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ORIGINAL ARTICLE

Evaluating the Performance of the Emergency Medical Services Index

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Background: In 2006 Emergency Medical Services Index (EMSI), which summarizes the performance of regional emergency medical services system, was developed. This study assesses the performance of the EMSI to help determine whether EMSI can be used as evaluation tool.

Methods: To build a composite score of the EMSI from predefined 24 indicators, 3 normalized values were calculated for each indicator, the normalized values of each indicator were weighted using 4 weighting methods, and the weighted values were aggregated into the final composite score using 2 aggregation schemes. The performance of EMSI was evaluated using 3 criteria: discrimination, construct validity, and sensitivity. Discrimination was the proportion of regions that did not include the overall median rank in the 5th to 95th percentiles rank interval, which was calculated from Monte Carlo simulation. Construct validity was a correlation among the alternative EMSIs. Sensitivity of EMSIs was evaluated by total shift of quartile membership and changes of 5th to 95th percentile intervals.

Results: The total discrimination performance of the EMSI was 50.0%. Correlation coefficients between EMSIs using standardized values and those using rescaled values ranged from 0.621 to 0.997. Variation of the quartile membership of regions ranged from 0.0% to 75.0%. The total change in the 5th to 95th percentile intervals ranged from -19 to +17 places.

Conclusion: The results suggested that the EMSI could be used as a tool for evaluating quality of regional EMS system and for identifying the areas for quality improvement.

Keywords: Emergency medical services; Quality assurance; Quality indicators, health care; Methods

INTRODUCTION

Improving the quality of the regional emergency medical services (EMS) system and promoting the accountability of its representatives are critical in advancing the EMS system's overall performance. The regionalization of the EMS system has generally resulted in improved patient care, reduced mortality rates for trauma patients, and lower costs, but a lack of accountability has contributed to poor problem identification and few improvements in quality [1,2]. Thus, the American College of Emergency Physicians evaluated their EMS system on a state by state basis to promote government policies for improving emergency care [3,4].

In Korea the EMS systems of different regions display a wide range of performance differences including trauma mortality rates and pre-hospital times [5,6]. To address some of the problems associated with these differences, the Ministry of Health and Welfare (MOHW) and the National Emergency Medical Center (NEMC) have evaluated the quality of emergency medical centers. However, because these programs focused only on emergency care at the hospital stage, other important aspects of the EMS systems, such as care at the pre-hospital stage and accountability of the regional governments, were not evaluated. Hence, in 2006, MOHW developed the Emergency Medical Services Index (EMSI) as a composite indicator to comprehensively evaluate the regional EMS system on a province by province basis [7]. The EMSI was expected to influence providers to focus on the quality of their EMS systems and to promote the accountability of the provincial governments in managing their EMS systems. The EMSI, however,

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was not validated for its own performance in the developing process by the MOHW.

Unlike individual indicators, composite indicators can summarize complex or multidimensional issues and are typically easier to interpret than attempting to determine a trend among many separate indicators. Additionally, composite indicators can place regional issues of performance and progress at the forefront of the policy arena, facilitate communication with ordinary citizens, and promote accountability. The construction of composite indicators, however, involves subjective judgments, such as the choice of an aggregation model or the weighting of the various indicators. These choices could bias policy messages and lend themselves to instrumental abuse [8-10].

Therefore, the purpose of this study was to assess the performance of the EMSI in terms of discrimination, construct validity, and sensitivity to help determine whether composite indicators can be used to evaluate the performance of regional EMS systems objectively and reliably.

METHODS

1. Evaluation Fields and Indicators of the Emergency Medical Services Index

The quality of 16 different regional EMS systems, including 9 provinces and 7 metropolitan regions, were evaluated using the EMSI. Evaluation fields of the EMSI consisted of six quality improvement areas: appropriateness and timeliness, safety and prevention, patient-centeredness, efficiency, equity, and planning and integration. Each of the six quality improvement areas were evaluated at the pre-hospital and hospital level for each EMS system.

An EMS meeting of experts using a Delphi panel selected the 24 indicators based on their perceived importance, scientific acceptability, usability, feasibility [11], and their ability to promote the accountability of the regional government managing each EMS system (Table 1). The EMS expert meeting was made up of 5 specialists in emergency medicine and quality improvement. The Delphi panel was composed of 10 members recommended by the Korean Society of Emergency Medicine, 5 consumer group representatives, 14 civil servants from the regional government, MOHW, NEMC, and the National Emergency Management Agency (NEMA). Each indicator was measured using a standard information form that included the definition of the indicator, available data sources, and calculation formulas. Multiple data sets were used to yield the value of indicators: data from the National Emergency Department Information System, claim data of the Health Insurance Review Assessment Service and National Health Insurance Service, annual statistical report of EMS of the NEMC, pre-hospital ambulance run report, National Acute Myocardial Infarction Project, emergency medical facility evaluation report, annual report on the cause of death statistics and emergency patient satisfaction survey. Table 2 shows calcu-

Table 1. Evaluation fields and indicators of Emergency Medical Services Index

	Pre-hospital	Hospital
Appropriateness & timeliness	No. of emergency medical technicians per population No. of emergency medical technicians per dimension No. of ambulances per population No. of ambulances per dimension Percentage of patients who were provided basic life support within 4 minutes by 119 rescue services Percentage of patients who were transported from scene to hospital within 10 (urban) or 30 minutes (rural)	Percentage of emergency room doctors who meet the requirements of the Emergency Medical Law Severity-adjusted mortality of trauma patients converted to W score Percentage of acute myocardial infarction patients who received thrombolytics within 30 minutes of hospital arrival Percentage of acute myocardial infarction patients who received percutaneous coronary intervention within 120 minutes of hospital arrival
Safety & prevention	Percentage of people with first aid education completed Mortality due to traffic injury	Percentage of transfer-out patients who were transferred in from other hospitals
Patient-centeredness	Percentage of patients who were satisfied with 119 rescue (pre-hospital) services	Percentage of patients who were satisfied with the emergency department services
Efficiency	Percentage of severe emergency patients using ambulance services Relevance index of utilization for the emergency room	Percentage of long-stay (over 6-hour stays in emergency room) patients
Equity	Coefficient of variation in transportation time	Percentage of patients who received subrogation payments for vulnerable groups
Planning & integration	EMS budget of the regional government per population No. of EMS officers of the regional government per population Completeness of the National Emergency Department Information System's data Qualitative assessment for the regional EMS committee	

EMS, emergency medical services.

lation methods and database used by each individual indicator.[1)]

