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Development and Application of New Risk-Adjustment Models to Improve the Current Model for Hospital Standardized Mortality Ratio in South Korea

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Purpose: This study assessed the validity of the hospital standardized mortality ratio (HSMR) risk-adjusted model by comparing models that include clinical information and the current model based on administrative information in South Korea.

Materials and Methods: The data of 53976 inpatients were analyzed. The current HSMR risk-adjusted model (Model 1) adjusts for sex, age, health coverage, emergency hospitalization status, main diagnosis, surgery status, and Charlson Comorbidity Index (CCI) using administrative data. As candidate variables, among clinical information, the American Society of Anesthesiologists score, Acute Physiology and Chronic Health Evaluation (APACHE) II, Simplified Acute Physiology Score (SAPS) 3, present on admission CCI, and cancer stage were collected. Surgery status, intensive care in the intensive care unit, and CCI were selected as proxy variables among administrative data. In-hospital death was defined as the dependent variable, and a logistic regression analysis was performed. The statistical performance of each model was compared using C-index values.

Results: There was a strong correlation between variables in the administrative data and those in the medical records. The C-index of the existing model (Model 1) was 0.785; Model 2, which included all clinical data, had a higher C-index of 0.857. In Model 4, in which APACHE II and SAPS 3 were replaced with variables recorded in the administrative data from Model 2, the C-index further increased to 0.863.

Conclusion: The HSMR assessment model improved when clinical data were adjusted. Simultaneously, the validity of the evaluation method could be secured even if some of the clinical information was replaced with the information in the administrative data.

Key Words: Hospital mortality, risk-adjustment, quality indicators, Republic of Korea

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INTRODUCTION

Hospital standardized mortality ratio (HSMR) is a generic quality indicator used to monitor acute care performance. It is used to assess all-cause mortality in medical institutions and is not limited to specific target diseases.[1] It is even more meaningful as a quality indicator as it measures the outcomes, not the structure or process of the healthcare services provided by medical institutions.[2] Moreover, it offers the advantage of enabling the general public—those with no medical knowledge—

to easily view the overall quality of medical institutions; it is thus widely used in many countries such as the United States, United Kingdom, Canada, and Australia.[3-5]

When measuring and comparing outcome indicators, such as HSMR, by medical institutions, considering the composition of patients in each institution is essential.[6] In particular, differences in predicted values of HSMR could occur depending on the adjusted model; hence, developing a sophisticated risk-adjusted model is necessary to enhance the validity of the results.[7] The Health Insurance Review & Assessment Service (HIRA) of South Korea adopted the HSMR assessment in 2016, using administrative data (i.e., health insurance claims data) to adjust for patient characteristics.[8]

Previous studies have compared the predictive power of risk-adjusted models using only administrative information to models that incorporate additional clinical information, but the results have been conflicting. Few studies have confirmed that using models with the addition of clinical information, rather than using administrative data-based models, can result in higher explanatory power.[9-11] Consequently, some studies have concluded that administrative information can suffice as clinical data since there is no difference in explanatory power between the two models.[12-18]

In addition, most previous studies on the development of mortality prediction models are confined to specific diseases (e.g., pneumonia, acute myocardial infarction, heart failure) and surgical procedures.[12-18]

As discussed above, the influence of clinical information on the prediction of mortality has not been clearly identified, and most previous studies have been limited to specific diseases. Therefore, the present study aimed to assess the validity of the existing HSMR risk-adjusted model based on administrative information by comparing models with the addition of clinical information. In addition, our study sought to determine whether clinical information can be replaced with administrative information.

