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Prediction model for 6-month mortality in incident older hemodialysis patients in South Korea

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Background: Early mortality following hemodialysis initiation hinders survival improvement in older patients. This study aimed to develop a clinical risk model for predicting 6-month mortality after dialysis initiation in older Korean hemodialysis patients.

Methods: We analyzed data from incident hemodialysis patients aged >70 years from the Korean Society of Geriatric Nephrology (KSGN) database. A prediction model was developed using multivariate logistic regression analysis and externally validated with independent datasets.

Results: Among 1,751 incident hemodialysis patients, the 6-month mortality rate was 15.5%. Using multivariate logistic analysis, we constructed the KSGN score as an independent risk factor for 6-month mortality, and its components and score are as follows: old age at dialysis initiation (≥85 years, score 2); hypertension and renovascular disease as a primary etiology of end-stage kidney disease (ESKD) (score 1); malignancy history (yes, score 1); low serum albumin (<3.5 g/dL, score 1); hypertension treatment (yes, score −1); prepared vascular access on maintenance dialysis (arteriovenous fistula/arteriovenous graft, score −3). In the development cohort, the area under the curve (AUC) for the KSGN score was significantly higher than the Alberta Wick's score (0.707 vs. 0.683, p = 0.001). In the validation cohort, the KSGN score's performance was comparable to existing models.

Conclusion: The KSGN score may be a valuable tool for predicting early mortality after dialysis initiation in older patients with ESKD, aiding in decision-making and management regarding dialysis initiation.

Keywords: Chronic kidney failure, Renal dialysis, Mortality

Introduction

The average age of dialysis patients has progressively increased worldwide over the last several decades [1,2]. According to the 2021 Korean Renal Data System annual report, the mean age at dialysis initiation has reached 68.1 years. The

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proportion of dialysis patients aged >65 years has increased annually from 37.4% in 2010 to 63.7% in 2020 [1,2]. Likewise, the number of older patients initiating dialysis has increased from 16,273 in 1996 (age, 70–84 years) to 28,407 in 2016 (age, >75 years), according to the United States Renal Data System (USRDS) database [3]. Older end-stage kidney disease (ESKD) patients present with a wide range of comorbidities, cognitive dysfunction, and a general decline in their functional abilities as they age. As older dialysis patients are accompanied by a high burden of functional impairment, limited life expectancy, and health care utilization, they have a substantially higher mortality rate than younger patients, with the 2-year survival rates of those aged >75 years starting dialysis reported to be 59% in the United States [3] and 73.1% in Korea [4]. A high early peak mortality rate has also been recorded among patients with ESKD who initiate hemodialysis (HD), making it difficult to decide whether to begin HD treatment in older patients. Mortality rate trajectories after the initiation of HD revealed that early peak mortality within 60 days after HD initiation was higher in older HD patients (>65 years) in a USRDS report [3], which strengthened the necessity for prediction models of early peak mortality in older chronic kidney disease (CKD) patients.

The American Society of Nephrology and Renal Physicians Association first published clinical guidelines on the shared decision-making (SDM) process for older individuals with ESKD who were no longer receiving dialysis in 2000 [5], and these were revised in 2010, reflecting recent treatment trends [6]. However, SDM clinical guidelines for Korean ESKD patients are lacking, and forgoing dialysis is still debated in Korea. Therefore, accurate prognosis prediction for older patients after the initiation of dialysis, identification of predictive prognostic factors, and development and follow-up of a clinical registry for older Korean patients are imperative. Thus, we aimed to create and define a mortality risk score for 6-month mortality after starting dialysis using a multicenter retrospective cohort of older adults to aid in the decision-making of whether to initiate dialysis among elderly ESKD patients.

Methods

Study population

We analyzed the medical records of incident HD patients aged ≥70 years who started HD between January 1, 2010 and December 31, 2017, at 15 university hospitals of the Korean Society of Geriatric Nephrology (KSGN). Patients with acute kidney injury requiring emergency dialysis, including continuous renal replacement therapy and peritoneal dialysis, were excluded from the study. We divided the patients into survival and death groups based on 6-month mortality events. Data collected at dialysis initiation included age, sex, height, body weight, body mass index (BMI), extent of mobility, comorbidities (such as history of admission, hypertension, diabetes mellitus, hepatitis, cardiovascular disease, and fractures), malignancy, history of medication, psychological symptoms including dementia, cause of ESKD, duration of HD, and presence of vascular access at dialysis initiation and during maintenance dialysis. Mortality data were collected from the Korean National Statistical Office (MicroData Integrated Service, on-demand, 20,180,619; https://mdis.kostat.go.kr) and medical chart review.

The study was performed in accordance with the principles of the Declaration of Helsinki, and clinical data from patients were obtained after receiving approval from the Institutional Review Board (IRB) at each center. The IRB waived the requirement for informed consent, and the information identifying the individual was protected. The full names and number of IRBs that waived the requirement for informed consent are presented in Supplementary Table 1 (available online).

Model development

We created a development cohort. Among a total of 2,468 patients who visited the HD clinic at 15 academic teaching hospitals and medical centers in Korea from the KSGN, 18 patients with no data for the primary etiology of ESKD, one patient with no information for dialysis access at HD initiation, and 698 patients with missing values were excluded (Fig. 1A).

