Development of Risk Prediction Nomogram for Sarcopenia in Patients Receiving Maintenance Hemodialysis

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Abstract

Background

Sarcopenia is a progressive and generalized skeletal muscle disorder characterized by accelerated loss of muscle mass and function that is more commonly observed in patients receiving maintenance hemodialysis compared to the general population. This study aimed to explore a simple nomogram to evaluate the risk of developing sarcopenia.

Methods

From March to June 2021, 615 patients on maintenance hemodialysis were identified at the First Affiliated Hospital College of Medicine Zhejiang University and randomly divided into development cohorts (n=369) and validation cohorts (n=246) in a 6:4 ratio. Multi-factor logistic regression analysis was used to screen out statistically significant variables to construct risk prediction models. The line plots were drawn to evaluate the effectiveness of the predictive models from three aspects: differentiation, calibration, and clinical net benefit, and were further tested by Bootstrap method.

Results

Our study indicated that 16.6% patients enrolled in our study were diagnosed with sarcopenia. Serum creatinine, serum albumin, C-reactive protein, serum phosphorus, body mass index, and upper arm muscle circumference were identified as independent risk factors for the development of sarcopenia in patients on maintenance hemodialysis. The area under the ROC curve of the line chart model was 0.88 with 90% sensitivity and 75% specificity. The Yoden index was 0.64, and the internal verification C-statistic was 0.864.

Conclusions

Our study not only proved that sarcopenia was commonly observed in patients on maintenance hemodialysis but also established a prediction nomogram to evaluate the risk for developing sarcopenia in such patients.

Introduction

Maintenance hemodialysis (MHD) is one of the most common treatments for patients with end-stage renal disease (ESRD) [1]. Epidemiology study[2] suggest that approximately 84% of all ESRD patients eventually receive hemodialysis treatment. Previous studies indicate that patients with MHD are predisposed to sarcopenia due to chronic inflammatory status, metabolic acidosis, malnutrition, and decreased physical activity[3]. Sarcopenia[4, 5] is characterized by a progressive and systemic loss of muscle mass and strength/function that is often associated with a variety of adverse outcomes. It has been estimated that 20-50% of all MHD patients can develop sarcopenia, which is much higher than the general population[6–9].

Previous studies indicated that MHD patients who were complicated with sarcopenia were associated with an increased risk of falling, fracture and cardiovascular events as well as re-hospitalization rate and mortality [10–12]. Fortunately, studies have shown that sarcopenia is not difficult to treat and even reversible if identified early[13, 14]. Therefore, it is important to establish a practical method to identify patients with increasing risks so prompt treatment can be arranged.

The diagnosis of sarcopenia[4] is mainly based on reduced skeletal muscle mass, decreased skeletal muscle strength, and skeletal muscle dysfunction that can be measured by magnetic resonance imaging (MRI), computed tomography (CT), dual-energy X-ray absorptiometry (DXA) and bioelectrical impedance analysis (BIA). However, the use of DXA, MRI, and CT is impeded in clinical practice by disadvantages such as high cost, complex procedures, and radiation exposure[15]. On the other hand, even though the BIA is convenient to perform, it is well-known that not all MHD patients can achieve the ideal volume status which subsequently jeopardizes the authority of the result [16]. In addition, muscle strength and physical function tests are often restricted under comorbid conditions such as joint problems and cognitive impairment[15]. To address the difficulties above, we developed and verified a simple risk prediction nomogram for sarcopenia in patients receiving maintenance hemodialysis

Methods

Study population

A total of 615 adult patients on maintenance hemodialysis were identified at the First Affiliated Hospital College of Medicine Zhejiang University from March to June 2021, and randomly divided into development cohorts (n=369) and validation cohorts (n=246) in a 6:4 ratio. Patients with the following conditions were excluded from the study: receiving maintenance hemodialysis for less than 3 months; implanted pacemaker or amputation surgeries. This study was reviewed and approved by the hospital ethics committee and all patients signed informed consent.

Measurements

After a systemic literature review, a total of 27 predictors for sarcopenia were identified. The following data were collected from each patient: demographic characteristics: age, gender, primary disease, dialysis age, etc.; self-rating anxiety scale (SAS), self-rating depression scale (SDS) psychological status assessment indicators; anthropometric indicators: height, post-dialysis weight, skeletal muscle mass index (SMI), grip strength, pacing speed, upper arm circumference, and triceps skinfold thickness, and body mass index (BMI) and upper arm muscle circumference (MAMC) which was calculated as brachial circumference − 3.14 × triceps skinfold thickness[16]. laboratory examination parameters that were measured at the first hemodialysis in each week after the enrolment: serum creatinine, blood uric acid, blood urea nitrogen, hemoglobin, serum albumin, prealbumin, C-reactive protein, serum phosphorus, serum calcium, blood lipid, serum potassium, parathyroid hormone and urea clearance index. Grip strength test was measured before dialysis with electronic grip strength meter. The patient was required to stand with naturally positioned feet and arms. Three measurements with an interval of 5 seconds were taken and the maximum value was taken. The walking speed test was also evaluated before dialysis and the average value of two consecutive

measurements was documented. Triceps skinfold thickness and upper arm circumference were measured at the end of dialysis. In addition, BIA was performed 15-20 minutes after the end of dialysis treatment to measure limb skeletal muscle mass (ASM), which was later used to calculate the SMI = ASM/height^2 [13].

Diagnosis

In this study, the diagnosis of sarcopenia was based on the 2019 Asian Sarcopenia Working Group guideline[17]. The diagnosis of sarcopenia was made in patients with decreased skeletal muscle content of four extremities: BIA < 7.0 kg/m^2 in males and < 5.7 kg/m^2 in females who had either of the following two conditions: decreased muscle strength: grip strength < 28 kg in males and < 18 kg in females or decreased physical function: 6-m walking speed < 1.0 m/s.

Statistical analysis

SPSS 26.0 and STATA 15 were used to analyze the collected data. Among the 27 predictor variables, prealbumin, urea clearance index, parathyroid hormone, upper arm circumference, and skinfold thickness were identified with missing data of less than 5% which were replaced by the sequential mean of the continuous variables before the model was developed. To ensure a more convenient clinical use, continuous variables such as age, serum phosphorus, serum calcium, parathyroid hormone, triglycerides, cholesterol, high-density lipoprotein, low-density lipoprotein, and very-low-density lipoprotein were converted into categorical variables according to clinical references. Other continuous variables were transformed into dichotomous variables according to the receiver operating characteristic curve using the optimal cut-off points of the analyzed variables with the Youden index criterion. Frequency or constituent ratio was used for statistical description, and chi-square test was used for comparison between groups. Through univariate logistic regression analysis, variables with univariate analysis results of $p < 0.10$ were included in multivariate logistic regression analysis. The backward stepwise regression method was then applied to select statistically significant factors that were used to construct the clinical risk prediction nomogram. The prediction nomogram was assessed in three aspects: discrimination, calibration, and clinical net benefit. The area under the receiver operating characteristic curve (ROC) was used to assess the discriminatory ability. The calibration curve and Hosmer-Lemeshow goodness of fit test were used to assess the calibration ability. The decision curve analysis (DCA) was used to assess the clinical effectiveness. The model was internally validated using the Bootstrap method. A p-value < 0.05 was considered statistically significant.