MATERIALS AND METHODS

Study data and population

For this study, we collected inpatient data based on the 2019 national health insurance claims data from the HIRA, mortality data from the Ministry of the Interior and Safety, and medical records data from five medical institutions. To adjust for patients' comorbidities, claims data for 1 year prior to hospitalization were collected. To collect clinical data from medical institutions, stratified random sampling considering the type of medical institution and the number of beds was applied to medical institutions targeted for HSMR assessment in 2019. Consequently, 14 medical institutions were initially selected. Of these, five hospitals (three tertiary and two general hospitals) that voluntarily consented to participate and could provide the required clinical data were included in the final analysis. All hospitals had approximately 800 or more beds, and hospitals in both metropolitan and non-metropolitan regions were included. Information was extracted from claims data, including the sequence number of claims, start and end dates of admission, existing risk adjustment factors, intensive care unit (ICU) admission status, and presence of cancer, for patients treated at participating medical institutions. These details were sent to the respective institutions, which then supplemented the records with clinical information and returned the updated records. All personal information was de-identified in this process.

The study population comprised patients in the primary diagnostic group; that is, those whose primary condition or disease was identified by a healthcare provider as the main reason for their hospitalization. This group accounted for 80% of in-hospital mortality, which was deduced by analyzing claims data of all inpatients, among all patients hospitalized in the participating hospitals in 2019.[8] Here, the primary diagnostic group was defined by the Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS).[19] Thirty-five AHRQ CCS out of a total of 259 were included for this study.[20] Please refer to Supplementary Table 1 (only online) to identify the included AHRQ CCS. After excluding patients who were transferred to another institution, those with a length of stay of less than 2 days, and patients receiving palliative care, a total of 53976 patients were included in the final study population.

Variables

The dependent variable is the in-hospital mortality rate. The HSMR assessment model currently used in South Korea (Model 1) is adjusted for administrative information: sex, age, health coverage, emergency hospitalization status, main diagnosis, surgery status including medical intervention, and Charlson Comorbidity Index (CCI).[8,21] Age is categorized as follows: <40 years, 5-year increments for individuals aged ≥40 to ≤84 years, and ≥ 85 years. Health coverage is categorized into health insurance and medical aid, which primarily serves low-income individuals. For the main diagnosis, the 7th revision of the Korean Standard Classification of Diseases codes was used. CCI, which is calculated by linking administrative data filed in the past year, is categorized as 0, 1 to 2, and ≥3 points.[21]

Through a comprehensive literature review and subsequent expert panel consensus, we distilled the risk factors for in-hospital mortality to four key factors: preoperative health status, severity of patients admitted to the ICU, comorbidities, and cancer stage.[22-25] Relevant clinical information was collected for use as candidate risk-adjustment variables: the American Society of Anesthesiologists (ASA) physical status classification system score, ICU severity score, present on admission (POA) CCI, and cancer stage, respectively. ASA is a system for assessing the fitness of patients before surgery.[26] ASA scores rank from 1 to 6, with higher scores indicating a more severe status

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of patients.[26] The Acute Physiology and Chronic Health Evaluation (APACHE) II score and Simplified Acute Physiology Score (SAPS) 3 score were used to calculate the ICU severity score. Both APACHE II and SAPS 3 are ICU severity scoring systems that are applied within 24 hours of a patient's admission to the ICU, with higher scores indicating greater severity.[27,28] Comorbidities are a major factor in adjusting a patient's severity; and in particular, using comorbidities present at the time of admission provides a more accurate assessment by excluding complications that occur in the hospital.[29-31] Cancer stage influences overall prognosis and is also used in studies to adjust mortality predictions for surgical cancer populations.[25,32] To compare with the clinical information, surgery status including medical intervention, CCI, and intensive care in the ICU were selected from administrative data. We could not find comparable information for cancer stage.