2. Construction of the Emergency Medical Services Index

No single, standard methodology exists for constructing a composite score for a group of quality indicators [12,13]. Therefore, we followed the construction methodology suggested by the Joint Research Centre of the European Commission [8,9]. To build a composite score from 24 indicators, 3 normalized values were calculated for each indicator, the normalized values of each indicator were weighted, and the weighted values were aggregated into the final

Table 2. Information of indicators

Indicators	Calculation methods	Database
No. of emergency medical technicians per population	No. of emergency medical technicians /population of the region	Annual statistical report of EMS
No. of emergency medical technicians per dimension	No. of emergency medical technicians /dimension of the region	Annual Statistical report of EMS
No. of ambulances per population	No. of ambulances /population of the region	Annual statistical report of EMS
No. of ambulances per dimension	No. of ambulances /dimension of the region	Annual statistical report of EMS
Percentage of patients who were provided basic life support within 4 minutes by 119 rescue services	Patients provided basic life support within 4 minutes /patients transported by 119 rescue services	Pre-hospital ambulance run report
Percentage of patients who were transported from scene to hospital within 10 (urban) or 30 minutes (rural)	Patients transported from scene to hospital within 10 (urban) or 30 minutes (rural)/patients transported by 119 rescue services	Pre-hospital ambulance run report
Percentage of emergency room doctors who meet the requirements of the Emergency Medical Law	No. of emergency medical facilities met the requirements of emergency room doctors by the Emergency Medical Law/ no. of emergency medical facilities in the region	Emergency medical facility evaluation report
Severity-adjusted mortality of trauma patients converted to W score	Severity-adjusted mortality of trauma patients converted to W score by the regions	Claim data of the Health Insurance Review Assessment Service
Percentage of acute myocardial infarction patients who received thrombolytics within 30 minutes of hospital arrival	No. of acute myocardial infarction patients received thrombolytics within 30 minutes of hospital arrival/no. of acute myocardial infarction patients received thrombolytics within 6 hours of hospital arrival	National Acute Myocardial Infarction Project
Percentage of acute myocardial infarction patients who received percutaneous coronary intervention within 120 minutes of hospital arrival	No. of acute myocardial infarction patients received percutaneous coronary intervention within 120 minutes of hospital arrival/no. of acute myocardial infarction patients received percutaneous coronary intervention within 24 hours of hospital arrival	National Acute Myocardial Infarction Project
Percentage of people with first aid education completed	No. of people with first aid education completed/population	Annual statistical report of EMS
Mortality due to traffic injury	No. of deaths by traffic accidents/no. of vehicles of the region	Annual report on the cause of death statistics
Percentage of transfer-out patients who were transferred in from other hospitals	No. of transfer-out patients after emergency room visit/No. of transfer-in patients	National Emergency Department Information System
Percentage of patients who were satisfied with 119 rescue (pre-hospital) services	Percentage of patients who were satisfied with 119 rescue (pre-hospital) services	Emergency patient satisfaction survey
Percentage of patients who were satisfied with the emergency department services	Percentage of patients who were satisfied with the emergency department services	Emergency patient satisfaction survey
Percentage of severe emergency patients using ambulance services	No. of patients using ambulance services/no. of severe emergency patients	National Emergency Department Information System
Relevance index of utilization for the emergency room	Relevance index of utilization for the emergency room of the region	Claim data of the Health Insurance Review Assessment Service and National Health Insurance Service
Percentage of long-stay (over 6-hour stays in emergency room) patients	No. of patients stayed over 6-hours in emergency room/no. of emergent patients of the region	National Emergency Department Information System
Coefficient of variation in transportation time	Coefficient of variation in transportation time of the region	Pre-hospital ambulance run report
Percentage of patients who received subrogation payments for vulnerable groups	No. of patients received subrogation payments for vulnerable groups/no. of emergency patients of the region	Claim data of the Health Insurance Review Assessment Service, annual statistical report of EMS
Completeness of the National Emergency Department Information System's data	No. of complete inputs of required data fields/no. of emergency patients of the region	National Emergency Department Information System
Qualitative assessment for the regional EMS committee	Qualitative assessment for the regional EMS committee	Data of each regional governments

EMS, emergency medical services.

1) The report presented by Kim et al. [7] contains detail information about the selection process and calculation methods of EMSI indicators developed by MOHW.

composite score.

First, for the normalizations, real values of indicators were transformed to dimensionless numbers using 3 normalization methods including standardization, rescaling, and ranking. Table 3 shows real values of indicators. In the standardization method, indicators were converted to a common scale with a mean of zero and standard deviation of 1 (Equation 1) so that all the standardized values had similar dispersion across the regions.

(Equation 1)

$$\text{Standardized value} = \frac{\text{real value of province-average across provinces}}{\text{standard deviation across provinces}}$$

In the rescaling method, real values of indicators were normalized to have an identical range (0; 1) (Equation 2).

(Equation 2)

$$\text{Rescaled value} = \frac{\text{real value of province - minimum value across all the provinces}}{\text{maximum value across all the provinces - minimum value across all the provinces}}$$

When geometrically aggregating, to avoid negative or zero values of indicators, a constant greater than the negative standardized or rescaled value, three or one for each, was added to the former value [14]. In the ranking method, the highest score was assigned to the best performer, and the lowest score was assigned to the worst performer. If two or more regions were ranked to the same position, all of those same ranks were given a better score that was very close to the highest score. All indicators were transformed when necessary to "more is better" variables [15].

Second, to reflect the relative importance of each indicator to the EMSI, weights were assigned to each normalized value of the indicators using four different weighting methods: equal weighting, expert weighting, weighting by factor analysis, and weighting by area under the receiver operating characteristic curve (AUC). Expert weighting was calculated by multiplying an average score of importance of an indicator by a score of relative importance among the six evaluation areas that resulted from two rounds of the Delphi survey (Appendix 1). Weighting by factor analysis was calculated by multiplying the factor loading by proportion of the explained variance. For weighting by AUC, a simple logistic regression analysis was repeatedly performed for each indicator using rescaled values of indicators as independent variables and W statistics calculated from the severity-adjusted mortality of emergency patients as the dependent variable. The W statistic is the difference between the actual and the predicted numbers of survivors, divided by the total number of patients per 100 patients. Usually, weights based on regression approach were calculated from multiple regression models. However, instead of using coefficients of the regression model as weighting scores, AUCs were