We used several variables according to previous studies. Couchoud et al. [7] provided variables such as sex, age, congestive heart failure (CHF), peripheral vascular disease, dysrhythmia, severe behavioral disorder, cancer, albuminemia, and mobility [8]. Thamer et al. [9] provided variables such as age, albumin, needs assistance in daily living, lives in nursing homes, cancer, heart failure, and hospitalization

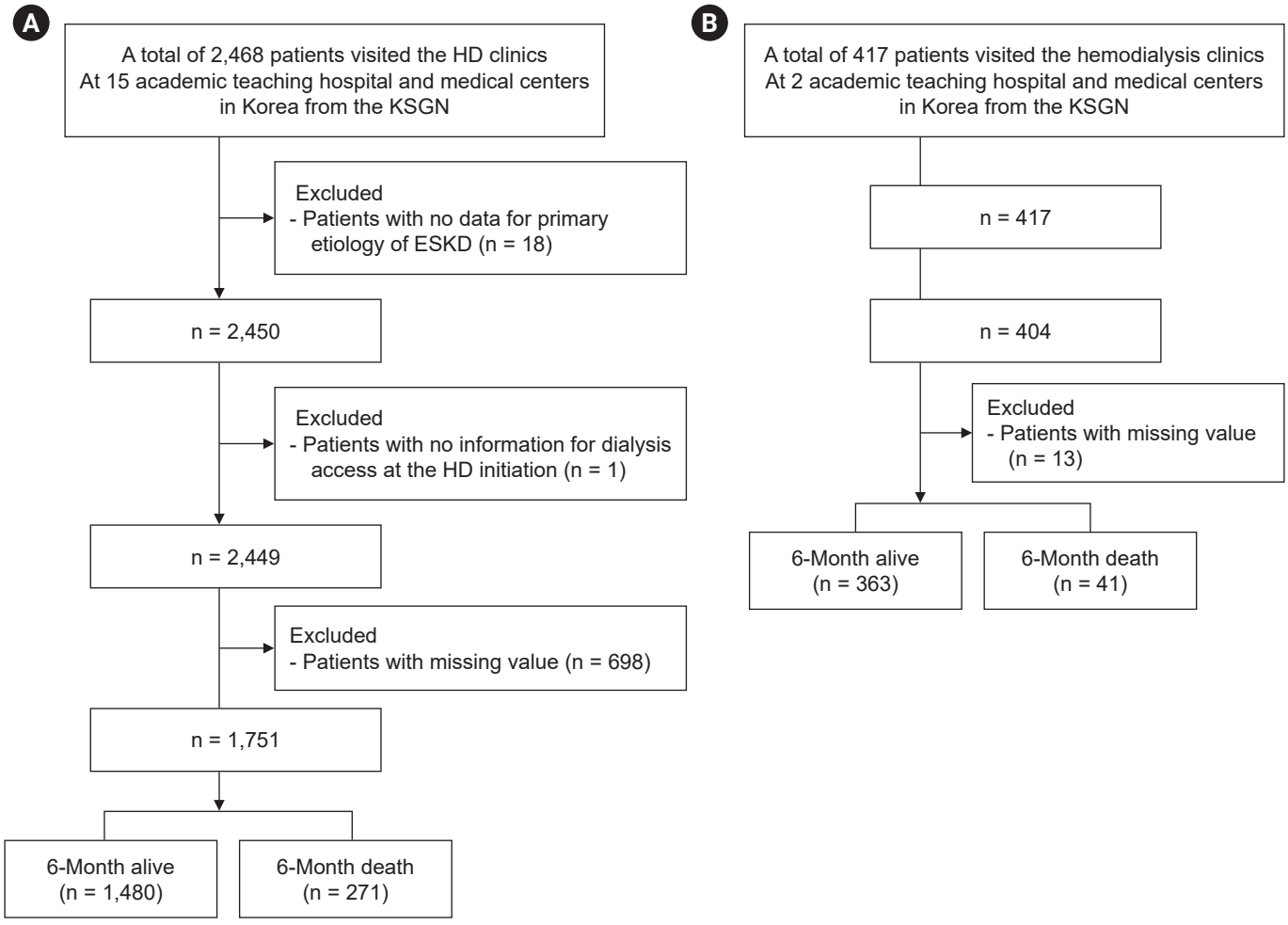

Figure 1. Study flowchart in the development cohort and validation cohort. (A) Development cohort: among a total of 2,468 patients who visited the hemodialysis (HD) clinic at 15 academic teaching hospitals and medical centers in Korea from the Korean Society of Geriatric Nephrology (KSGN), 18 patients with no data for primary etiology of end-stage kidney disease (ESKD), one patient with no information for dialysis access at HD initiation, and 698 patients with missing values were excluded. (B) Validation cohort: among a total of 417 patients who visited the HD clinic at two academic teaching hospitals and medical centers in Korea from the KSGN, 13 patients with missing values were excluded.

[10]. Wick et al. [11] provided the variables such as age, estimated glomerular filtration rate, atrial fibrillation, CHF, lymphoma, metastatic cancer, and hospitalization in the prior 6 months [9].

We used logistic regression models to develop a mortality risk prediction model for patients on HD. Multivariate logistic regression was used to evaluate several risk factors, including age (categorized as 70–74, 75–79, 80–84, and ≥85 years), sex, BMI (categorized as <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, and ≥30.0 kg/m^2), primary etiology of ESKD (hypertension, diabetes mellitus, autosomal dominant polycystic kidney disease, or chronic glomerulonephritis), malignancy, malignancy with metastatic disease, ischemic heart disease, cerebrovascular accident, CHF, atrial fibrillation, diabetes mellitus, hypertension, severe behavior disorder, history of hospitalization 6 months prior to HD initiation, activities of daily living (ADL) dependency, nursing hospital care at dialysis initiation, the type of vascular access at dialysis initiation and on maintenance dialysis, serum albumin level, and total cholesterol level. All patients with missing data values for two continuous variables, albumin and total cholesterol levels, with their respective continuous variable counterparts, were excluded (Fig. 1A) [12,13]. A multivariate logistic regression