To account for preoperative health status, non-surgery cases were classified as "no surgery," while surgery cases were classified by ASA scores[26] as follows: 1 to 2 points, 3 points, 4 to 6 points, and "not available (N/A)" for missing. For ICU severity score, patients with an ICU stay of <48 hours were classified as "not admitted to the ICU." Among patients with an ICU stay of ≥48 hours, those with an APACHE II score of 0 to 14 points or an SAPS 3 score of 0 to 49 points were classified as "low"; those with an APACHE II score of 15 to 24 points or an SAPS 3 score of 50 to 64 points were classified as "middle-low"; those with an APACHE II score of 25 to 34 points or an SAPS 3 score of 65 to 84 points were classified as "middle-high"; and those with an APACHE II score of ≥35 points or an SAPS 3 score of ≥85 points were classified as "high."[27,28] Patients missing both APACHE II and SAPS 3 scores were classified as "N/A". Administrative data were used to generate data for intensive care in the ICU that were not included in the current model. Among patients with an ICU stay of ≥48 hours, those who received one or more of the following treatments were defined as having received intensive care: artificial ventilation, hemodialysis, continuous renal replacement therapy, or extracorporeal membrane oxygenation. POA CCI scores were calculated after verifying the clinical data for the POA status of secondary diagnoses included in the index admission administrative data. POA CCI was defined as 0, 1 to 2, and ≥3 points. Cancer stage[33] was classified as "not cancer," stages 1 to 3, stage 4, and "N/A" for missing.[27,28]

Statistical analysis

A chi-square test was performed to identify the risk factors influencing mortality rate.

Cramer's V correlation analysis was performed to identify the correlation between clinical and administrative information. The correlation between clinical and administrative information for each risk factor was 0.91 for preoperative health status, 0.79 for the severity of patients admitted to the ICU, and 0.40 for comorbidities (Table 1). Since the clinical and administrative information paired with risk factors are highly correlated, they were used interchangeably rather than being input together in a single model.

Model 1 (current HSMR assessment model) comprises sex, age, health coverage, emergency hospitalization status, main diagnosis, surgery status, and CCI. Model 2 was analyzed by including all four types of clinical information in Model 1: ASA score, ICU severity score, POA CCI, and cancer stage. For Models 3 to 5, the clinical information from Model 2 was sequentially replaced with administrative information in the order of their highest correlation (Table 1). If the C-indexes of the model became lower after the clinical information was replaced with administrative information, the information was changed back to clinical information, and the next most correlated clinical information was replaced with administrative information. Model 3 included ICU severity score, POA CCI, and cancer stage among clinical information, and ASA score was replaced with surgery status. Model 4 included ASA score, POA CCI, and cancer stage among clinical information, and ICU severity score was replaced with intensive care in the ICU. Model 5 included ASA score and cancer stage among clinical information, while ICU severity score was replaced with intensive care in the ICU, and POA CCI was replaced with CCI.

To identify the explanatory power of the models, the main diagnoses were grouped by the AHRQ CCS. Since the factors affecting mortality differ according to the main diagnosis, a separate risk-adjusted model was applied for each AHRQ CCS. Average values were calculated for C-indexes obtained by multiple logistic regression analysis using backward elimination for each AHRQ CCS. All analyses in this study were performed using SAS Enterprise Guide 7.1, and the study was exempted from review by the Institutional Review Board of the Health Insurance Review and Assessment Service (HIRA 2022-011-002).

RESULTS

Table 2 presents the demographic characteristics of the study

Table 1. Correlation between Administrative and Clinical Information

	Preoperative health status	Severity of patients admitted to the ICU	Comorbidities	Cancer stage
Administrative data	Surgery status	Intensive care in the ICU	CCI	-
	↕	↕	↕	↕
Clinical data	ASA score	ICU severity score	POA CCI	Cancer stage
Cramer's V	0.91	0.79	0.40	-

ICU, intensive care unit; ASA, American Society of Anesthesiologists; POA, present on admission; CCI, Charlson Comorbidity Index.