Results

Demographic parameters

A total of 615 MHD patients were eventually included in this study and were randomly divided into the development cohort (n = 369) and the validation cohort (n = 246) in a 6:4 ratio, as shown in Fig. 1(Figure 1). Among all enrolled patients, 381 (62%) were male and 234 (38%) were female. The most common reason for dialysis was chronic glomerulonephritis (430 patients), followed by diabetic nephropathy (101 patients), and other causes (hypertensive nephropathy, polycystic kidney disease, lupus nephritis, etc.). There were

102 patients (16.60%) diagnosed with sarcopenia and the demographic parameters of patients with or without sarcopenia were summarized in (Table 1).

Table 1
Baseline characteristics of the Development and Validation cohorts.(n,%)

Characteristics	All patients(N=615)	Development cohor(N=369)	Validation cohort(N=246)	Pvalue
	615(100.00)	369(60.00)	246(40.00)	
Gender				
Male	381(62.00)	231(62.60)	150(61.00)	0.684
Female	234(38.00)	138(37.40)	96(39.00)	
sarcopenia				
no	513(83.40)	310(84.00)	203(82.50)	0.626
yes	102(16.60)	59(16.00)	43(17.50)	
Cause of ESKD				
Chronic glomerulonephrit	430(69.90)	259(70.20)	171(69.50)	0.11
Diabetic nephropathy	101(16.40)	67(18.20)	34(13.80)	
Other	84(13.70)	43(11.70)	41(16.70)	
Age				
≤65years	380(61.80)	235(63.70)	145(58.90)	0.236
>65years	235(38.20)	134(36.30)	101(41.10)	
Duration of dialysis				
≤60months	308(50.10)	190(51.50)	74(30.10)	0.392
>60months	307(49.90)	179(48.50)	172(69.90)	
Hemoglobin				
≤106g/L	198(32.8)	124(33.6)	103(41.9)	0.36
>106g/L	417(67.80)	245(66.4)	143(58.1)	
Serum Creatinine				
≤804μmol/L	196(31.90)	124(33.60)	72(29.30)	0.258
>804μmol/L	419(68.10)	245(66.40)	174(70.70)	
Uric acid				
≤353μmol/L	109(17.70)	69(18.70)	40(16.30)	0.438
>353μmol/L	506(82.30)	300(81.30)	206(83.70)	

Characteristics	All patients(N=615)	Development cohor(N=369)	Validation cohort(N=246)	Pvalue
Urea nitrogen				
≤21.52mmol/L	240(39.00)	146(39.60)	94(38.20)	0.736
>21.52mmol/L	375(61.00)	223(60.40)	152(61.80)	
Serum Albumin				
≤40g/L	336(54.60)	194(52.60)	142(57.70)	0.209
>40g/L	279(45.40)	175(47.40)	104(42.30)	
CRP				
≤7.935mg/L	494(80.30)	292(79.10)	202(82.10)	0.362
>7.935mg/L	121(19.70)	77(20.90)	44(17.90)	
Serum Phosphorus				
<1.13mmol/L	22(3.60)	14(3.80)	8(3.30)	0.696
1.13-1.78mmol/L	238(38.70)	147(39.80)	91(37.00)	
>1.78mmol/L	355(57.70)	208(56.40)	147(59.70)	
Serum Calcium				
<2.1mmol/L	133(21.60)	68(18.40)	65(26.40)	0.048
2.1-2.5mmol/L	376(61.20)	238(64.50)	138(56.10)	
>2.5mmol/L	106(17.20)	63(17.10)	43(17.50)	
alkaline phosphatase				
≤70.5 U/L	284(46.20)	175(47.40)	109(44.30)	0.448
>70.5 U/L	331(53.80)	194(52.60)	137(55.70)	
BMI				
<18.5kg/m2	117(19.00)	71(19.20)	46(18.70)	0.972
18.5-24.9kg/m2	354(57.60)	211(57.20)	143(58.10)	
>25kg/m2	144(23.40)	87(23.60)	57(23.20)	
Serum Prealbumin				
≤28.4mg/dL	182(29.60)	112(30.40)	70(28.50)	0.614
>28.4mg/dL	433(70.40)	257(69.60)	176(71.50)	
Kt/V				

Characteristics	All patients(N=615)	Development cohor(N=369)	Validation cohort(N=246)	Pvalue
≤1.4	199(32.40)	121(32.80)	78(31.70)	0.778
>1.4	416(67.60)	248(67.20)	168(68.30)	
MAC				
≤27.8cm	303(49.30)	176(47.70)	127(51.60)	0.34
>27.8cm	312(50.70)	193(52.30)	119(48.40)	
MAMC				
≤22.64cm	263(42.80)	151(40.90)	112(45.50)	0.258
>22.64cm	352(57.20)	218(59.10)	134(54.50)	
TSF				
≤1.36cm	358(58.20)	218(59.10)	140(56.90)	0.593
>1.36cm	257(41.80)	151(40.90)	106(43.10)	
SAS				
≤40	579(94.10)	346(93.80)	233(94.70)	0.624
>40	36(5.90)	23(6.20)	13(5.30)	
SDS				
≤41	541(88.00)	328(88.90)	213(86.60)	0.39
>41	74(12.00)	41(11.10)	33(13.40)	
Serum Potassium				
≤5.2mmol/L	377(61.30)	219(59.30)	158(64.20)	0.224
>5.2mmol/L	238(38.70)	150(40.70)	88(35.80)	
PTH				
<150ng/L	254(41.30)	157(42.50)	97(39.40)	0.18
150-300ng/L	222(36.10)	138(37.40)	84(34.10)	
>300ng/L	139(22.60)	74(20.10)	65(26.40)	
Triglycerides				
≤1.7mmol/L	321(52.20)	194(52.60)	127(51.60)	0.818
>1.7mmol/L	294(47.80)	175(47.40)	119(48.40)	
Cholesterol				

Characteristics	All patients(N=615)	Development cohor(N=369)	Validation cohort(N=246)	Pvalue
≤5.2mmol/L	578(94.00)	348(94.30)	230(93.50)	0.678
>5.2mmol/L	37(6.00)	21(5.70)	16(6.50)	
HDL				
≤1.03mmol/L	381(62.00)	228(61.80)	153(62.20)	0.919
>1.03mmol/L	234(38.00)	141(38.20)	93(37.80)	
LDL				
≤3.37mmol/L	601(97.70)	362(98.10)	239(97.20)	0.44
>3.37mmol/L	14(2.30)	7(1.90)	7(2.80)	
VLDL				
≤0.78mmol/L	329(53.50)	198(53.70)	131(53.30)	0.921
>0.78mmol/L	286(46.50)	171(46.30)	115(46.70)	
Kt/V:Urea clearance index;MAC:Mid-upper arm circumference;MAMC:Mid-upper arm muscle circumference;TSF:triceps skin fold;SAS:self rating anxiety scale;SDS:self rating depression scale;PTH:Parathyroid hormone ;HDL:High-density lipoprotein;LDL:Low-density lipoprotein;VLDL:Very low-density lipoprotein.				