Table 3. Measured values of indicators

Region	EMT-p	EMT-d	Amb-p	Amb-d	TA	1st-edu	sev- Amb	vTT	ER-Dr	W- trauma	TL	PCI	LS	SRG	reT	Com	Budget	NEDISc	Officer	RI	PE-ED	PE-119	BLS	ALS
A	46.8	48.2	22.9	23.6	3.7	64.0	21.4	85.5	100.0	0.85	13.8	65.6	22.8	0.2	3.0	6.0	0.4	89.8	0.6	14.6	84.8	93.5	39.0	31.1
B	155.9	13.9	68.2	6.1	6.5	21.3	17.4	102.4	80.0	-0.11	28.6	64.7	23.0	9.4	6.4	0.0	1.1	89.7	0.5	19.0	81.1	70.5	27.1	77.7
C	98.3	28.7	50.1	14.6	5.0	88.3	12.0	113.1	100.0	-0.19	12.9	28.6	2.2	24.5	0.0	0.0	0.4	87.5	0.2	9.0	76.8	76.9	63.7	67.2
D	55.5	150.1	18.5	50.0	3.2	27.1	30.2	67.4	80.0	0.66	2.9	67.4	22.0	10.4	3.5	0.0	0.4	88.2	0.2	12.1	60.5	82.3	37.3	19.4
E	46.8	776.3	11.0	181.7	2.7	74.6	21.9	47.6	92.3	0.00	8.1	48.8	18.5	4.1	3.8	1.0	0.2	84.3	0.0	12.8	73.0	82.3	24.6	68.9
F	54.9	158.3	18.0	52.0	4.3	35.6	13.6	61.8	80.0	0.13	4.3	67.4	44.8	5.9	9.0	4.0	0.4	90.4	0.2	10.8	65.3	75.4	47.7	36.4
G	98.8	21.9	49.4	10.9	9.0	48.0	52.9	64.1	100.0	-0.70	19.0	40.0	5.6	2.8	3.7	1.0	0.2	88.5	0.4	31.4	64.1	65.8	27.1	62.0
H	70.2	9.8	41.5	5.8	8.0	19.9	32.9	83.4	100.0	-0.47	26.5	46.2	4.4	4.7	5.4	0.0	0.4	86.6	0.2	28.4	81.3	79.6	27.0	76.6
I	52.1	245.9	15.8	74.6	4.2	195.4	47.6	79.4	50.0	-0.19	19.8	61.1	38.0	4.8	7.9	1.0	0.3	92.2	0.1	12.5	51.7	54.7	31.6	58.4
J	91.6	26.9	34.6	10.2	6.2	49.2	45.1	94.1	75.0	-0.42	21.4	66.7	32.0	1.7	6.9	1.0	0.3	90.0	0.4	29.2	73.9	51.9	30.3	68.5
K	42.8	111.7	16.6	43.3	3.7	38.3	19.3	135.5	100.0	-0.17	19.6	39.4	10.4	8.4	2.0	0.0	0.5	88.2	0.2	23.5	86.8	89.3	28.2	24.7
L	49.8	10.0	52.4	10.5	6.1	27.6	17.2	82.9	66.7	-0.42	16.7	56.3	22.5	3.8	4.5	2.0	0.4	88.4	0.1	25.6	78.5	81.0	26.3	78.3
M	85.2	19.2	39.6	8.9	8.1	41.5	28.4	92.6	83.3	-0.50	10.2	65.5	36.8	5.2	16.3	0.0	0.6	87.7	0.3	18.1	74.1	83.0	21.6	63.9
N	78.9	12.1	45.9	7.0	11.3	32.7	20.1	134.7	62.5	-0.56	33.3	52.6	5.5	1.5	9.2	1.0	0.5	88.3	0.3	24.8	85.9	81.3	26.6	76.2
O	61.4	175.5	16.7	47.9	4.7	46.9	28.4	86.4	60.0	-0.78	13.6	52.3	42.8	0.2	19.9	0.0	0.5	89.5	0.2	12.3	80.6	83.2	22.6	41.3
P	40.1	42.4	18.9	19.9	3.9	11.8	9.4	108.5	88.9	-0.30	13.8	46.7	25.0	3.4	1.8	0.0	0.2	87.0	0.1	24.6	75.2	83.0	18.8	86.8

EMT-p, no. of emergency medical technician per population; EMT-d, no. of emergency medical technician per dimension; Amb-p, no. of ambulance per population; Amb-d, no. of ambulance per dimension; TA, mortality due to traffic injury; 1st-edu, percentage of first aid education completed; sev-Amb, percentage of severe emergent patients using ambulance services; vTT, variations in transportation time; ER-Dr, percentage of emergency room doctors that meet the requirements; W-trauma, severity adjusted mortality of trauma patients; TL, thrombolytics received within 30 minutes of hospital arrival; PCI, percutaneous coronary intervention (PCI received within 120 minutes of hospital arrival); LS, percentage of long-stay patients; SRG, subrogation payments for vulnerable groups; reT, percentage of retransfer; Com, regional EMS committee; Budget, EMS budget of regional government; NEDISc, National Emergency Department Information System (completeness of NEDIS data); Officer, no. of EMS officer of regional government; RI, regional relevance index; PE-ED, patients' experiences evaluation for the emergency departments; PE-119, patients' experiences evaluation for the 119 rescue services; BLS, elapsed time to providing basic life supports; ALS, elapsed time to providing advanced life supports.

used for weighting because when correlations among the indicators are strong, and regression coefficients cannot estimate the effect of indicators on the index due to multicollinearity [8]. Because of the statistically significant correlation among the indicators of the EMSI in this study, the AUC derived using a simple logistic regression analysis was used to weight each indicator. It was regarded as an event when rescaled W statistics were ≥ 0.5 but not an event when <0.5.

Finally, weighted normalized values of indicators were aggregated using linear (Equation 3) and geometric schemes (Equation 4).

(Equation 3)

$$\text{EMSI} = \sum \text{normalized value} \times \text{weight}$$

(Equation 4)

$$\text{EMSI} = \prod \text{normalized value}^{\text{weight}}$$

3. Evaluating the performance of the Emergency Medical Services Index

Twenty-four alternative EMSIs could be constructed and were expressed as "EMSI_{ijk}," where i is the type of normalization, j is the type of weighting scheme, and k is the type of aggregation system (Figure 1). The performance of EMSI was evaluated using three criteria: discrimination, construct validity, and sensitivity. Discrimination is the ability of the EMSI to differentiate performance as measured by statistically significant deviations from the median performance [16,17]. Considering the uncertainties in EMSI building, a Monte Carlo simulation was conducted. The output variable was the EMSI rank for a region and the input factors were the type of normalization for the indicators (standardization, rescaling, and ranking), the weighting scheme (equal weights, expert weights, weights by factor analysis, and weights by AUC), and the aggregation methods (linear and geometric). Uncertain input factors (k) were sampled from a discrete uniform distribution in a quasi-random sampling scheme using a base sample of size n = 512. EMSI ranks per region were calculated by performing 2n (k + 1) = 4096 simulations [10]. Regions were classified into a high performer group when the 95th percentile of the EMSI ranks for the region was equal to or better than median, a low performer group when the 5th percentile of the EMSI ranks was equal to or worse than the median, or a middle performer group if otherwise. The measure of discrimination of performance was expressed as the sum of the percentages of the high and low performers.