Table 2. Demographic Characteristics of the Study Population

Variables	Total	Deaths in hospital		p value
		Yes	No	
Total	53976	1711 (3.2)	52265 (96.8)	
Sex				<0.001
Male	30290	1073 (3.5)	29217 (96.5)	
Female	23686	638 (2.7)	23048 (97.3)	
Age				<0.001
0 to 39 years	4385	33 (0.8)	4352 (99.2)	
40 to 44 years	1672	28 (1.7)	1644 (98.3)	
45 to 49 years	3022	51 (1.7)	2971 (98.3)	
50 to 54 years	4237	80 (1.9)	4157 (98.1)	
55 to 59 years	5782	126 (2.2)	5656 (97.8)	
60 to 64 years	7076	128 (1.8)	6948 (98.2)	
65 to 69 years	6249	137 (2.2)	6112 (97.8)	
70 to 74 years	6491	218 (3.4)	6273 (96.6)	
75 to 79 years	6556	254 (3.9)	6302 (96.1)	
80 to 84 years	5165	299 (5.8)	4866 (94.2)	
≥85 years	3341	357 (10.7)	2984 (89.3)	
Health coverage				<0.001
Medical aid	5399	219 (4.1)	5180 (95.9)	
National health insurance	48577	1492 (3.1)	47085 (96.9)	
Emergency status				<0.001
Yes	17832	1285 (7.2)	16547 (92.8)	
No	36144	426 (1.2)	35718 (98.8)	
Surgery status				<0.001
Yes	19010	1312 (6.9)	17698 (93.1)	
No	34966	399 (1.1)	34567 (98.9)	
CCI				<0.001
0	12565	354 (2.8)	12211 (97.2)	
1 to 2	12770	371 (2.9)	12399 (97.1)	
≥3	28641	986 (3.4)	27655 (96.6)	
Intensive care in the ICU				<0.001
Intensive care in the ICU	1480	678 (45.8)	802 (54.2)	
Admitted to the ICU	1925	111 (5.8)	1814 (94.2)	
Not admitted to the ICU	50571	922 (1.8)	49649 (98.2)	
ASA score				<0.001
No surgery	37106	527 (1.4)	36579 (98.6)	
1 to 2	4468	21 (0.5)	4447 (99.5)	
3	2287	116 (5.1)	2171 (94.9)	
4 to 6	238	58 (24.4)	180 (75.6)	
N/A	9877	989 (10.0)	8888 (90.0)	
ICU severity score				<0.001
Not admitted to the ICU	50571	922 (1.8)	49649 (98.2)	
Low	1057	123 (11.6)	934 (88.4)	
Middle-low	701	205 (29.2)	496 (70.8)	
Middle-high	367	169 (46.0)	198 (54.0)	
High	119	91 (76.5)	28 (23.5)	
N/A	1161	201 (17.3)	960 (82.7)	
POA CCI				<0.001
0	23164	632 (2.7)	22532 (97.3)	
1 to 2	14914	533 (3.6)	14381 (96.4)	
≥3	15898	546 (3.4)	15352 (96.6)	
Cancer stage				<0.001
Not cancer	28565	1331 (4.7)	27234 (95.3)	
1 to 3	7761	27 (0.3)	7734 (99.7)	
4	5545	113 (2.0)	5432 (98.0)	
N/A	12105	240 (2.0)	11865 (98.0)	

CCI, Charlson Comorbidity Index; ICU, intensive care unit; N/A, not available; POA, present on admission; ASA, American Society of Anesthesiologists. Data are presented as n (%).

population. A total of 53976 patients were included in the final analysis, including 1711 cases (3.2%) of in-hospital mortality. The number of patients with ASA scores of 1 to 2, 3, and 4 to 6 points was 4468 (8.3%), 2287 (4.2%), and 238 (0.4%), respectively. A total of 3405 patients (6.3%) were admitted to the ICU, of which 1480 (2.7%) received intensive care in the ICU. The number of patients with low, middle-low, middle-high, and high ICU severity scores was 1057 (2.0%), 701 (1.3%), 367 (0.7%), and 119 (0.2%), respectively. The number of patients with POA CCI scores of 0, 1 to 2, and ≥3 points was 23164 (42.9%), 14914 (27.6%), and 15898 (29.5%), respectively. Moreover, 25411 patients (47.1%) had cancer, including 7761 patients (14.4%) in stages 1 to 3, and 5545 patients (10.3%) in stage 4. All clinical data that candidate risk-adjustment variables indicated significant differences in the risk of in-hospital mortality (p<0.001).