model was created, incorporating all significant variables ($p < 0.05$) in the univariate analysis. We performed stepwise backward selection using the Akaike information criterion (AIC) as a stopping rule [14]. Stepwise backward selection using the AIC is similar to stepwise backward selection using p-values, but it differs in its stopping rule, which focuses on reaching the lowest AIC. The AIC method penalizes model complexity by adjusting the p-value threshold to remove variables based on the number of variables in the model. As the number of variables decreased, the p-value threshold for exclusion became less stringent [14]. The odds ratios (ORs) obtained from the final multivariate logistic model were used to quantify the 6-month mortality risk. These ORs were transformed into log(OR) by taking their natural logarithms and scaled appropriately to create a practical and usable risk score as follows: $1 < \log(OR) \leq 1.5$, score 2; $0 < \log(OR) \leq 1$, score 1; $-1 \leq \log(OR) < 0$, score –1; $-1.5 \leq \log(OR) < -1$, score –2; and $\log(OR) < -1.5$, score –3. The comparison between the models was conducted using the Delong method tests, which assess the difference in the area under the curve (AUC) of receiver operating characteristic (ROC) curves between the scores. With three models—Alberta Wick, USRDS Thamer, and KSGN—each comparison was made between two models at a time, resulting in three pairwise comparisons. In the development cohort, all risk variables in the univariate analysis were included in the multivariate model to identify factors related to overall survival. The final scoring system parameters were determined by a p-value <0.05 in the final regression model [10,15,16].

Statistical analyses and validation of the model

The baseline characteristics of the development and validation cohorts included continuous and categorical variables. Continuous variables with a normal distribution are expressed as mean ± standard deviation and were analyzed using the Student t test, independent two-sample t test, or Wilcoxon rank sum test. Categorical variables are expressed as frequency counts and percentages and were analyzed using the chi-square or Fisher exact tests. We performed logistic regression models to develop a mortality risk model 6 months after dialysis initiation among older Korean HD patients. The p-values <0.05 were considered statistically significant. Multivariate models were constructed using stepwise selection. Multicollinearity was verified using the variance inflation factor. We used the AUC to assess model discrimination. We compared our models with two existing registry-based models [9,11] using the area under the ROC (AUROC) curve for validation. Consequently, we obtained and evaluated an external dataset from other research institutions and accumulated additional cases. In the validation cohort, among a total of 417 patients who visited the HD clinic at two academic teaching hospitals and medical centers in Korea from the KSGN, 13 patients with missing values were excluded (Fig. 1B). Additional statistical analyses were performed using the R programming language (version 4.4.1; R Foundation for Statistical Computing).

Results

Baseline characteristics in the development cohort

Among the 2,468 potential patients, 1,751 were enrolled after applying the exclusion criteria (Fig. 1A). The group that included patients surviving for >6 months after HD initiation comprised 1,480 patients, and 271 patients died within 6 months (15.5%). The proportion of patients aged >85 years at HD initiation was significantly higher among those who died than among those who survived. The comparison between the groups of deceased and living individuals showed significant differences in several areas of health. The proportions of underweight (BMI, <18.5 kg/m^2) and serum albumin <3.5 g/dL were significantly higher in the 6-month death group than in the alive group. The proportion of patients with malignancy was higher among deceased individuals. Additionally, the rate of metastatic malignancy was higher among deceased individuals. The incidences of CHF and atrial fibrillation were also higher in the deceased group, whereas the rates of diabetes mellitus and hypertension were lower. The proportion of patients requiring assistance for ADL was higher in the deceased group, as was the rate of severe behavior disorders. The rates of hospitalization within 6 months prior to the initiation of HD, hospitalization at a nursing facility at the time of HD, and use of a catheter for vascular access for dialysis initiation and maintenance dialysis were all higher in the group of deceased individuals. The findings are presented in Table 1.

Table 1. Baseline characteristics in the development cohort from the Korean Society of Geriatric Nephrology retrospective cohort

Characteristic	Total	6-Month death	6-Month alive	p-value
No. of patients	1,751	271	1,480	
Age at the HD initiation (yr)				
70–74	609 (34.8)	57 (21.0)	552 (37.3)	<0.001[a]
75–79	583 (33.3)	90 (33.2)	493 (33.3)	
80–84	359 (20.5)	59 (21.8)	300 (20.3)	
≥85	200 (11.4)	65 (24.0)	135 (9.1)	
Sex				
Female	772 (44.1)	117 (43.2)	655 (44.3)	0.79[a]
Male	979 (55.9)	154 (56.8)	825 (55.7)	
Body mass index (kg/m^2)				
<18.5	147 (8.4)	43 (15.9)	104 (7.0)	<0.001[a]
18.5–22.9	745 (42.5)	118 (43.5)	627 (42.4)	
23.0–24.9	370 (21.1)	52 (19.2)	318 (21.5)	
25.0–29.9	392 (22.4)	46 (17.0)	346 (23.4)	
≥30.0	97 (5.5)	12 (4.4)	85 (5.7)	
Primary etiology				
Glomerulonephritis	856 (48.9)	104 (38.4)	752 (50.8)	0.002[a]
Diabetic kidney disease	122 (7.0)	19 (7.0)	103 (7.0)	
Hypertension	439 (25.1)	83 (30.6)	356 (24.1)	
Others	334 (19.1)	65 (24.0)	269 (18.2)	
Malignancy				
Curative state	235 (13.4)	53 (19.6)	182 (12.3)	<0.001[a]
Ongoing or palliative treatment	53 (3.0)	18 (6.6)	35 (2.4)	
Malignancy with metastatic disease	73 (4.2)	27 (10.0)	46 (3.1)	<0.001[a]
Ischemic heart disease	391 (22.3)	63 (23.2)	328 (22.2)	0.75[a]
Cerebrovascular disease	326 (18.6)	48 (17.7)	278 (18.8)	0.74[a]
Congestive heart failure	333 (19.0)	70 (25.8)	263 (17.8)	0.002[a]
Atrial fibrillation	191 (10.9)	43 (15.9)	148 (10.0)	0.006[a]
Diabetes mellitus	1,029 (58.8)	134 (49.4)	895 (60.5)	0.001[a]
Hypertension	1,582 (90.3)	226 (83.4)	1,356 (91.6)	<0.001[a]
Activities of daily living dependency				
None	1,053 (60.1)	116 (42.8)	937 (63.3)	<0.001[a]
Partial	485 (27.7)	95 (35.1)	390 (26.4)	
Total	213 (12.2)	60 (22.1)	153 (10.3)	
Severe behavior disorder	99 (5.7)	25 (9.2)	74 (5.0)	0.009[a]
Hospitalization history prior to HD initiation within 6 mo				
None	1,181 (67.4)	172 (63.5)	1,009 (68.2)	0.02[a]
<1 mo	512 (29.2)	83 (30.6)	429 (29.0)	
More than 1 mo	58 (3.3)	16 (5.9)	42 (2.8)	
Nursing hospital care at dialysis initiation	167 (9.5)	43 (15.9)	124 (8.4)	<0.001[a]
Vascular access at dialysis initiation				
Temporary catheter	1,425 (81.4)	254 (93.7)	1,171 (79.1)	<0.001[a]
AVF	256 (14.6)	14 (5.2)	242 (16.4)	
AVG	70 (4.0)	3 (1.1)	67 (4.5)	