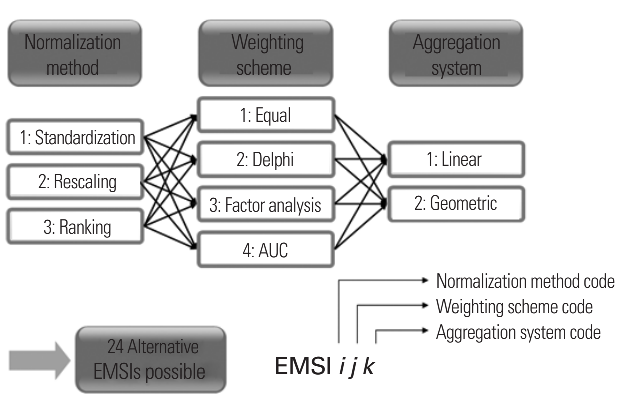

Figure 1. Alternative EMSIs. AUC, area under the receiver operating characteristic curve; EMSI, Emergency Medical Services Index.

Construct validity is the degree of association between the composite and other aggregate measures of quality [16-18]. In this study, for looking primarily at the consistency among the alternative EMSIs, construct validity was operationally defined as a correlation among the alternative EMSIs.

Sensitivity of ranks due to different construction rules was assessed based on the total shift of the quartile membership. The regions were classified into quartiles, and thus ranking variations that provoked a shift from one quartile to another were reported [19]. In addition, the influence of each component of the construction method was assessed by total change in the 5th to 95th percentile intervals of the EMSI ranks when any one method (e.g., standardization or equal weights) was excluded from the EMSI construction methodology. The analysis was undertaken in SimLab ver. 2.2.1 (Joint Research Centre of the European Commission, Brssels, Belgium), SAS ver. 9.1 (SAS Institute Inc., Cary, NC, USA), SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA), and Microsoft Excel 2003.

RESULTS

1. Discrimination Performance

Four high performers and four low performers were detected among the 16 regions and thus the total discrimination performance of the overall EMSI was 50.0%. For the EMSI based on the stages of the EMS system, the total discrimination performance of the pre-hospital stage EMSI was 68.8% and that of the hospital stage EMSI was 56.3%. For the EMSI based on the evaluation areas, the total discrimination performance was 50.0% for the appropriateness and timeliness area, 87.5% for the safety and prevention area, 100.0% in the patient-centeredness area, 68.8% in both the efficiency and equity areas, and 75.0% in the planning and integration area (Figure 2).

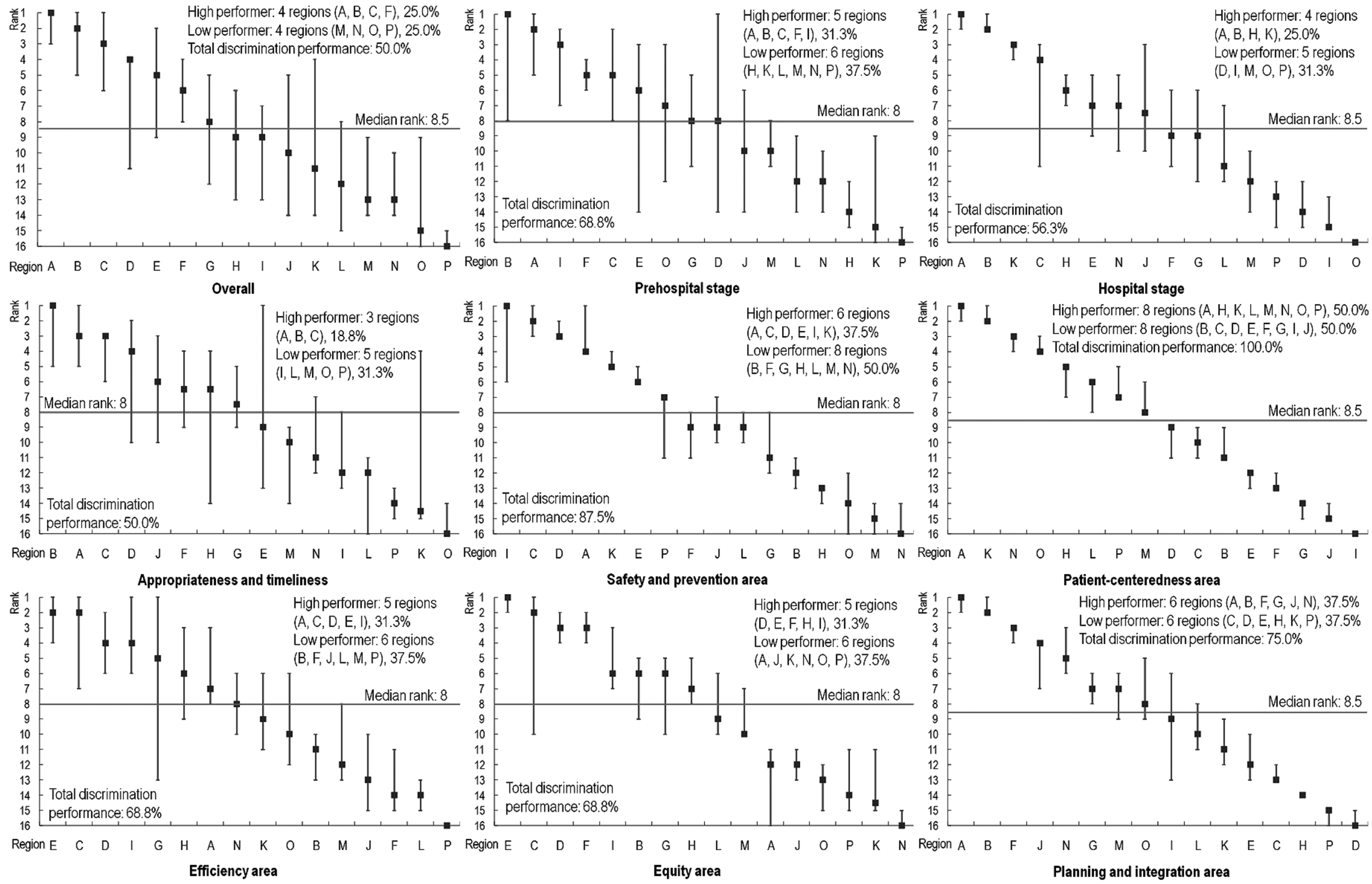

Figure 2. Results of uncertainty analysis on Emergency Medical Services Index (EMSI) ranks. The median (■) and the corresponding 5th and 95th percentiles (bounds) of the EMSIs for 16 regions.