Construction of prediction nomogram

Univariate logistic regression analysis was performed with the included 27 independent variables and the results suggested that age, serum creatinine, blood uric acid, blood urea nitrogen, hemoglobin, albumin, C-reactive protein, serum phosphorus, alkaline phosphatase, BMI, prealbumin, urea clearance index, upper arm circumference, upper arm muscle circumference, triglycerides, and high-density lipoprotein levels were significantly different between two groups ($P < 0.1$), as shown in (Table 2). Next, significant independent variables obtained from the above univariate logistic regression analysis were included in multivariate logistic regression analysis following a backward stepwise regression method. The results showed that serum creatinine, albumin, C-reactive protein, serum phosphorus, BMI, and upper arm muscle circumference were independent risk factors for sarcopenia in MHD patients, as shown in Table 2.

Table 2
Univariate and multivariate analysis of Sarcopenia in the Development cohort(n=369)

Characteristics	Univariate analysis			Multivariate analysis		
	β	Pvalue	OR(95%CI)	β	Pvalue	OR(95%CI)
Age						
≤60year			Reference			
>60year	-1.134	<0.001	0.322(0.182~0.570)			
Serum Creatinine						
≤804μmol/L			Reference			Reference
>804μmol/L	1.829	<0.001	6.230(3.390~11.448)	-0.883	0.019	0.414(0.198~0.863)
Uric acid						
≤353μmol/L			Reference			
>353μmol/L	1.202	<0.001	3.327(1.804~6.137)			
Urea nitrogen						
≤21.5mmol/L			Reference			
>21.5mmol/L	0.794	0.006	2.213(1.259~3.888)			
Serum Albumin						
≤40g/L			Reference			Reference
>40g/L	0.943	0.002	2.568(1.401~4.707)	-0.67	0.086	0.512(0.238~1.1)
CRP						
≤7.935mg/L			Reference			Reference
>7.935mg/L	-1.479	<0.001	0.228(0.126~0.413)	1.368	<0.001	3.926(1.863~8.272)
alkaline phosphatase						
≤71U/L			Reference			
>71U/L	-0.58	0.049	0.560(0.314~0.997)			
Serum Prealbumin						
≤28.4mg/dL			Reference			
>28.4mg/dL	0.888	0.002	2.430(1.376~4.293)			

Characteristics	Univariate analysis			Multivariate analysis		
	β	Pvalue	OR(95%CI)	β	Pvalue	OR(95%CI)
Kt/V						
≤1.4			Reference			
>1.4	-1.297	0.001	0.273(0.125~0.597)			
MAMC						
≤22.64cm			Reference			Reference
>22.64cm	1.933	<0.001	6.908(3.574~13.354)	-1.17	0.008	0.31(0.13~0.741)
Triglycerides						
≤1.7mmol/L			Reference			
>1.7mmol/L	0.668	0.025	1.950(1.008~3.494)			
HDL						
≤1.03mmol/L			Reference			
>1.03mmol/L	-0.536	0.061	0.585(0.334~1.025)			
BMI						
<18.5kg/m^2			Reference			Reference
18.5-24.9kg/m^2	2.662	<0.001	14.327(4.725~43.445)	-1.289	0.001	0.276(0.126~0.603)
>25kg/m^2	1.07	0.053	2.916(0.986~8.622)	-2.217	0.003	0.109(0.025~0.48)
Serum Phosphorus						
<1.13mmol/L			Reference			Reference
1.13-1.78mmol/L	2.828	<0.001	16.920(5.166~55.419)	-2.403	0.001	0.09(0.022~0.368)
>1.78mmol/L	0.88	0.005	2.410(1.308~4.441)	-3.322	<0.001	0.036(0.008~0.156)
Hemoglobin						
≤106g/L			Reference			
>106g/L	0.7	0.015	2.013(1.145~3.542)			

Kt/V:Urea clearance index;MAMC:Mid-upper arm muscle circumference;CRP:C-reactive protein;HDL:High-density lipoprotein;BMI:Body mass index .

A risk prediction model for sarcopenia in MHD patients was then established based on the formula: P = 1/(1 + e^Y) where e was the base of natural logarithm, Y = 2.839 – 0.883 × predialysis creatinine > 804 μmol/L – 0.670 × albumin > 40 g/L + 1.368 × C-reactive protein > 7.935 mg/L – 2.403 × serum phosphorus 1.13 – 1.78 mmol/L – 3.322 × serum phosphorus > 1.78 mmol/L – 1.289 × BMI18.5 – 24.9 kg/m^2 – 2.217 × BMI ≥ 25 kg/m^2 – 1.170 × upper arm muscle circumference > 22.64 cm. A nomogram of the risk prediction model for sarcopenia in MHD patients was also plotted, as shown in (Figure 2). The corresponding score for each variable was obtained by crossing to the gram, and the total score was used to predict the risk of developing sarcopenia in MHD patients.

Validation of prediction model

The validation of this prediction model was performed by plotting the ROC curve and calculating the AUC. Our data indicated that the AUC for this model was 0.8806 (95% CI (0.83913 to 0.92205)(Figure 3), with a 90% sensitivity and 75% specificity as well as a Youden index of 0.643 in the development cohort. Similarly, the AUC of the validation cohort was 0.8613 (95% CI (0.80085 to 0.92180)(Figure 4), with a sensitivity of 88%, a specificity of 74%, and a Youden index of 0.628. In addition, the Hosmer-Leme show goodness-of-fit test showed promising fit (development cohort X^2 = 4.67, P = 0.9119; validation cohort X^2 = 12.66, P = 0.2435). The above data demonstrated that the predicted probability of this model was well documented with good calibration and alignment between development (Figure 5)and validation cohorts(Figure 6). The model was then internally validated using the Bootstrap method with an internal validation C-statistic of 0.864.

Clinical validity

The clinical validity of this predictive model was assessed using a decision curve (DCA). The analyses of DCA for the development and validation cohorts were shown in (Figure 7) and (Figure 8), which suggested that patients can benefit from this novel prediction model when the threshold was set as 10 – 90% and 10 – 70% for the development and validation cohorts, respectively.

Discussion

In the present study, we developed and validated a simple nomogram model to predict the risk of developing sarcopenia in MHD patients with a total of six clinical relevant variables including serum creatinine, albumin, C-reactive protein, serum phosphorus, BMI and upper arm muscle circumference. The AUC, internal validation C-statistic, calibration curve, and DCA curve were constructed and verified the reliability as well as the accuracy of this model. The discovery of this model would not only help to identify MHD patients with increased risk of developing sarcopenia, but may also predict the disease course and provide reference for prognosis estimation.

Nomogram can predict the probability of disease by analyzing and integrating identified disease risk factors, therefore providing valuable information for making better clinical decisions. It has been widely used in oncology and chronic diseases worldwide[18]. For instance, Cheng et al. [19]developed a nomogram to predict the risk of initiating renal replacement therapy within 3 years in patients with diabetic nephropathy

and Jing et al [20]developed a nomogram including multiple echocardiographic measures to assess 3-year all-cause mortality in hemodialysis patients which both showed good accuracy and reliability. In addition, Ouyang et al. [21]developed and validated an easy-to-use nomogram that can accurately predict 1-year, 5-year, and 10-year survival in hemodialysis patients. However, to the best of our knowledge, no study has been conducted to develop a nomogram that can predict sarcopenia in MHD patients.