(Continued to the next page)

Table 1. Continued

Characteristic	Total	6-Month death	6-Month alive	p-value
Vascular access on maintenance dialysis				
Temporary catheter	304 (17.4)	137 (50.6)	167 (11.3)	<0.001[a]
AVF	1,115 (63.7)	101 (37.3)	1,014 (68.5)	
AVG	332 (19.0)	33 (12.2)	299 (20.2)	
Albumin (g/dL)				
<3.5	939 (53.6)	194 (71.6)	745 (50.3)	<0.001[a]
≥3.5	812 (46.4)	77 (28.4)	735 (49.7)	
eGFR (mL/min/1.73 m^2)				
≤15	138 (7.9)	40 (14.8)	98 (6.6)	<0.001[a]
>15	1,613 (92.1)	231 (85.2)	1,382 (93.4)	
Total cholesterol (mg/dL)				
<200	1,548 (88.4)	244 (90.0)	1,304 (88.1)	0.42[a]
≥200	203 (11.6)	27 (10.0)	176 (11.9)	
Hemoglobin (g/dL)	9.3 ± 3.0	9.1 ± 1.7	9.3 ± 2.4	0.25[b]
Blood urea nitrogen (mg/dL)	78.5 ± 34.5	76.2 ± 35.3	79.0 ± 34.4	0.23[b]
Sodium (eEq/L)	136.4 ± 7.5	135.7 ± 6.2	136.5 ± 7.7	0.05[b]
Potassium (mEq/L)	4.9 ± 3.8	4.7 ± 1.1	4.9 ± 4.1	0.047[b]
Total CO_2 (mEq/L)	18.7 (15.1–22.0)	18.1 (15.0–22.0)	18.7 (15.3–22.0)	0.67[c]
Uric acid (mg/dL)	7.8 ± 2.9	7.9 ± 3.3	7.8 ± 2.8	0.66[b]
Calcium (mg/dL)	8.2 ± 1.0	8.2 ± 0.9	8.2 ± 1.0	0.98[b]
Phosphorus (mg/dL)	4.8 (3.9–5.8)	4.8 (3.6–5.8)	4.8 (3.9–5.8)	0.44[c]
Magnesium (mg/dL)	2.4 ± 0.6	2.4 ± 0.6	2.4 ± 0.6	0.44[b]
AST (IU/L)	19.0 (14.0–25.0)	21.0 (15.0–32.0)	18.0 (14.0–25.0)	<0.001[c]
ALT (IU/L)	13.0 (9.0–21.0)	14.0 (9.0–23.0)	13.0 (9.00–21.0)	0.21[c]
ALP (IU/L)	107.0 (71.0–226.0)	115.0 (73.5–246.0)	105.0 (70.0–223.0)	0.13[c]
CPK (IU/L)	102.0 (57.0–182.0)	76.0 (44.0–158.0)	106.5 (59.0–189.3)	0.001[c]
LDH (IU/L)	333.0 (243.0–476.0)	367.0 (248.0–500.0)	327.0 (242.0–470.0)	0.08[c]

Data are expressed as number only, number (%), mean ± standard deviation, or median (interquartile range).
ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; AVF, arteriovenous fistula; AVG, arteriovenous graft; CPK, creatine phosphokinase; eGFR, estimated glomerular filtration rate; HD, hemodialysis; LDH, lactate dehydrogenase.
[a]p-value obtained from chi-square test for categorical values; [b]p-value obtained from independent two-sample t test; [c]p-value obtained from Wilcoxon rank sum test.

Multivariate logistic regression analysis and risk score modeling

Multivariate analysis and construction of the final scoring model for risk factors associated with mortality were performed using the study cohort from the KSGN database. The results of the patient scores using the KSGN score are shown in Table 2 with development to the KSGN prediction score. In the multivariate logistic regression analysis, age at dialysis initiation (75–79 years: OR, 1.39; 95% confidence interval [CI], 0.96–2.05; p = 0.08; ≥85 years: OR, 3.06; 95% CI, 1.96–4.76; p < 0.001 [final score 2]), hypertension and renovascular disease as a primary etiology of ESKD (OR, 1.69; 95% CI, 1.19–2.39; p = 0.003 [final score 1]), malignancy (curative state: OR, 1.57; 95% CI, 1.07–2.3; p = 0.02 [final score 1]; palliative treatment: OR, 2.06; 95% CI, 1.05–4.03; p = 0.03 [final score 1]), and serum albumin levels (<3.5 g/dL: OR, 1.85; 95% CI, 1.36–2.53; p < 0.001 [final score 1]) were independent risk factors for 6-month mortality. Hypertension treatment with medication (OR, 0.59; 95% CI, 0.38–0.92; p = 0.02 [final score –1]), and planned dialysis with vascular access on maintenance dialysis (arteriovenous fistula [AVF]: OR, 0.16; 95% CI, 0.12–0.22; p < 0.001 [final score –3]; arteriovenous graft [AVG]: OR, 0.17; 95% CI, 0.11–0.27; p < 0.001 [final score –3]) compared to the temporary catheter group were favorable effect on the 6-month