2. Construct Validity

Spearman's rank correlation coefficients among the alternative EMSIs ranged from 0.309 to 0.997. Correlation coefficients between EMSIs using standardized values and those using rescaled values ranged from 0.621 to 0.997. However, correlation coefficients between EMSIs using ranked values and those using standardized or rescaled values were of relatively lower levels that ranged from 0.309 to 0.879 (Table 4).

3. Sensitivity

The EMSI111 rank was used as reference value for each region. Variation of the quartile membership of regions ranged from 0.0% to 75.0% such that the placements of the regions did not remain in the same quartile with the EMSI111 reference rank. For EMSI using standardized (EMSI1jk) and rescaled values (EMSI2jk), total shift in quartile membership ranged from 0.0% to 56.3% and from 0.0% to 50.0%, respectively. However, in the case of the EMSI using ranked values (EMSI3jk), percentages of the quartile membership shift were relatively higher (range, 31.3% to 75.0%) than for the other EMSIs. Additionally, the order of two or more shifts in the quartile membership was higher in EMSI3jk than in EMSI1jk or EMSI2jk (Table 5).

The total change in the 5th to 95th percentile intervals ranged from -19 to +17 places and when the ranked values were excluded from the uncertainty analysis, the uncertainty interval exhibited the greatest reduction (-18 places). When either the expert weights or the geometric aggregation was removed from the analysis, the uncertainty interval was reduced by one place or five places, respectively (Table 6).

DISCUSSION

We evaluated the performance of the EMS systems of 16 regions in Korea based on terms of discrimination, construct validity, and

Table 4. Correlation of alternative EMSIs

	EMSI111	EMSI121	EMSI131	EMSI141	EMSI112	EMSI122	EMSI132	EMSI142	EMSI211	EMSI221	EMSI231	EMSI241	EMSI212	EMSI222	EMSI232	EMSI242	EMSI311	EMSI321	EMSI331	EMSI341	EMSI312	EMSI322	EMSI332	EMSI342
EMSI111	1.000	0.909†	0.976†	0.909†	0.894†	0.726†	0.974†	0.782†	0.991†	0.871†	0.968†	0.865†	0.979†	0.832†	0.979†	0.806†	0.873†	0.812†	0.853†	0.747†	0.776†	0.712†	0.812†	**0.524***
EMSI121	0.909†	1.000	0.879†	0.824†	0.912†	0.891†	0.909†	0.759†	0.921†	0.968†	0.874†	0.806†	0.929†	0.974†	0.876†	0.756†	0.735†	0.724†	0.703†	**0.553***	0.612*	0.653†	0.656†	**0.382**
EMSI131	0.976†	0.879†	1.000	0.874†	0.879†	0.735†	0.982†	0.774†	0.976†	0.865†	0.997†	0.844†	0.968†	0.821†	0.997†	0.776†	0.837†	0.776†	0.871†	0.697†	0.756†	0.679†	0.812†	**0.476**
EMSI141	0.909†	0.824†	0.874†	1.000	0.874†	0.621*	0.874†	0.906†	0.912†	0.797†	0.856†	0.982†	0.900†	0.738†	0.876†	0.944†	0.879†	0.815†	0.765†	0.829†	0.785†	0.712†	0.768†	0.697†
EMSI112	0.894†	0.912†	0.879†	0.874†	1.000	0.859†	0.915†	0.912†	0.926†	0.897†	0.871†	0.888†	0.950†	0.879†	0.876†	0.882†	0.754†	0.741†	0.724†	0.621*	0.741†	0.685†	0.729†	**0.585***
EMSI122	0.726†	0.891†	0.735†	0.621*	0.859†	1.000	0.774†	0.685†	0.768†	0.909†	0.744†	0.659†	0.806†	0.953†	0.732†	0.638†	**0.515***	0.603*	**0.565***	**0.309**	**0.532***	0.618*	**0.553***	**0.312**
EMSI132	0.974†	0.909†	0.982†	0.874†	0.915†	0.774†	1.000	0.809†	0.982†	0.874†	0.976†	0.847†	0.974†	0.850†	0.979†	0.806†	0.844†	0.803†	0.865†	0.709†	0.785†	0.709†	0.829†	**0.518***
EMSI142	0.782†	0.759†	0.774†	0.906†	0.912†	0.685†	0.809†	1.000	0.821†	0.768†	0.756†	0.944†	0.835†	0.715†	0.768†	0.979†	0.742†	0.712†	0.647†	0.703†	0.756†	0.641†	0.712†	0.747†
EMSI211	0.991†	0.921†	0.976†	0.912†	0.926†	0.768†	0.982†	0.821†	1.000	0.894†	0.971†	0.888†	0.994†	0.862†	0.979†	0.829†	0.873†	0.824†	0.865†	0.747†	0.785†	0.732†	0.821†	**0.547***
EMSI221	0.871†	0.968†	0.865†	0.797†	0.897†	0.909†	0.874†	0.768†	0.894†	1.000	0.868†	0.806†	0.918†	0.974†	0.862†	0.756†	0.649†	0.641†	0.647†	**0.471**	**0.532***	**0.574***	**0.574***	**0.321**
EMSI231	0.968†	0.874†	0.997†	0.856†	0.871†	0.744†	0.976†	0.756†	0.971†	0.868†	1.000	0.829†	0.962†	0.824†	0.994†	0.756†	0.816†	0.765†	0.865†	0.674†	0.741†	0.671†	0.797†	**0.447**
EMSI241	0.865†	0.806†	0.844†	0.982†	0.888†	0.659†	0.847†	0.944†	0.888†	0.806†	0.829†	1.000	0.888†	0.747†	0.847†	0.962†	0.837†	0.788†	0.729†	0.791†	0.765†	0.706†	0.744†	0.721†
EMSI212	0.979†	0.929†	0.968†	0.900†	0.950†	0.806†	0.974†	0.835†	0.994†	0.918†	0.962†	0.888†	1.000	0.882†	0.971†	0.835†	0.835†	0.788†	0.832†	0.700†	0.756†	0.706†	0.785†	**0.532***
EMSI222	0.832†	0.974†	0.821†	0.738†	0.879†	0.953†	0.850†	0.715†	0.862†	0.974†	0.824†	0.747†	0.882†	1.000	0.818†	0.697†	0.649†	0.685†	0.665†	**0.453**	**0.562***	0.650†	0.606*	**0.326**
EMSI232	0.979†	0.876†	0.997†	0.876†	0.876†	0.732†	0.979†	0.768†	0.979†	0.862†	0.994†	0.847†	0.971†	0.818†	1.000	0.779†	0.848†	0.779†	0.879†	0.718†	0.759†	0.682†	0.815†	**0.497**
EMSI242	0.806†	0.756†	0.776†	0.944†	0.882†	0.638†	0.806†	0.979†	0.829†	0.756†	0.756†	0.962†	0.835†	0.697†	0.779†	1.000	0.779†	0.729†	0.671†	0.771†	0.776†	0.644†	0.721†	0.788†
EMSI311	0.873†	0.735†	0.837†	0.879†	0.754†	**0.515***	0.844†	0.742†	0.873†	0.649†	0.816†	0.837†	0.835†	0.649†	0.848†	0.779†	1.000	0.931†	0.923†	0.940†	0.872†	0.844†	0.919†	0.719†
EMSI321	0.812†	0.724†	0.776†	0.815†	0.741†	0.603*	0.803†	0.712†	0.824†	0.641†	0.765†	0.788†	0.788†	0.685†	0.779†	0.729†	0.931†	1.000	0.879†	0.824†	0.909†	0.974†	0.932†	0.659†
EMSI331	0.853†	0.703†	0.871†	0.765†	0.724†	**0.565***	0.865†	0.647†	0.865†	0.647†	0.865†	0.729†	0.832†	0.665†	0.879†	0.671†	0.923†	0.879†	1.000	0.844†	0.874†	0.812†	0.938†	0.621*
EMSI341	0.747†	**0.553***	0.697†	0.829†	0.621*	**0.309**	0.709†	0.703†	0.747†	**0.471**	0.674†	0.791†	0.700†	**0.453**	0.718†	0.771†	0.940†	0.824†	0.844†	1.000	0.847†	0.724†	0.847†	0.844†
EMSI312	0.776†	0.612*	0.756†	0.785†	0.741†	**0.532***	0.785†	0.756†	0.785†	**0.532***	0.741†	0.765†	0.756†	**0.562†**	0.759†	0.776†	0.872†	0.909†	0.874†	0.847†	1.000	0.885†	0.965†	0.824†
EMSI322	0.712†	0.653†	0.679†	0.712†	0.685†	0.618*	0.709†	0.641†	0.732†	**0.574***	0.671†	0.706†	0.706†	0.650†	0.682†	0.644†	0.844†	0.974†	0.812†	0.724†	0.885†	1.000	0.897†	0.635†
EMSI332	0.812†	0.656†	0.812†	0.768†	0.729†	**0.553**	0.829†	0.712†	0.821†	**0.574***	0.797†	0.744†	0.785†	0.606*	0.815†	0.721†	0.919†	0.932†	0.938†	0.847†	0.965†	0.897†	1.000	0.735†
EMSI342	**0.524***	**0.382**	**0.476**	0.697†	**0.585***	**0.312**	**0.518***	0.747†	**0.547***	**0.321**	**0.447**	0.721†	**0.532***	**0.326**	**0.497**	0.788†	0.719†	0.659†	0.621*	0.844†	0.824†	0.635†	0.735†	1.000