In this study, the multivariate logistic regression analysis indicated that serum creatinine was an independent risk factor for sarcopenia in MHD patients, which was consistent with the findings of Lin et al. [22] Creatinine is a metabolite of human skeletal muscle and is mainly excreted through glomerular filtration. In MHD patients with limited renal function, serum creatinine is not only a marker of renal failure, but also a predictor of nutritional status and decreased skeletal muscle mass [23]. Hyperphosphatemia is a common complication in MHD patients which is closely related to increased risk of vascular calcification and cardiovascular mortality [24]. Interestingly, our study indicated that lower serum phosphorus level was associated with the development of sarcopenia in MHD patients, which was consistent with the findings of Ren et al[8]. We hypothesized that a high-protein diet is the main source of phosphorus for uremic patients who are often accompanied by loss of appetite or even anorexia. A decrease in food intake will inevitably lead to a decrease in serum phosphorus, malnutrition, and protein energy expenditure in patients which ultimately leads to the occurrence of sarcopenia [25]. In our clinical practice, renal function and electrolytes are measured every 1-3 months in MHD patients to assess changes in the condition. In this study, when the measured serum creatinine and serum phosphorus levels were significantly decreased, a detailed assessment of the presence of malnutrition and sarcopenia was conducted in MHD patients and nutritional support with dietary guidance and health education was provided. This intervention might help to reduce the occurrence of sarcopenia.

BMI and MAMC are conventional nutritional assessments for MHD patients and previous studies[26–28] indicated that both were independent predictors of survival. The study by Su et al [29]showed that in MHD patients, the decrease in MAC was associated with increased all-cause mortality and cardiac events, especially those with low BMI. Unsurprisingly, data in our study showed that MHD patients with decreased BMI and MAMC were more likely to develop sarcopenia, which was consistent with previous studies[22, 30]. Therefore, more attention should be paid to MHD patients with low BMI and/or low MAC and sufficient nutritional intervention should be applied in a timely manner to reduce the occurrence of sarcopenia.

Consistent with previous studies[12, 26], this study also found out that the level of C-reactive protein was increased while the level of serum albumin was decreased in MHD patients who developed sarcopenia compared to non-sarcopenia patients. C-reactive protein is one of the most commonly used biochemical indicators to examine inflammation. It has been well established in the field that hemodialysis patients are often under microinflammatory state due to multiple reasons[31]. The close association between inflammation and sarcopenia has been well studied. Inflammatory factors can activate many signaling pathways involved in the pathogenesis of sarcopenia, resulting in decreased anabolism and increased catabolism of proteins [32]. Serum albumin is often used to estimate nutrition levels in MHD patients and is closely related to patient prognosis [33]. Low serum albumin may lead to increased protein catabolism and decreased muscle strength[34]. However, the study by Alves et al. [35]showed that the nutritional status of

patients with low serum albumin group was not significantly different from that of patients with normal serum albumin level under non-inflammatory conditions but significantly associated with higher mortality under systemic inflammation. Therefore, more attention should be paid to patients' inflammatory status, especially for those with decreased serum albumin level.

At present, the commonly used scales for sarcopenia are SARC-F score which measures strength, assistance walking, rising from a chair, climbing stairs and falling, and modified SARC-assisted Cal F score which also measures the situation of the calf. A meta-analysis [36]showed that the sensitivity of SARC-F was low to moderate (28.9% – 55.3%) as well as the specificity (68.9% – 88.9%). Although SARC-CalF is associated with a higher specificity (87.7% – 91.3%), its sensitivity was not satisfying (45.9% – 57.2%). The relatively low sensitivity of these two scales renders a higher risk for miss diagnosis. On the contrary, our novel nomogram provided an alternative method with increased clinical efficacy. The AUC of our constructed nomogram model was 0.8806 in the development cohort and 0.8613 in the validation cohort with an internal validation C-statistic of 0.864. The validity of this novel model was further verified by calibration curves and DCA curves. More importantly, all six variables included in this model are laboratory tests and anthropometric measures that are routinely measured in clinical practice and do not require additional examinations as well as costs.

However, this study has some limitations. First, even though the number of enrollments was relatively large, it was conducted at a single center that might not be representable for the general population. In addition, the constructed nomogram model was not validated with external data. Furthermore, this study excluded cases with incomplete data, which may lead to a selection bias. Therefore, this model should be validated through prospective, multicenter clinical studies in the future.

Conclusion

In this study, we not only proved that sarcopenia was commonly observed in patients on maintenance hemodialysis but also established a prediction nomogram model based on conventional serology and noninvasive anthropometric measurements that was able to accurately predict the risk of developing sarcopenia in MHD patients.

Abbreviations

MHD
maintenance hemodialysis
ESRD
end-stage renal disease
MRI
magnetic resonance imaging
CT
computed tomography
DXA

dual energy X-ray absorptiometry
BIA
bioelectrical impedance analysis
SAS
self-rating anxiety scale
SDS
self-rating depression scale
BMI
body mass index
ASM
appendicular skeletal muscle mass
ROC
receiver operating characteristic
AUC
the area under the receiver operrating characteristic curve
DCA
decision curve analysis
Kt/V
Urea clearance index
MAC
Mid-upper arm circumference
MAMC
Mid-upper arm muscle circumference
TSF
triceps skin fold
SAS
self rating anxiety scale
SDS
self rating depression scale
PTH
Parathyroid hormone
HDL
High-density lipoprotein
LDL
Low-density lipoprotein
VLDL
Very low-density lipoprotein
SARC-F
strength, assistance walking, rise from a chair, climb stairs and falls
SARC-CalF
strength, assistance walking, rise from a chair, climb stairs, falls and calf

Declarations

Ethics approval and consent to participate

The research protocol was approved by the Institutional Review Board of the First Affiliated Hospital, Zhejiang University School of Medicine, and conducted according to the principles of the Declaration of Helsinki. Due to the retrospective nature of the study, written informed consent for participation was waived by the Institutional Review Board of the First Affiliated Hospital, Zhejiang University School of Medicine.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no conflict of interest.

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Authors' contributions

Genlian Cai participated in study design, data collection, data analysis, and manuscript draft.Xiabing Lang, Mengyan Pan are contributed to the performance of research and modifcation of the draft.Weiping Yu,Qinqin Zhang participated in data collection. Jinping Ying contributed to the study design, implementation, manuscript draft, and critical revision of the article. All authors read and approved the final manuscript.