Table 2. Multivariate analysis and final scoring model for mortality-associated risk factors in the Korean Society of Geriatric Nephrology study cohort

Variable	Univariate OR (95% CI)	p-value[a]	Multivariate with stepwise selection OR (95% CI)	p-value[b]	Final score (coefficient)
Age (yr)					
70–74	Reference				
75–79	1.77 (1.24–2.52)	0.002	1.39 (0.96–2.05)	0.08	
80–84	1.90 (1.29–2.81)	0.001	1.31 (0.86–2.00)	0.22	
≥85	4.66 (3.12–6.97)	<0.001	3.06 (1.96–4.76)	<0.001	2
Sex					
Female	Reference				
Male	1.05 (0.80–1.36)	0.741			
Body mass index (kg/m^2)					
25.0–29.9	Reference				
<18.5	3.11 (1.94–4.98)	<0.001			
18.5–22.9	1.42 (0.98–2.04)	0.06			
23.0–24.9	1.23 (0.80–1.88)	0.34			
≥30.0	1.06 (0.54–2.09)	0.86			
Primary etiology					
Glomerulonephritis	Reference				
Diabetic kidney disease	1.33 (0.78–2.27)	0.29	0.88 (0.47–1.65)	0.71	
Hypertension and renovascular disease	1.69 (1.23–2.31)	0.001	1.69 (1.19–2.39)	0.003	1
Others	1.75 (1.24–2.45)	0.001	1.21 (0.82–1.78)	0.34	
Malignancy					
None	Reference				
Curative state	1.84 (1.31–2.58)	<0.001	1.57 (1.07–2.30)	0.02	1
Ongoing or palliative treatment	3.25 (1.80–5.85)	<0.001	2.06 (1.05–4.03)	0.03	1
Malignancy with metastatic disease					
No	Reference				
Yes	3.45 (2.10–5.65)	<0.001			
Ischemic heart disease					
No	Reference				
Yes	1.06 (0.78–1.45)	0.69			
Cerebrovascular disease					
No	Reference				
Yes	0.93 (0.66–1.30)	0.68			
Congestive heart failure					
No	Reference				
Yes	1.61 (1.19–2.18)	0.002			
Atrial fibrillation					
No	Reference				
Yes	1.70 (1.18–2.45)	0.005			
Diabetes mellitus					
No	Reference				
Yes	0.64 (0.49–0.83)	<0.001			
Hypertension					
No	Reference				
Yes	0.46 (0.32–0.66)	<0.001	0.59 (0.38–0.92)	0.02	–1

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Table 2. Continued

Variable	Univariate OR (95% CI)	p-value[a]	Multivariate with stepwise selection OR (95% CI)	p-value[b]	Final score (coefficient)
Activities of daily living dependency					
None	Reference				
Partial	1.97 (1.46–2.64)	<0.001			
Total	3.17 (2.22–4.52)	<0.001			
Severe behavior disorder					
No	Reference				
Yes	1.93 (1.20–3.10)	0.006			
Hospitalization history prior to HD initiation within 6 mo					
None	Reference				
<1 mo	1.13 (0.85–1.51)	0.38			
More than 1mo	2.23 (1.23–4.06)	0.008			
Nursing hospital care at dialysis initiation					
No					
Yes	2.06 (1.42–3.00)	<0.001			
Vascular access at dialysis initiation					
Temporary catheter	Reference				
AVF	0.27 (0.15–0.46)	<0.001			
AVG	0.21 (0.06–0.66)	0.008			
Vascular access on maintenance dialysis					
Temporary catheter	Reference				
AVF	0.12 (0.09–0.16)	<0.001	0.16 (0.12–0.22)	<0.001	–3
AVG	0.13 (0.09–0.21)	<0.001	0.17 (0.11–0.27)	<0.001	–3
Albumin (g/dL)					
≥3.5	Reference				
<3.5	2.49 (1.87–3.30)	<0.001	1.85 (1.36–2.53)	<0.001	1
eGFR (mL/min/1.73 m^2)					
>15	Reference				
≤15	0.41 (0.28–0.61)	<0.001			
Total cholesterol (mg/dL)					
<200	Reference				
≥200	0.82 (0.53–1.26)	0.36			

AVF, arteriovenous fistula; AVG, arteriovenous graft; CI, confidence interval; eGFR, estimated glomerular filtration rate; HD, hemodialysis; OR, odds ratio.
[a]p-value obtained from logistic regression, crude model (univariate model); [b]p-value obtained from logistic regression, adjusted model after stepwise variable selection (multivariate model).

mortality (Table 2). Therefore, the valuables of KSGN score are extremely old age at dialysis initiation (≥85 years, score 2), hypertension and renovascular disease as a primary etiology of ESKD (score 1), malignancy history (curative state, score 1 and ongoing or palliative treatment, score 1), low serum albumin (<3.5 g/dL, score 1), hypertension treatment (score –1) and prepared vascular access on maintenance dialysis (AVF, score –3; AVG, score –3).

Baseline characteristics in the validation cohort and validation of the Korean Society of Geriatric Nephrology prediction score

An independent validation dataset was used to validate the model, and the results are presented in Tables 3 and 4. Among the 417 potential patients, 404 were enrolled after applying the exclusion criteria (Fig. 1B). The group that included patients surviving for >6 months after HD initia-

tion comprised 363 patients, and 41 patients died within 6 months (10.1%). In the validation cohort, the comparison between the groups of deceased and living individuals showed no significant differences except CHF. The proportion of CHF was significantly higher in the deceased group than in the living group (Table 3). AUROC curves were constructed to compare the validated prognostic models. In the development cohort, the AUC values were as follows: KSGN score, 0.707 (95% CI, 0.670–0.743); USRDS Thamer score, 0.683 (95% CI, 0.650–0.715); and Alberta Wick's score, 0.632 (95% CI, 0.598–0.667). The AUC for the KSGN score was significantly higher compared to the Alberta Wick's score (p = 0.01). Although, there was no statistical significance, the AUC for KSGN score was higher compared to the USRDS Thamer's score (p = 0.25) (Fig. 2A). In the validation cohort, the AUC values were as follows: KSGN score, 0.513 (95% CI, 0.427–0.600); USRDS Thamer score, 0.545 (95% CI, 0.462–0.629); and Alberta Wick score, 0.513 (95% CI, 0.417–0.610). The KSGN score's performance was comparable to existing models (Fig. 2B). In subgroup analyses of discrimination performance in the KSGN cohort, all variables were better in the development cohort than in the validation cohort (Table 4).