Spearman's rank correlation coefficients. Correlation coefficients in boldface are not good correlation (<0.6).
EMSI, Emergency Medical Services Index.
*$p<0.05$. †$p<0.01$.

Table 5. Sensitivity of ranks due to different computation rules compared to EMSI111

	Order 1 shift of quartile membership (%)		Order 2 shift of quartile membership (%)		Order 3 shift of quartile membership (%)		Total shift of quartile membership (%)
	↑	↓	↑	↓	↑	↓	
EMSI121	25.0	25.0	0.0	0.0	0.0	0.0	50.0
EMSI131	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMSI141	18.8	18.8	0.0	0.0	0.0	0.0	37.5
EMSI112	18.8	18.8	0.0	0.0	0.0	0.0	37.5
EMSI122	25.0	12.5	6.3	12.5	0.0	0.0	56.3
EMSI132	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMSI142	25.0	12.5	0.0	6.3	0.0	0.0	43.8
EMSI211	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMSI221	18.8	18.8	0.0	0.0	0.0	0.0	37.5
EMSI231	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMSI241	18.8	18.8	0.0	0.0	0.0	0.0	37.5
EMSI212	6.3	6.3	0.0	0.0	0.0	0.0	12.5
EMSI222	25.0	25.0	0.0	0.0	0.0	0.0	50.0
EMSI232	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EMSI242	25.0	12.5	0.0	6.3	0.0	0.0	43.8
EMSI311	18.8	18.8	0.0	0.0	0.0	0.0	37.5
EMSI321	12.5	12.5	6.3	6.3	0.0	0.0	37.5
EMSI331	18.8	12.5	0.0	6.3	0.0	0.0	37.5
EMSI341	18.8	37.5	12.5	0.0	0.0	0.0	68.8
EMSI312	18.8	6.3	0.0	6.3	0.0	0.0	31.3
EMSI322	18.8	12.5	6.3	0.0	0.0	6.3	43.8
EMSI332	18.8	6.3	0.0	6.3	0.0	0.0	31.3
EMSI342	25.0	25.0	12.5	12.5	0.0	0.0	75.0

EMSI, Emergency Medical Services Index.

Table 6. Change in the 5th–95th percentile intervals after excluding any one method from the Emergency Medical Services Index construction methodology

Excluded method	Change in the 5th-95th percentile intervals by region																Total change in the 5th-95th percentile interval
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
Standardization	0	-1	+1	+3	+1	0	+1	+2	0	+1	0	0	+2	+1	0	0	+11
Rescaling	0	0	+1	+3	+2	0	+1	+1	+3	+2	0	0	+2	0	0	+1	+16
Ranking	0	-3	-3	-2	-2	0	0	-2	+3	+1	-3	-3	0	+1	-6	+1	-18
Equal weights	0	0	+1	+3	+2	0	+1	+2	+2	+2	0	0	+2	+1	0	+1	+17
Expert weights	0	0	-2	0	-2	0	+1	0	+3	-3	-2	0	+2	+1	0	+1	-1
Weights by factor analysis	-1	0	-1	+3	+1	-1	-1	+2	+3	+2	0	0	+2	+1	0	+1	+11
Weights by AUC	0	0	+1	+3	+2	0	-1	+1	0	-1	0	0	0	0	-3	0	+2
Linear aggregation	0	0	0	+3	+2	0	-1	0	+2	+2	0	-3	+2	0	0	+1	+8
Geometric aggregation	0	-1	0	0	0	0	0	+1	0	-1	0	-3	-2	+1	0	0	-5

AUC, area under the receiver operating characteristic curve.

sensitivity. With regard to uncertainty of the EMSI rankings, the Monte Carlo simulation showed that the 5th to 95th percentile intervals of the EMSI ranks ranged from 1 to 10 places and exhibited 5 places or more in 11 of the regions. Regions D and E were not included in the high performer group although their medians were at a better level than that of region F. Such an uncertainty of the EMSI rank order suggested that using only the median rank of a region for reporting the performance of the regional EMS system is not appropriate. When uncertainty intervals around the EMSI ranks are estimated by repeated simulations, considerable overlap can exist among the distribution of EMSI ranks [15]. Therefore, in this study, the performance of the regional EMS system was presented as the "better or worse than the median" rank across regions. However, other cutoff criteria might be considered such as grouping by regions of which the uncertainty intervals overlap with each other.