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Figures

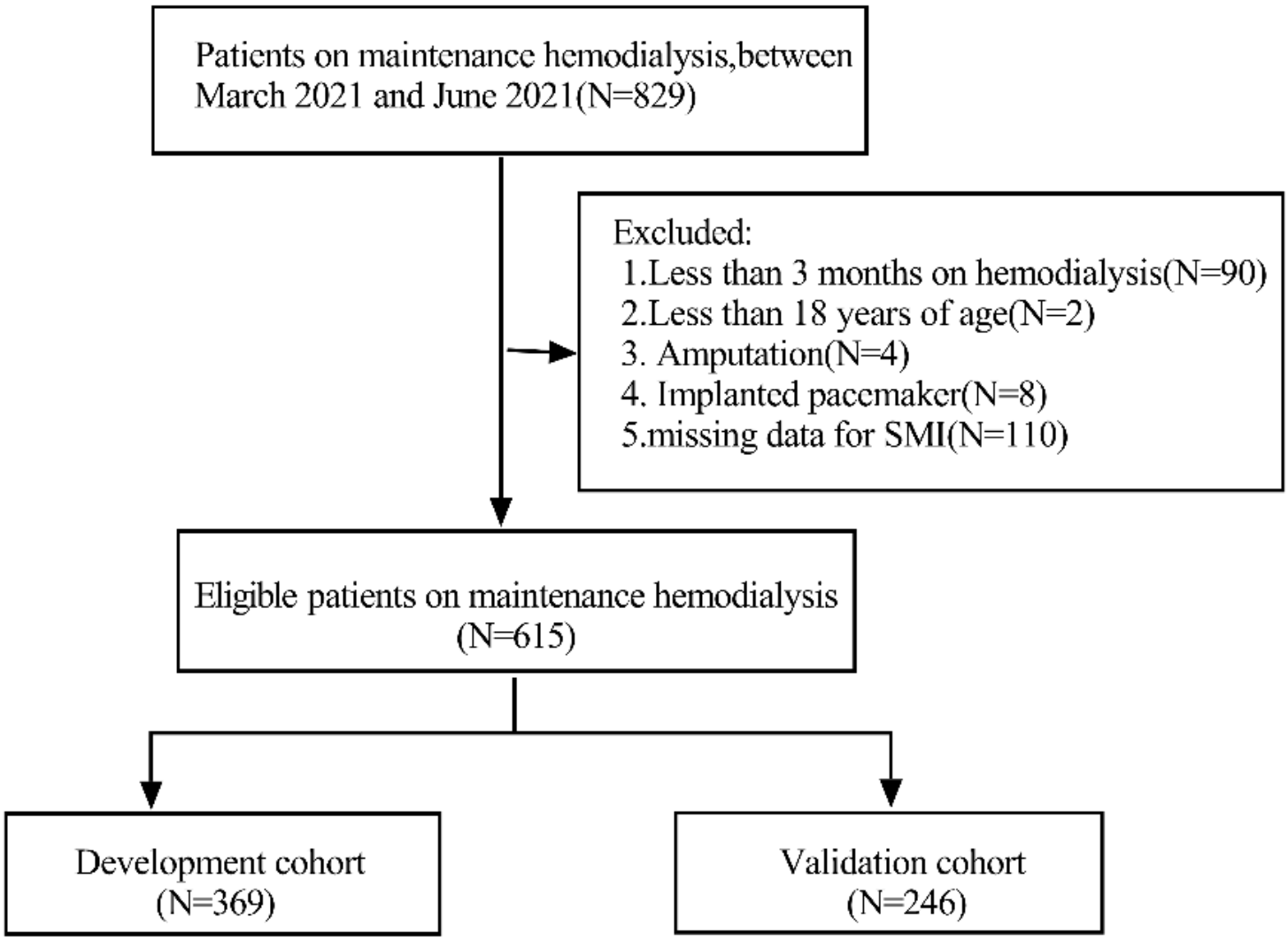

Figure 1

A workflow to develop the prediction models for sarcopenia in MHD patients.

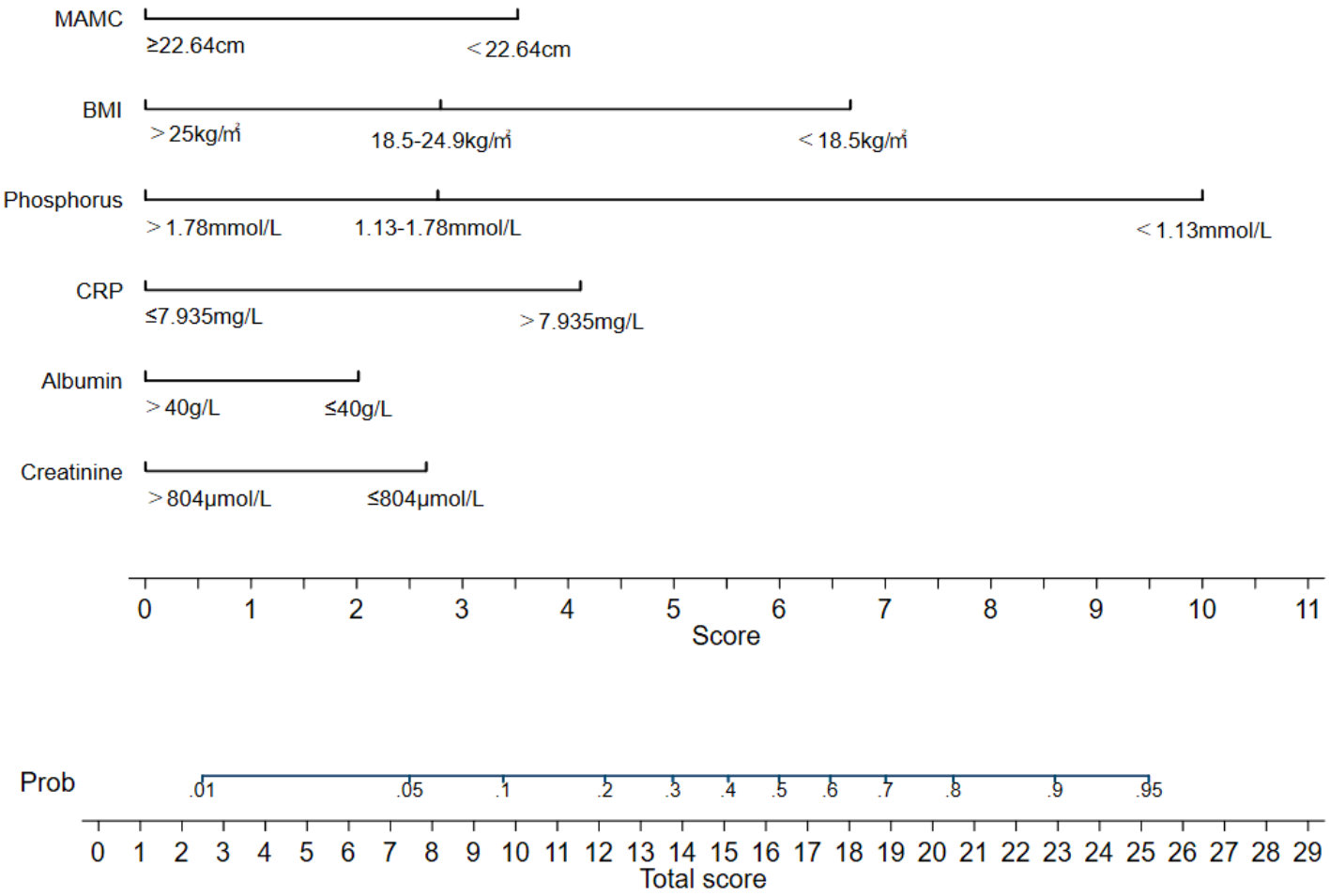

Figure 2

Nomogram to predict risk of sarcopenia in MHD patients.

