. Electrolyte and acid-base balance disorders in advanced chronic kidney disease. *Nefrologia*. 2008; 28 S:87–93.
36. Zhang R, Wang S, Zhang M, *et al*. Hyponatremia in patients with chronic kidney. *Hemodial Int*. 2017; 21:3–10.
37. Verbalis JG, Barsony J, Sugimura Y, *et al*. Hyponatremia-induced osteoporosis. *J Bone Miner Res*. 2010; 25:554–563.
38. Ayus JC, Fuentes N, Go AS, *et al*. Chronicity of uncorrecter hyponatremia and clinical outcomes in older patients undergoing hip fracture repair. *Front Med*. 2020; 7:263.
39. Adunsky A, Mizrahi EH, Kaplan A, *et al*. Elevated blood urea, independent of glomerular filtration rate (GFR), confers increased risk of adverse functional outcome in elderly hip fracture patients. *Arch Gerontol Geriatr*. 2011; 53:e174–e178.
40. Howell SJ. Preoperative hypertension. *Curr Anesthesiol Rep*. 2018; 8:25–31.
41. McNeil CJ, Myint PK, Sandu AL, *et al*. Increased diastolic blood pressure is associated with MRI biomarkers of dementia-related brain pathology in normative ageing. *Age Ageing*. 2018; 47:95–100.
42. Meta M, Lu Y, Keyak JH, *et al*. Young-elderly differences in bone density, geometry and strength indices depend on proximal femur sub-region: A cross sectional study in Caucasian-American women. *Bone*. 2006; 39:152–158.
43. Guerra MTE, Thober TA, Bigolin AV, *et al*. Hip fracture: postoperative evaluation of clinical and functional outcomes. *Rev Bras Orthop*. 2015; 45:577–582.
44. Bergeron E, Lavoie A, Moore L, *et al*. Is the delay to surgery for isolated hip fracture predictive of outcome in efficient systems? *J Trauma*. 2006; 60:753–757.