Table 3 presents the crude odds ratios (ORs) for mortality without adjusting for patient characteristics. Among the new variables, patients with an ASA score of 4 to 6 points [OR, 22.37; 95% confidence interval (CI), 16.43 to 30.44] showed higher OR compared to patients who did not receive surgical treatment. As for the ICU severity score, patients with high ICU severity scores showed highest OR for mortality compared to patients who were not admitted to the ICU (OR, 174.94; 95% CI, 113.97 to 268.53). A significantly higher OR was found among patients who received intensive care in the ICU than those who did not (OR, 45.52; 95% CI, 40.33 to 51.39). Patients with a POA CCI score of 1 to 2 points (OR, 1.32; 95% CI, 1.18 to 1.49) showed higher OR compared to patients with a score of 0 points. Cancer stage showed an OR of 0.07 (95% CI, 0.05 to 0.11) for patients with stages 1 to 3 compared to patients without cancer.

Table 4 presents the average C-index of candidate models. The existing model (Model 1) had a C-index of 0.785. Compared to Model 1, Model 2, which included all clinical data, showed a higher C-index value of 0.857. In Model 3, in which the ASA score from Model 2 was replaced with surgery status,

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Table 3. OR for Mortality not Adjusted for Patient Characteristics

Variables	OR	95% CI
Sex		
Male	Ref.	
Female	0.75	0.68–0.83
Age		
0 to 39 years	0.41	0.28–0.61
40 to 44 years	0.92	0.61–1.40
45 to 49 years	0.93	0.67–1.29
50 to 54 years	1.05	0.79–1.39
55 to 59 years	1.21	0.94–1.55
60 to 64 years	Ref.	
65 to 69 years	1.22	0.95–1.55
70 to 74 years	1.89	1.51–2.35
75 to 79 years	2.19	1.76–2.71
80 to 84 years	3.34	2.70–4.12
≥85 years	6.50	5.29–7.99
Health coverage		
Medical aid	1.34	1.16–1.54
National health insurance	Ref.	
Emergency status		
Yes	6.51	5.83–7.28
No	Ref.	
Surgery status		
Yes	6.42	5.73–7.19
No	Ref.	
CCI		
0	Ref.	
1 to 2	1.03	0.89–1.20
≥3	1.23	1.09–1.39
Intensive care in the ICU		
Intensive care in the ICU	45.52	40.33–51.39
Admitted to the ICU	3.30	2.69–4.03
Not admitted to the ICU	Ref.	
ASA score		
No surgery	Ref.	
1 to 2	0.33	0.21–0.51
3	3.71	3.02–4.56
4 to 6	22.37	16.43–30.44
N/A	7.72	6.93–8.61
ICU severity score		
Not admitted to the ICU	Ref.	
Low	7.09	5.81–8.65
Middle-low	22.26	18.68–26.52
Middle-high	45.96	37.06–57.01
High	174.94	113.97–268.53
N/A	11.28	9.56–13.30
POA CCI		
0	Ref.	
1 to 2	1.32	1.18–1.49
≥3	1.27	1.13–1.42
Cancer stage		
Not cancer	Ref.	
1 to 3	0.07	0.05–0.11
4	0.43	0.35–0.52
N/A	0.41	0.36–0.48

OR, odds ratio; CI, confidence interval; CCI, Charlson Comorbidity Index; ICU, intensive care unit; N/A, not available; POA, present on admission; ASA, American Society of Anesthesiologists.