Discrimination performance of the overall EMSI was 50.0% and those of the stage and evaluation area EMSI ranged from 56.3% to 68.8% and from 50.0% to 100.0%, respectively. For construct validity, correlation between the EMSIs using standardized and rescaled values was strong (Spearman's rho = 0.621-0.997). For the cases including the patient safety indicators (PSIs) and inpatient quality indicators (IQIs), the composite measure developed by the Agency for Healthcare Research and Quality (AHRQ), the discrimination performance of PSIs ranged from 11.6% to 40.9%; that of IQIs ranged from 2.9% to 14.1% for selected procedures and from 6.7% to 29.7% for selected conditions. Correlation coefficients of PSIs ranged from 0.517 to 0.962; those of IQIs ranged from 0.159 to 0.846 for selected procedures and from 0.559 to 0.999 for selected conditions [16,17]. As above, these results suggest that discrimination performance and construct validity of the EMSI were reasonable.

Total shift in the quartile membership was less than 60% with the exception of EMSI34k. The stability of EMSI rankings was better than some other composite measures developed for evaluating the quality of life in Italy [19], but the variations in the EMSI rankings were considerable. When excluding the ranked values, expert weights, or geometric aggregation, the total change in the 5th to 95th percentile intervals decreased, although rank variation decreased only slightly with regard to expert weights and geometric aggregation. However, excluding the latter two methods from the construction methodology for the EMSI might not be appropriate because expert weights typically reflect the directions of EMS policies and improve the legitimacy of the overall performance evaluation. Moreover, geometric aggregation can be a solution for full compensability of additive aggregation: "poor performance in some indicators can be compensated by sufficiently high values of other indicators" [8,9]. Among the normalization methods, normalization by ranking had the greatest effect on reducing the rank variations and exhibited the lowest construct validity. Ranking was not affected by outliers, but lost information on absolute levels such that no conclusion could be drawn about differences in performance [8,9]. Accordingly, using ranked values in constructing the EMSI may not be appropriate. The 5th to 95th percentile intervals of the EMSI ranks was most increased when re-scaling, equal weights, and linear aggregation methods were excluded. This yielding method could be used a representative technique for constructing EMSI because it can minimize the uncertainty of regional EMSI ranks through constructing EMSI using various methods. However, it could not be the absolute golden standard for constructing EMSI. Therefore, it will be an ideal process that all stakeholders participate in the process of constructing EMSI and make consensus regarding yielding method.

Using the results of discrimination performance, the quality

Table 7. Quality differences in the regional EMS systems

Region	Overall performance	Performance by stage		Performance by evaluation area					
		Pre-hospital	Hospital	Appropriateness & timeliness	Safety & prevention	Patient-centeredness	Efficiency	Equity	Planning & integration
A	High	High	High	High	High	High	High	Low	High
B	High	High	High	High	Low	Low	Low	Middle	High
C	High	High	Middle	High	High	Low	High	Middle	Low
D	Middle	Middle	Low	Middle	High	Low	High	High	Low
E	Middle	Middle	Middle	Middle	High	Low	High	High	Low
F	High	High	Middle	Middle	Low	Low	Low	High	High
G	Middle	Middle	Middle	Middle	Low	Low	Middle	Middle	High
H	Middle	Low	High	Middle	Low	High	Middle	High	Low
I	Middle	High	Low	Low	High	Low	High	High	Middle
J	Middle	Middle	Middle	Middle	Middle	Low	Low	Low	High
K	Middle	Low	High	Middle	High	High	Middle	Low	Low
L	Middle	Low	Middle	Low	Low	High	Low	Middle	Middle
M	Low	Low	Low	Low	Low	High	Low	Middle	Middle
N	Low	Low	Middle	Middle	Low	High	Middle	Low	High
O	Low	Middle	Low	Low	Low	High	Middle	Low	Middle
P	Low	Low	Low	Low	Middle	High	Low	Low	Low

EMS, emergency medical services; High, high performer; Middle, middle performer; Low, low performer.

differences in the regional EMS systems are summarized in Table 7. The overall high performer group of regions A, B, C, and F showed by and large, better performance at the pre-hospital and hospital stages than either the middle or low performer group. This overall performance result was similar to the performance result for the appropriateness and timeliness area, probably because this area was regarded as more important than other areas to EMSI developers, with more indicators consequently being included. EMSI developed by MOHW equally weighted each individual indicator and weighted differently among evaluation fields: appropriateness and timeliness area (40%); safety and prevention area (10%); patient-centeredness area (10%); efficiency (10%); equity area (10%); and planning and integration area (20%) [7]. That is, the field of appropriateness and timeliness is being considered as more important policy priority in EMS.

The performance at the planning and integration area, however, was not consistent with the overall performance because of little variation in performance for this area. Yet, the absolute values of indicators in this area were very poor except for completeness of the National Emergency Department Information System's data. This suggests that the absolute values of indicators should be considered in addition to the relative differences among the regions when evaluating the performance of regional EMS systems.

The EMSI has an inherent limitation, namely, a lack of data for measuring the quality indicators of the EMSI. The lack of relevant data is the greatest problem when constructing a composite indicator [20] and the major barrier to quality improvement of the EMS system [2,21,22]. Here, for developing the EMSI, nine different indicators (e.g., preventable trauma death rate) were not included among the final indicators of the EMSI simply because no data were available. In Korea the development of information systems for the evaluation of EMS systems are now in progress and should contribute to the construction of more stable and valid EMSIs for the quality improvement of EMS systems in the future.

This is the first study to investigate the performance of composite indicators for evaluating EMS systems. We presented the methodology for evaluating the performance of composite indicators and reported the results of this performance. Our findings should be useful to establish policies for the quality improvement of EMS systems as well as to support and promote the accountability of the regional governments for managing their EMS systems both financially and technically.