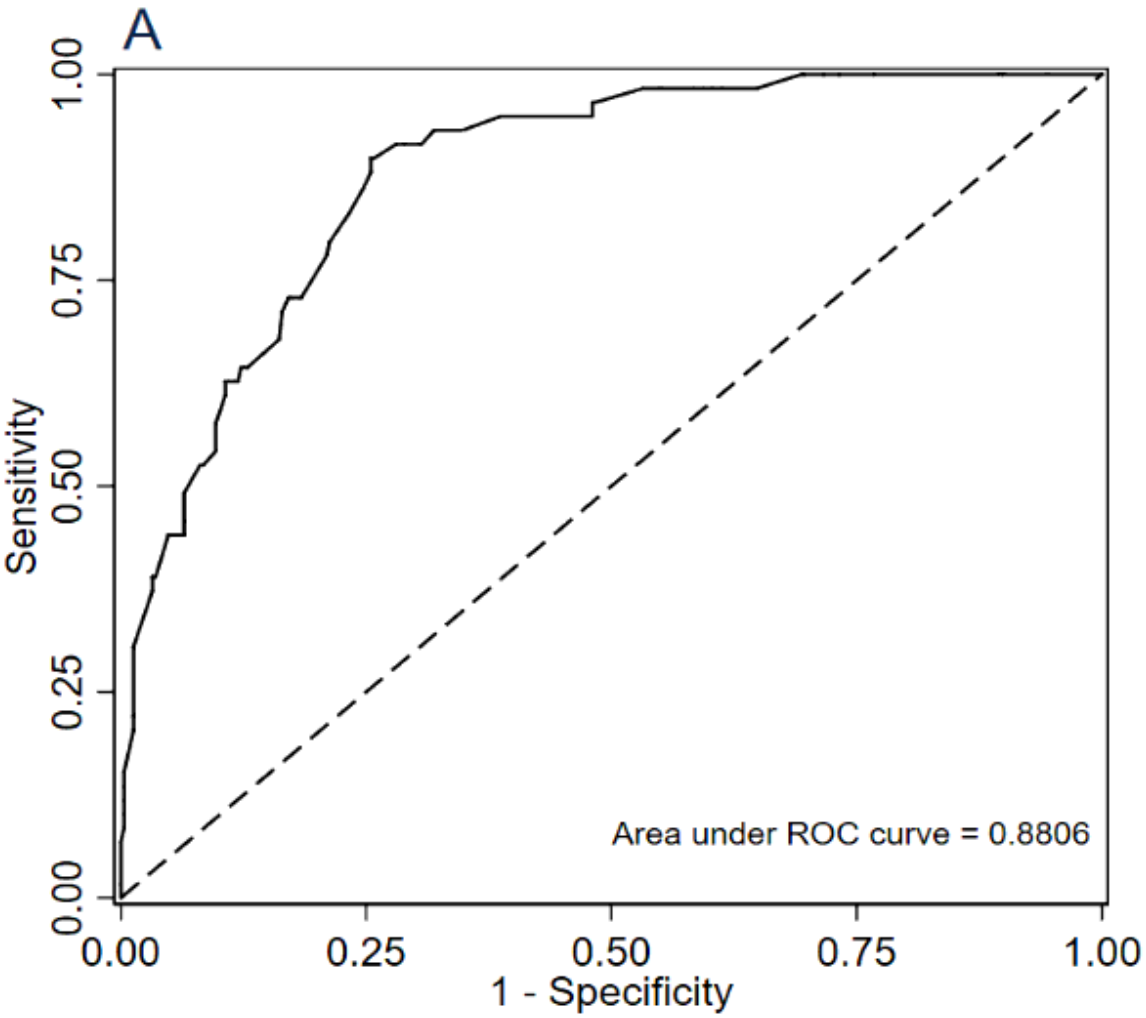

Figure 3

AUC of development cohort

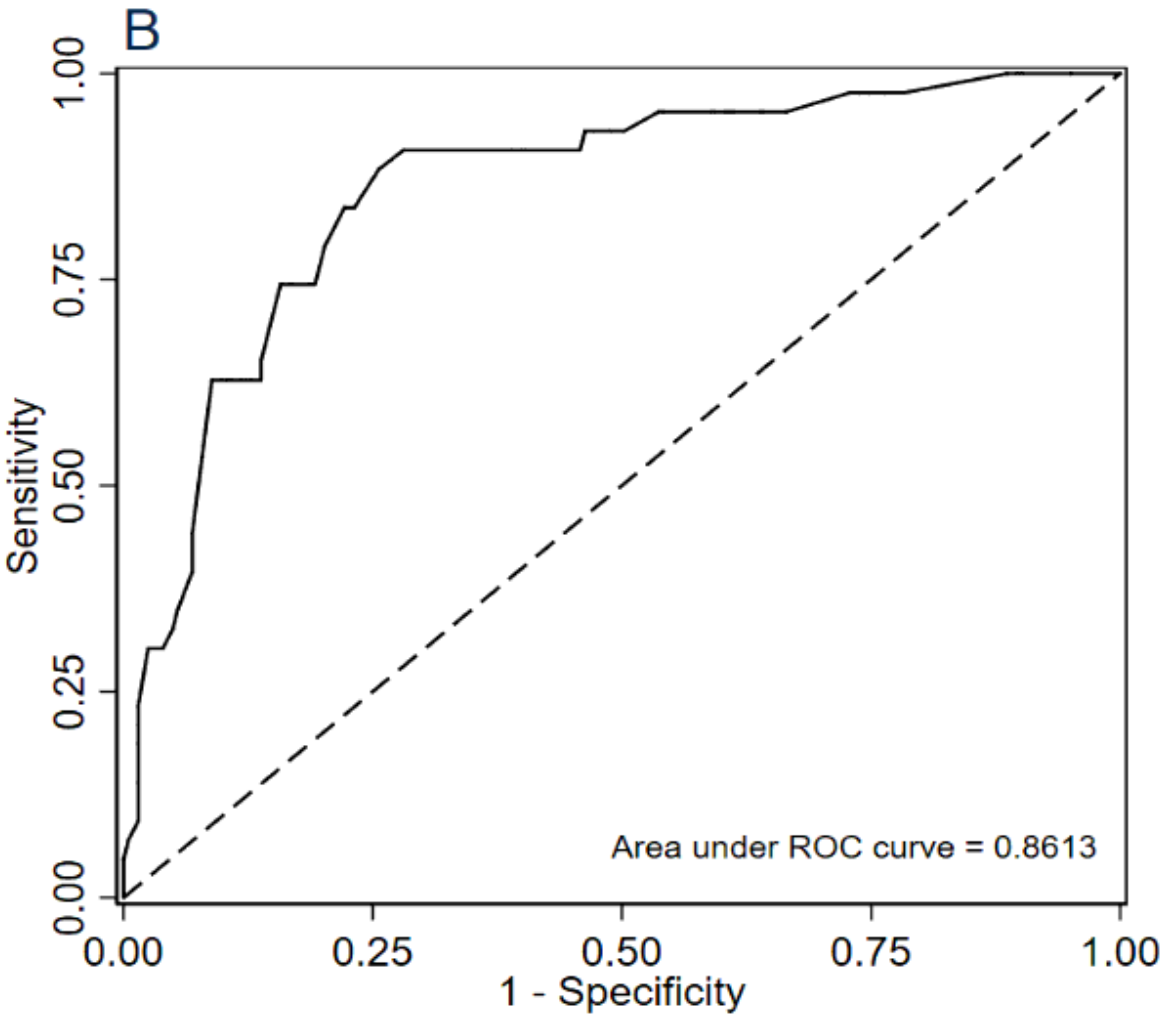

Figure 4

AUC of validation cohort

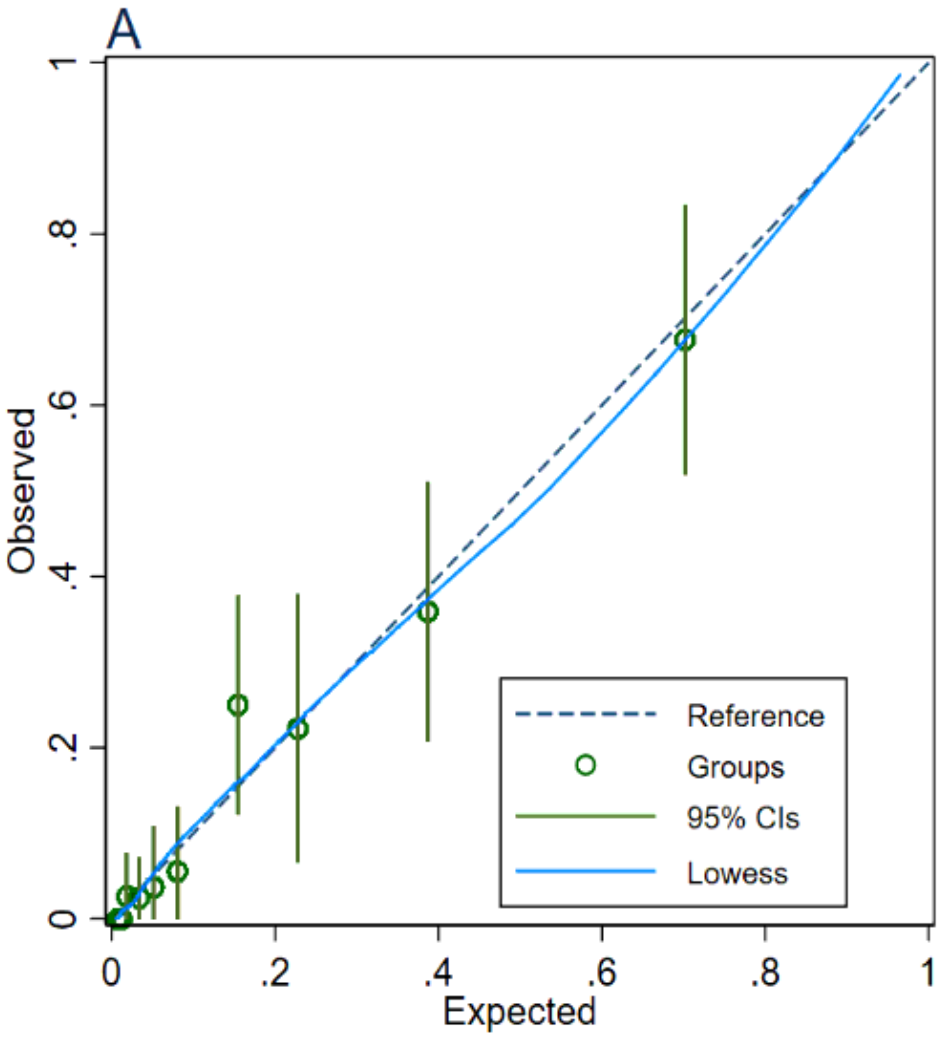