Table 4. Average C-Index of Risk-Adjusted Models

Adjusted variables	Model 1	Model 2	Model 3	Model 4	Model 5
Claim data					
Sex	O	O	O	O	O
Age	O	O	O	O	O
Health coverage	O	O	O	O	O
Emergency status	O	O	O	O	O
Main diagnosis	O	O	O	O	O
Surgery status	O		O		
CCI	O				O
Intensive care in the ICU				O	O
Clinical data					
ASA score		O		O	O
ICU severity score		O	O		
POA CCI		O	O	O	
Cancer stage		O	O	O	O
Average C-index	0.785	0.857	0.830	0.863	0.853

CCI, Charlson Comorbidity Index; ICU, intensive care unit; ASA, American Society of Anesthesiologists; POA, present on admission.

the C-index decreased to 0.830. In Model 4, which substituted the ICU severity score with variables recorded in the administrative data from Model 2, the C-index increased to 0.863. Finally, in Model 5, which replaced the POA CCI from Model 4 with the CCI from administrative data, the C-index decreased to 0.853. For C-indexes by AHRQ CCS, please refer to Supplementary Table 1 (only online).

DISCUSSION

We determined that preoperative health status, severity of patients admitted to the ICU, comorbidities, and cancer stage are major risk factors for mortality. Furthermore, an analysis of clinical data from participating medical institutions showed that adding all four types of clinical information, including ASA score, ICU severity score, POA CCI, and cancer stage, enhanced the statistical explanatory power compared to the existing model, which supported prior findings.[26-28,33] We also found that the model in which the ICU severity score from clinical information was replaced by the intensive care in the ICU from administrative information had the highest explanatory

power of 0.863, an increase of 0.078 compared to the existing model's explanatory power of 0.785.

In our study, the C-index increased by a maximum of 0.078. Although this may seem like a modest improvement, it is significant as it surpasses the generally accepted threshold of 0.8 for excellent discrimination.[34] This level of improvement is also consistent with the general magnitude of enhancements observed in similar studies aimed at improving risk adjustment models, which have reported C-index improvements in the range from 0.10 to 0.02.[7,9,10,15,16,21,23,24] Furthermore, our new model can be considered clinically more desirable in the following contexts.

ASA classification is superior for predicting postoperative mortality compared to other clinical information.[33] Moreover, surgery status in the existing HSMR model includes all medical procedures and all types of surgery, whereas ASA score measurement is limited to patients who underwent surgery under general anesthesia, which could have had an impact on the accuracy of mortality predictions. According to the results, patients with an ASA score of 3 to 6 points had higher odds of mortality, and the risk-adjustment model that included ASA scores showed greater explanatory power. These results support those of previous research showing that ASA is a major variable in predicting mortality among clinical information.[35]

Currently, comorbidities are adjusted by calculating CCI using administrative data for 1 year prior to hospitalization for HSMR assessment in South Korea. This can prevent the over-adjustment of patient conditions by excluding adverse events or complications that occurred at medical institutions. However, concerns regarding under-adjustment due to misinterpretation of pre-existing conditions remain. Therefore, using POA appears to be the ideal approach from both a clinical significance or statistical explanatory power perspective.[29-31] Our study also found that POA CCI had a higher explanatory power for death compared to CCI using administrative data. These results, along with those of previous studies, reinforce the value of using POA to predict patient mortality.

Cancer stage is an important factor for predicting treatment outcomes of patients with cancer.[27,28] However, according to a previous study, patients with cancer, who were repeatedly hospitalized for cancer therapy, had a lower mortality rate per hospitalization compared to patients without cancer in the short-term.[36] Our study results also suggest that cancer patients had lower mortality than those without cancer. Consequently, stage progression should be considered to ensure that severity is accurately adjusted. The increase in the explanatory power of the model when cancer stage was included suggests that the information related to this factor is insufficient in the existing model.