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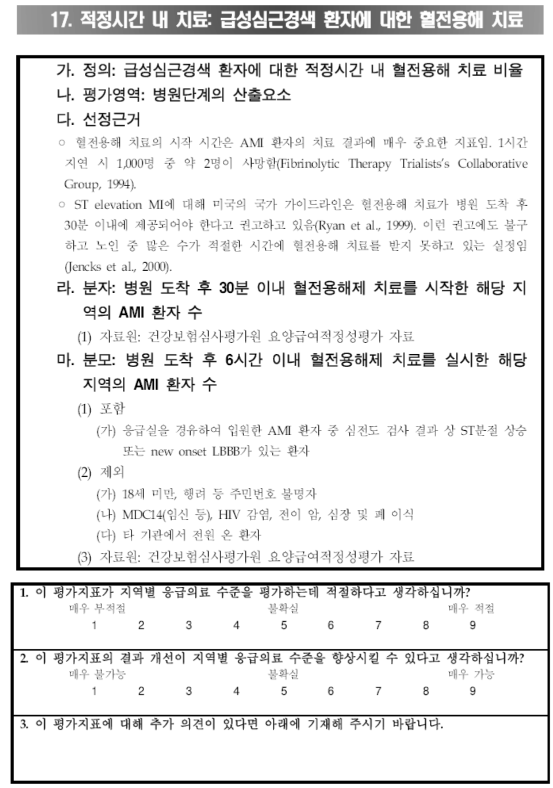
Appendix 1. Weighting method by Delphi survey

The Delphi panel was composed of 10 members recommended by the Korean Society of Emergency Medicine, 5 consumer group representatives, 14 civil servants from the regional government, the Ministry of Health and Welfare, the National Emergency Medical Center, and the National Emergency Management Agency. Panel members independently answered two main questions with 9 point Likert scale: 1) whether individual indicator can appropriately evaluate regional emergency medical services (EMS) quality and 2) whether improvement of indicator means enhancement of regional EMS status (Figure 3). Also, weights of each evaluation field were measured.

The survey was performed from November, 2006 to January, 2007 with 2 rounds. The results of 1st round were presented according to each indicator during the 2nd round survey. The response rates of individual question were distributed between 85.2% and 88.9%. Weighting by Delphi method was calculated by multiplying an average score of importance of an indicator by a score of relative importance among the six evaluation areas that resulted from two rounds of the Delphi survey.

The results of Delphi shows that the weights of individual indicator (A) ranged between 12.13 and 15.96; and the weights of evaluation fields (B) distributed between 0.096 and 0.365. Weights by Delphi method were 1.186 to 5.818 calculated by multiplying (A) and (B) (Table 8).


17. 적정시간 내 치료: 급성심근경색 환자에 대한 혈전용해 치료

가. 정의: 급성심근경색 환자에 대한 적정시간 내 혈전용해 치료 비율
나. 평가영역: 병원단계의 산출요소
다. 선정근거
○ 혈전용해 치료의 시작 시간은 AMI 환자의 치료 결과에 매우 중요한 지표임. 1시간 지연 시 1,000명 중 약 2명이 사망함(Fibrinolytic Therapy Trialists's Collaborative Group, 1994).
○ ST elevation MI에 대해 미국의 국가 가이드라인은 혈전용해 치료가 병원 도착 후 30분 이내에 제공되어야 한다고 권고하고 있음(Ryan et al., 1999). 이런 권고에도 불구하고 노인 중 많은 수가 적절한 시간에 혈전용해 치료를 받지 못하고 있는 실정임(Jencks et al., 2000).
라. 분자: 병원 도착 후 30분 이내 혈전용해제 치료를 시작한 해당 지역의 AMI 환자 수
(1) 자료원: 건강보험심사평가원 요양급여적정성평가 자료
마. 분모: 병원 도착 후 6시간 이내 혈전용해제 치료를 실시한 해당 지역의 AMI 환자 수
(1) 포함
(가) 응급실을 경유하여 입원한 AMI 환자 중 심전도 검사 결과 상 ST분절 상승 또는 new onset LBBB가 있는 환자
(2) 제외
(가) 18세 미만, 행려 등 주민번호 불명자
(나) MDC14(임신 등), HIV 감염, 전이 암, 심장 및 폐 이식
(다) 타 기관에서 전원 온 환자
(3) 자료원: 건강보험심사평가원 요양급여적정성평가 자료

1. 이 평가지표가 지역별 응급의료 수준을 평가하는데 적절하다고 생각하십니까?
매우 부적절 … 불확실 … 매우 적절
1 2 3 4 5 6 7 8 9

2. 이 평가지표의 결과 개선이 지역별 응급의료 수준을 향상시킬 수 있다고 생각하십니까?
매우 불가능 … 불확실 … 매우 가능
1 2 3 4 5 6 7 8 9

3. 이 평가지표에 대해 추가 의견이 있다면 아래에 기재해 주시기 바랍니다.

Figure 3. Example of questionnaire for Delphi survey.

Table 8. Weights of indicators by Delphi method

Areas	Indicators	Weights of indicators (A)	Weights of areas (B)	Weights (A × B)
Appropriateness & timeliness	No. of emergency medical technician per population and dimension	12.13	0.365	4.421
	No. of ambulance per population and dimension	12.58		4.588
	Elapsed time to providing basic life supports	14.42		5.256
	Elapsed time to providing advanced life supports	14.04		5.119
	Percentage of emergency room doctors that meet the requirements	15.96		5.818
	Severity adjusted mortality of trauma patients	13.88		5.059
	Thrombolytics received within 30 minutes of hospital arrival	14.67		5.347
	PCI received within 120 minutes of hospital arrival	13.92		5.074
Safety & prevention	Mortality due to traffic injury	12.83	0.127	1.631
	Percentage of first aid education completed	15.13		1.922
	Percentage of retransfer	14.17		1.800
Patient-centeredness	Patients' experiences evaluation for the 119 rescue services	12.92	0.108	1.399
	Patients' experiences evaluation for the emergency departments	14.00		1.517
Efficiency	Percentage of severe emergent patients using ambulance services	13.63	0.110	1.504
	Regional relevance index	12.38		1.366
	Percentage of long-stay patients	12.79		1.412
Equity	Variations in transportation time	13.71	0.096	1.445
	Subrogation payments for vulnerable groups	12.38		1.314
Planning & integration	No. of EMS officer of regional government	14.25	0.194	1.186
	Regional EMS committee	13.92		2.761
	EMS budget of regional government	15.29		2.696
	Completeness of NEDIS data	13.75		2.963

PCI, percutaneous coronary intervention; EMS, emergency medical services; NEDIS, National Emergency Department Information System.