Figure 5

Calibration plot of development cohort

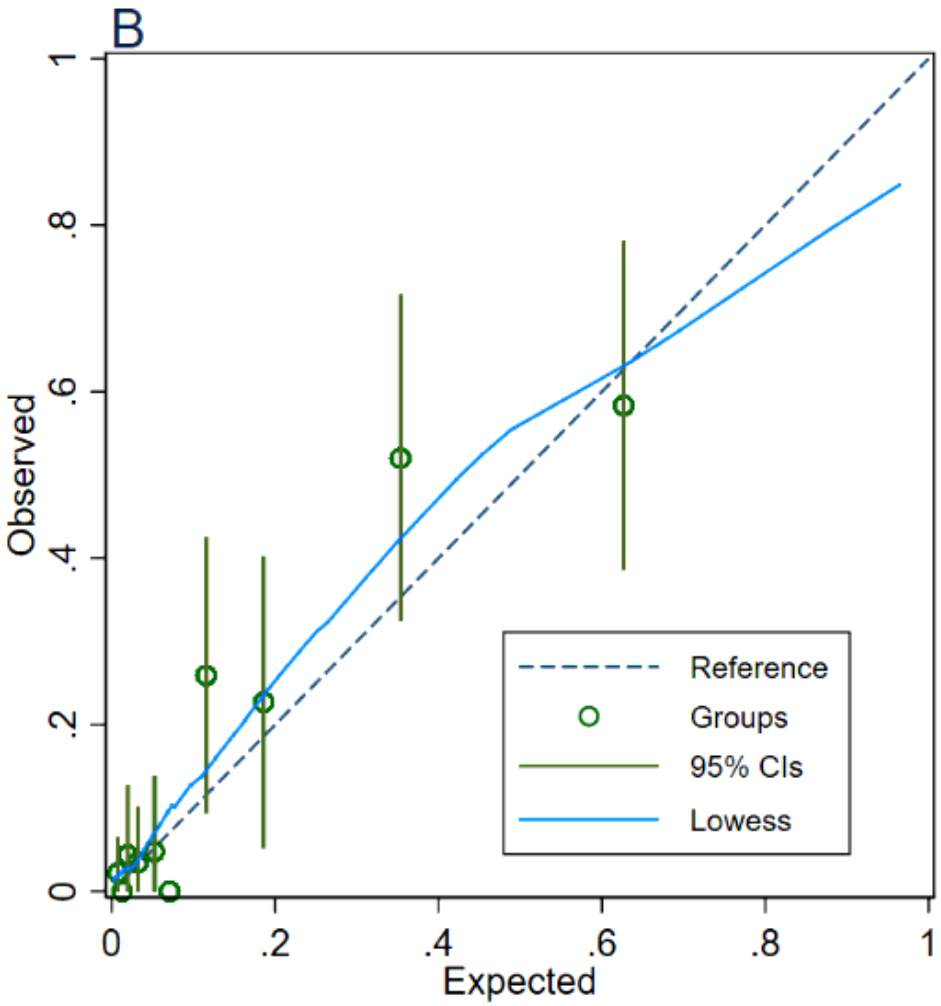

Figure 6

Calibration plot of validation cohort