Discussion

This study was the first to implement a nationwide multicenter-validated risk prediction model in Korea for significant risk factors associated with early death among patients with ESKD. Significant risk factors included the initiation of HD at an older age (≥85 years) than at an age of 70–75 years, hypertension and renovascular disease as a primary etiology of ESKD, low serum albumin (<3.5 g/dL), and having a malignant disease. The mortality risk was significantly decreased when an AVF or AVG was used during maintenance dialysis compared with the application of a temporary catheter. Furthermore, the mortality risk was reduced if patients took the antihypertensive medications at dialysis initiation. Finally, the KSGN risk score generated in this study was subjected to validation analysis and verification using variables from other models.

We then compared the previously developed score in the study using USRDS data by Thamer et al. [9] and Wick et al. [11] from Alberta, Canada. These scores were developed to estimate the probability of 6-month mortality among older adult patients initiating dialysis [9,11]. The performance of our model improved mortality prediction compared to that of the USRDS, and Alberta score (Fig. 2A). Thamer et al. [9] also assessed USRDS data retrospectively and focused on the 3- and 6-month mortality following dialysis. The model by Thamer et al. [9] utilized USRDS data (patients aged ≥67 years) to validate and provide a simple risk assessment score based on the collected data for the risk factors of mortality. However, this model has not been independently validated; it also excludes psychosocial data, such as cognitive dysfunction, a pivotal factor for self-care dialysis. Additionally, the model excluded patients who did not elect to undergo dialysis therapy and included only those with a follow-up of <2 years [9]. Our model had a higher AUROC value than the variable model proposed by Thamer et al. [9]. Recent studies have attempted to validate prediction models for older Korean ESKD patients, with demonstrating good calibration results [8]. We determined that the AUC of our score was comparable to that of the Thamer model using USRDS data [9] and that of the Alberta score [11]. Using the French National Renal Epidemiology and Information Network registry, Couchoud et al. [7] focused on the very early 3-month mortality in patients aged ≥75 years initiating dialysis. They found that male sex, age of ≥85 years, CHF, severe peripheral vascular disease, arrhythmias, severe behavioral disorders, active malignancies, serum albumin levels, and gait disturbances were independently associated with 3-month mortality. Despite the comprehensive cohort design, the model evaluated only the immediate short-term prognosis at 3 months; hence, we did not use it for the model comparison.

One of the most significant findings of our study was that patients who initiated dialysis with planned vascular access, such as AVF or AVG, had a significantly lower risk of death than those who began dialysis using a temporary catheter. Additionally, compared with patients who continued HD with catheters on maintenance dialysis, those who continued HD with an AVF or AVG had a lower risk of death (Table 2). This finding was also consistent with those of several previous studies in older adults. Roy et al. [17] found that the 3-month and 1-year mortality rates were significantly higher in unplanned dialysis patients aged ≥75 years than in planned dialysis patients. However, initiating HD with a temporary catheter is common among older HD patients, and the practice of patients undergoing HD with

Table 3. Baseline characteristics of the external validation cohort for the Korean Society of Geriatric Nephrology score

Variable	Total (n = 404)	6-Month death (n = 41)	6-Month alive (n = 363)	p-value
Age at the hemodialysis initiation (yr)				0.80[a]
70–74	86 (21.3)	11 (26.8)	75 (20.7)	
75–79	116 (28.7)	11 (26.8)	105 (28.9)	
80–84	116 (28.7)	10 (24.4)	106 (29.2)	
≥85	86 (21.3)	9 (22.0)	77 (21.2)	
Sex				0.41[a]
Female	187 (46.3)	22 (53.7)	165 (45.5)	
Male	217 (53.7)	19 (46.3)	198 (54.5)	
Body mass index (kg/m^2)				0.67[a]
<18.5	38 (9.4)	6 (14.6)	32 (8.8)	
18.5–22.9	153 (37.9)	13 (31.7)	140 (38.6)	
23.0–24.9	94 (23.3)	11 (26.8)	83 (22.9)	
25.0–29.9	91 (22.5)	9 (22.0)	82 (22.6)	
≥30.0	28 (6.9)	2 (4.9)	26 (7.2)	
Primary etiology				0.14[a]
Glomerulonephritis	186 (46.0)	20 (48.8)	166 (45.7)	
Diabetic kidney disease	37 (9.2)	2 (4.9)	35 (9.6)	
Hypertension	125 (30.9)	9 (22.0)	116 (32.0)	
Others	56 (13.9)	10 (24.4)	46 (12.7)	
Malignancy				0.37[a]
No	313 (77.5)	29 (70.7)	284 (78.2)	
Yes	91 (22.5)	12 (29.3)	79 (21.8)	
Malignancy with metastatic disease	18 (17.6)	2 (13.3)	16 (18.4)	>0.99[a]
Ischemic heart disease	73 (18.1)	7 (17.1)	66 (18.2)	>0.99[a]
Cerebrovascular disease	114 (28.2)	11 (26.8)	103 (28.4)	0.98[a]
Congestive heart failure	83 (20.5)	14 (34.1)	69 (19.0)	0.04[a]
Atrial fibrillation	31 (7.7)	4 (9.8)	27 (7.4)	0.54[a]
Diabetes mellitus	235 (58.2)	24 (58.5)	211 (58.1)	>0.99[a]
Hypertension	344 (85.1)	35 (85.4)	309 (85.1)	>0.99[a]
Severe behavior disorder	34 (8.4)	4 (9.8)	30 (8.3)	0.77[a]
Hospitalization history prior to HD initiation within 6 mo				0.11[a]
None	198 (49.0)	22 (53.7)	176 (48.5)	
<1 mo	159 (39.4)	11 (26.8)	148 (40.8)	
More than 1 mo	47 (11.6)	8 (19.5)	39 (10.7)	
Nursing hospital care at dialysis initiation	20 (5.0)	2 (4.9)	18 (5.0)	>0.99[a]
Vascular access at dialysis initiation				0.60[a]
Temporary catheter	349 (86.4)	37 (90.2)	312 (86.0)	
AVF	55 (13.6)	4 (9.8)	51 (14.0)	
AVG	0 (0)	0 (0)	0 (0)	
Vascular access on maintenance dialysis				0.37[a]
Temporary catheter	71 (17.6)	8 (19.5)	63 (17.4)	
AVF	313 (77.5)	33 (80.5)	280 (77.1)	
AVG	20 (5.0)	0 (0)	20 (5.5)	
Albumin (g/dL)				0.45[a]
≥3.5	185 (45.8)	16 (39.0)	169 (46.6)	
<3.5	219 (54.2)	25 (61.0)	194 (53.4)	
eGFR (mL/min/1.73 m^2)				0.25[a]
≤15	37 (9.2)	6 (14.6)	31 (8.5)	
>15	367 (90.8)	35 (85.4)	332 (91.5)	
Hemoglobin (g/dL)	9.03 ± 1.76	8.96 ± 2.13	9.04 ± 1.72	0.83[b]