The ICU severity score showed an increase in explanatory power when replaced with administrative information. This could be attributed to the fact that patients admitted to the ICU accounted for only 6.3% of all patients, which could have been too small of a sample to have a significant influence. Moreover, in highly severe cases that resulted in death within a short time, the severity score may not have been measurable even though the patient was admitted to the ICU, which could have distorted the results.

However, if a standardized system is not established beforehand, many human resources may be exhausted in the collection of clinical information, making it difficult to ensure reliability and accuracy.[26-28,33] Regarding POA, the establishment of a POA management system has been mandatory only for tertiary hospital designation in South Korea since 2020.[37] Consequently, small- and medium-sized general hospitals may still face difficulties in collecting such information. Furthermore, POA could be over- or under-reported depending on the characteristics of medical institutions; however, previous studies have found that the impact of such over- or under-reporting on HSMR assessment results is insignificant.[38] Although the National Cancer Registry collects cancer-related data, determining the cancer stage at the time of hospitalization is difficult, as the project is limited to index cases. Additionally, various staging methods are used depending on the cancer type,[39] and ICU severity assessment tools used vary from one medical institution to another.[40] To use these in HSMR assessment, the measurement tools should be unified. In the long term, the validity of risk-adjusted models could be effectively enhanced by the stepwise addition of clinical information that can be collected through the establishment of an appropriate information system. Among these, the most rapidly implementable measure appears to be the POA data. The Korean government, in its first National Health Insurance Comprehensive Plan (2019–2023), announced the expansion of the POA information management system. Consequently, it is expected that once POA data is collected, it can be applied to the HSMR assessment.

Our study had some limitations. First, only five medical institutions were selected in this study. Therefore, additional studies must be conducted with more institutions to confirm the generalizability of the results. Nonetheless, our study was meaningful in that it mostly accounted for regional and size characteristics of medical institutions for HSMR assessment. Second, all clinical information used in the analysis was submitted by medical institutions and contained some missing values. Despite these limitations, our study also had the following strengths. First, it assessed the validity of Korean HSMR assessment models by linking clinical and administrative information from medical institutions. Second, it included all diseases targeted for HSMR assessment, rather than being limited to just some diseases. Lastly, it derived and comprehensively considered various clinical information that influences mortality and can be used as risk-adjustment variables, which has a major implication for relevant future studies.

In conclusion the HSMR assessment model improved when clinical data were adjusted compared to the model based solely on information recorded in the administrative data. Simultaneously, this study confirmed that the validity of the evalua-

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tion method could be secured even if some of the clinical information was sufficed with the information in the administrative data. In the future, the validity of the HSMR assessment model could be enhanced by collecting standardized clinical information from all medical institutions.

DATA AVAILABILITY STATEMENT

Permission to use the data must be obtained from the Health Insurance Review and Assessment Service.

AUTHOR CONTRIBUTIONS

Conceptualization: Hyeki Park, Ji-Sook Choi, Min Sun Shin, Hyekyoung Kim, Nahyeong Im, Soon Joo Park, Donggyo Shin, Youngmi Song, Yunjung Cho, Hyunmi Joo, Hyeryeon Hong, and Yong-Hwa Hwang. Data curation: Hyeki Park. Formal analysis: Hyeki Park. Funding acquisition: Choon-Seon Park. Investigation: Hyeki Park, Min Sun Shin, Soomin Kim, Hyekyoung Kim, and Nahyeong Im. Methodology: Hyeki Park, Ji-Sook Choi, and Min Sun Shin. Project administration: Hyeki Park. Resources: Choon-Seon Park. Software: Hyeki Park. Supervision: Choon-Seon Park. Validation: all authors. Visualization: Hyeki Park. Writing—original draft: Hyeki Park and Ji-Sook Choi. Writing—review & editing: Hyeki Park and Ji-Sook Choi. Approval of final manuscript: all authors.

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