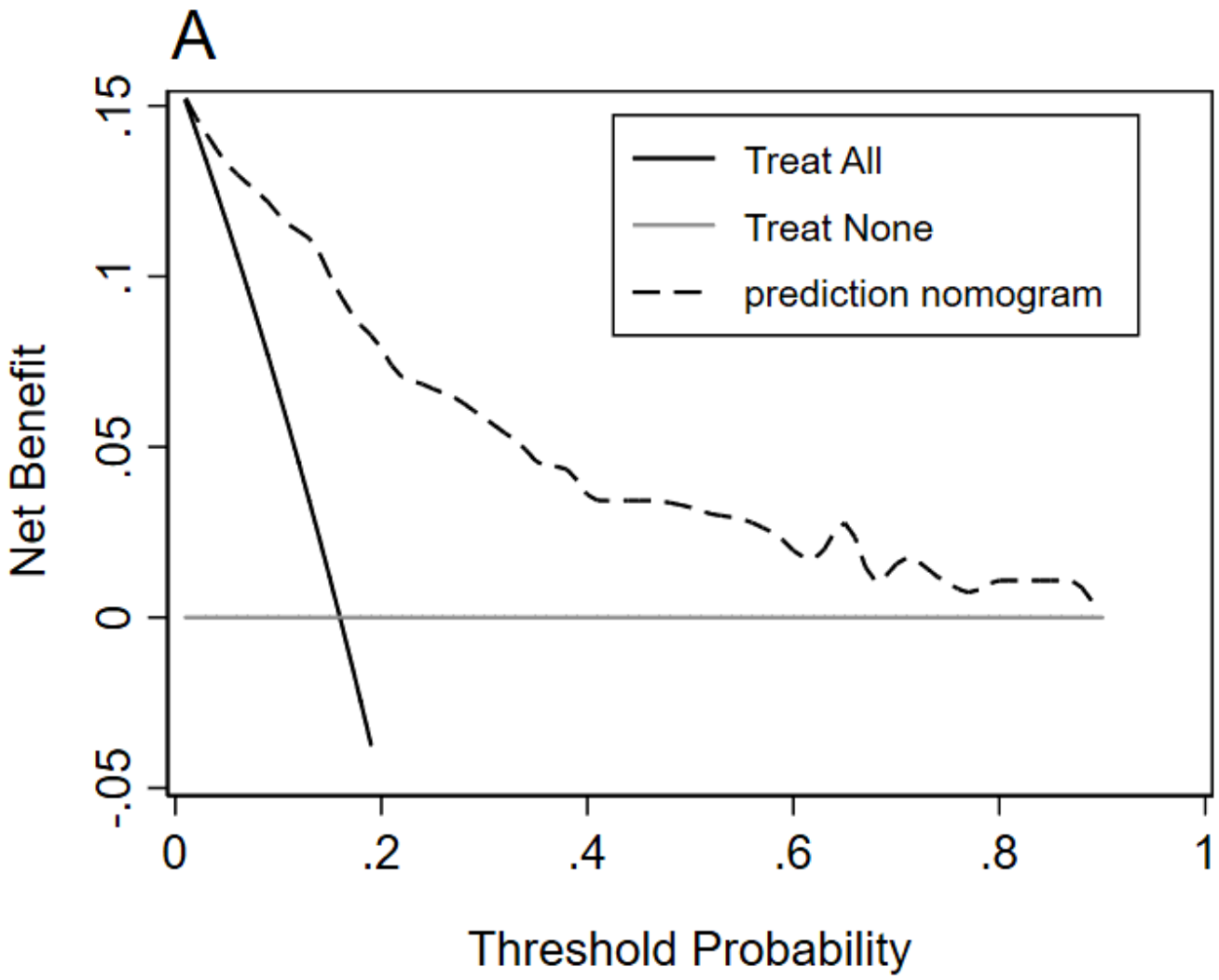

Figure 7

Decision curve analysis for development cohort

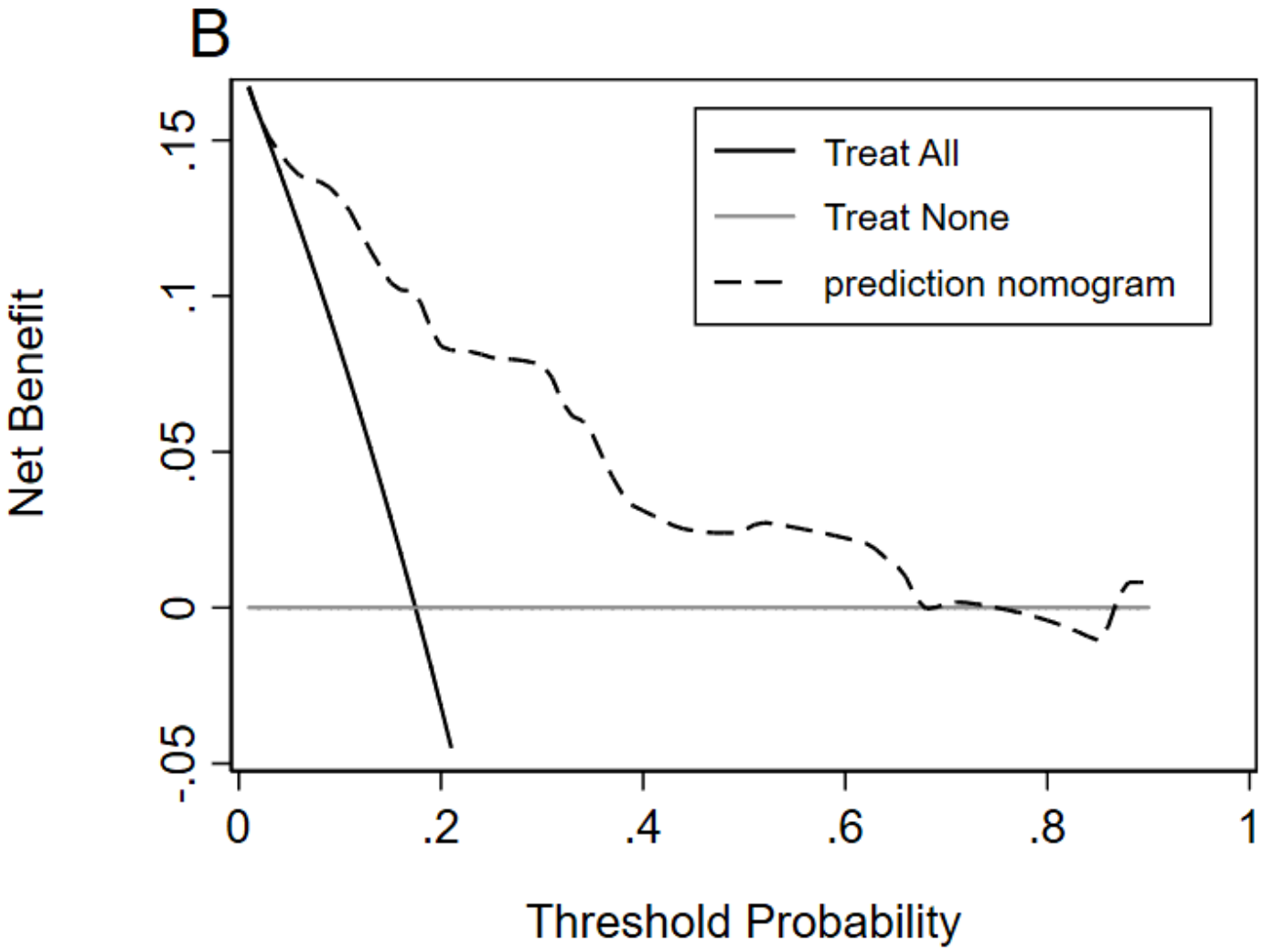

Figure 8

Decision curve analysis for validation cohort