Data are expressed as number (%) or mean ± standard deviation. In malignancy, no was defined as no history of cancer, and yes was defined as a curative state, ongoing or palliative treatment state.

AVF, arteriovenous fistula; AVG, arteriovenous graft; eGFR, estimated glomerular filtration rate; HD, hemodialysis.

[a]p-value obtained from chi-squared test for categorical values; [b]p-value obtained from independent two-sample t test.

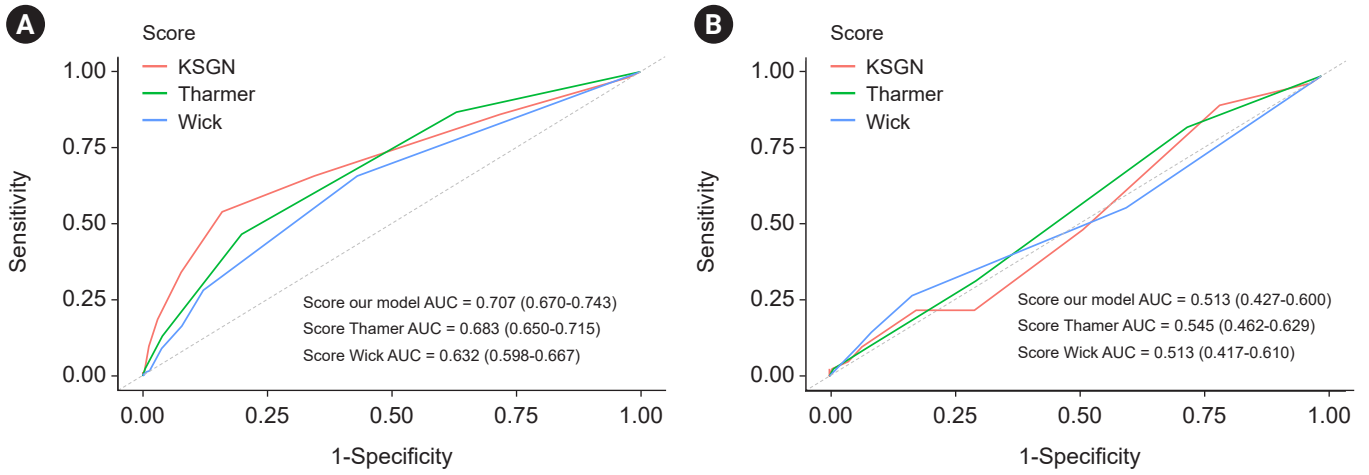

Figure 2. Comparison of ROC curves between prognostic models. Comparison of ROC curves for predicting 6-month mortality following dialysis initiation using our score (Korean Society of Geriatric Nephrology [KSGN]), United States Renal Data System (USRDS) Thamer, and Alberta Wick scores. (A) Development cohort: KSGN score, 0.71 (95% confidence interval [CI], 0.670–0.743); USRDS Thamer score, 0.68 (95%, 0.650–0.715); and Alberta Wick score, 0.63 (95% CI, 0.598–0.667). With three models—Alberta Wick, USRDS Thamer, and KSGN—each comparison was made between two models at a time, resulting in three pairwise comparisons. The p-value for the difference between the KSGN score and the Alberta Wick score was 0.001, and the p-value for the difference between the KSGN score and the USRDS Thamer score was 0.25. The area under the curve (AUC) difference between the Alberta Wick score and the USRDS Thamer score was 0.0143. (B) Validation cohort: KSGN score, 0.51 (95% CI, 0.427–0.600); USRDS Thamer score, 0.55 (95% CI, 0.462–0.629); and Alberta Wick score, 0.51 (95% CI, 0.417–0.610). The p-value for the difference between the KSGN score and the Alberta Wick score was 0.998, and the KSGN score and the USRDS Thamer score was 0.334. The AUC difference between the Alberta Wick score and the USRDS Thamer score was 0.562.
ROC, receiver operating characteristic.

a catheter has been continually increasing in Korea [1,18]. As patients with multiple comorbidities are referred to a nephrologist late and are not prepared for vascular access prior to dialysis, it is essential that patients be referred to a nephrologist as early as possible for evaluation and appropriate estimation of the risk of early death following dialysis to reduce the premature mortality rate associated with dialysis. Notably, previous studies have not confirmed whether AVF or AVG has a favorable prognosis in older ESKD patients receiving HD, especially among East Asian individuals, considering the differences in body size. Lee et al. [18] used national health insurance data from 2008 to 2016 to conduct a nationwide retrospective study of vascular access in HD patients. The use of AVF was found to have the best prognosis for patient survival, followed by AVG and catheter use. In particular, using an AVF and AVG achieved a better prognosis than temporary catheters in the oldest patient group, although there was no significant difference between using an AVF and AVG. DeSilva et al. [19] also evaluated all-cause mortality among 115,425 incident HD patients aged ≥67 years using USRDS data. There was no difference in survival between the use of an AVF and an AVG in all patient groups. Furthermore, because patient survival was greater than that of patients equipped with a temporary catheter, the study concluded that initiating HD with an AVG or AVF achieved a favorable prognosis in older patients with ESKD [19]. In agreement with these results, this study found that, in older Korean patients with ESKD, initiating dialysis with a specific type of fistula was not necessarily the optimal option for HD patients. Therefore, when considering dialysis for older patients with ESKD, planning and relying only on an AVF alone may not be the best option.

Song et al. [20] conducted a systematic review by integrating data from 28 studies. Functional impairment, cognitive impairment, falls, low BMI, frailty, advanced age, higher Charlson comorbidity index, early dialysis initiation, and central venous catheter use were all independently associated with mortality in elderly patients undergoing HD [20]. This was consistent with our findings that extremely

Table 4. Subgroup analyses of discrimination performance in the Korean Society of Geriatric Nephrology cohort

Subgroup	AUROC (95% CI)	
	Development cohort	Validation cohort
Overall	0.707 (0.670–0.743)	0.513 (0.427–0.600)
Age (yr)		
70–74	0.648 (0.566–0.730)	0.492 (0.309–0.675)
75–79	0.701 (0.639–0.763)	0.642 (0.522–0.763)
80–84	0.632 (0.543–0.720)	0.523 (0.320–0.726)
≥85	0.709 (0.631–0.788)	0.413 (0.152–0.673)
Primary etiology		
Glomerulonephritis	0.695 (0.637–0.752)	0.576 (0.459–0.692)
Diabetic kidney disease	0.682 (0.529–0.834)	0.593 (0.322–0.864)
Hypertension	0.669 (0.593–0.744)	0.361 (0.172–0.549)
Others	0.734 (0.657–0.812)	0.549 (0.330–0.768)
Malignancy		
None	0.681 (0.637–0.725)	0.489 (0.399–0.579)
Curative state	0.705 (0.621–0.789)	0.574 (0.374–0.775)
Ongoing or palliative treatment	0.824 (0.715–0.932)	NA
Hypertension		
No	0.761 (0.674–0.848)	0.503 (0.258–0.749)
Yes	0.708 (0.667–0.748)	0.516 (0.423–0.610)
Vascular access on maintenance dialysis		
Temporary catheter	0.549 (0.486–0.613)	0.659 (0.497–0.820)
Arteriovenous fistula	0.531 (0.472–0.590)	0.487 (0.405–0.569)
Arteriovenous graft	0.543 (0.439–0.646)	NA
Albumin (g/dL)		
≥3.5	0.752 (0.711–0.792)	0.532 (0.393–0.672)
<3.5	0.667 (0.597–0.738)	0.468 (0.351–0.585)

AUROC, area under the receiver operating characteristic curve; CI, confidence interval; NA; not available.

old age, low BMI, and dialysis catheter use are associated with a high mortality risk. However, our study did not find any statistically significant differences in functional or cognitive deficits. As expected, the older the patient's absolute age, the greater the risk of mortality, even among patients with ESKD; however, the cutoff age at which older Korean dialysis patients experience an increased absolute risk has not yet been established. In our study, mortality increased significantly after the age of 85 years compared to that in the 70 to 75-year-old group. The 2021 Korean Society of Nephrology Clinical Practice Guideline (KSN CPG) for optimal HD treatment meta-analysis demonstrated that dialysis contributed more to survival than conservative care, with a recommendation for HD based on the patient's condition [21]. The meta-analysis included 11 studies that also revealed that dialysis improved survival, even in older adults (hazard ratio [HR], 0.42; 95% CI, 0.37–0.47, $p < 0.001$) [21]. However, this KSN CPG meta-analysis did not include data from Korean older patients with ESKD; thus, our findings might address this gap and help determine whether dialysis should be initiated in geriatric patients.

Our study had some limitations. As this study primarily included older and newly started HD patients, no information on peritoneal dialysis was available. Furthermore, the retrospective nature of the study may have led to unmeasured confounding factors. However, we sought to overcome this limitation by conducting a large-scale, multicenter, nationwide study in South Korea. This limitation might impede the generalization of our findings; thus, a KSGN prospective cohort of older patients with predialysis CKD has been recruited since 2019, and the long-term outcomes might be elucidated. Finally, this prognostic score aims to act as a predictive tool for determining the application of maintenance dialysis in older CKD5-non-dialysis

patients based on the expected short-term prognosis estimated by the ESKD-Life Plan. As older dialysis patients are accompanied by a high burden of functional impairment, limited life expectancy, and healthcare utilization, these patients have a substantially higher mortality rate than younger patients. Furthermore, our study showed that the prognosis of ESKD patients with planned dialysis was better than that of patients with unplanned dialysis. Therefore, this score can be applied to older patients with ESKD who need to prepare for dialysis according to the ESKD-Life Plan, especially those aged >70 years. Together, our results indicate that reducing the risk of premature HD mortality is feasible by using AVF or AVG at the initiation of HD and during maintenance dialysis.

In conclusion, this study proposes a readily accessible tool to predict early mortality following HD initiation in older Korean patients. The KSGN score may be a valuable tool for predicting early mortality after dialysis initiation in older patients with ESKD and can inform decision-making and management regarding dialysis initiation.

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Conflicts of interest

All authors have no conflicts of interest to declare.

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Data sharing statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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