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Continuing Quality Assessment Program Improves Clinical Outcomes of Hospitalized Community-Acquired Pneumonia: A Nationwide Cross-Sectional Study in Korea

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ABSTRACT

Background: Pneumonia, which is the third leading cause of death in South Korea, is continuously increasing with the aging society. The Health Insurance Review and Assessment of South Korea conducted a quality assessment (QA) for improving the outcome of community-acquired pneumonia (CAP).
Methods: We conducted a nationwide cross-sectional study of hospitalized CAP in South Korea. First to third QA data were gathered into a single database. The national health insurance database was merged with the QA database for analyzing the medical claims data. Comorbidities, pneumonia severity, and pneumonia care appropriateness were calculated using Charlson comorbidity index (CCI), CURB-65, and core assessment of CAP scores (CAP scores), respectively.
Results: Overall, 54,307 patients were enrolled. The CAP scores significantly improved on QA program implementation ($P < 0.001$). All the variables demonstrated an association with in-hospital mortality, hospital length of stay (LOS), and 30-day mortality in the univariate analyses. Following the adjustments, higher CCI and CURB-65 scores were associated with higher in-hospital mortality, longer hospital LOS, and higher 30-day mortality. Male sex was associated with higher in-hospital/30-day mortality and shorter hospital LOS. Higher CAP scores were associated with shorter hospital LOS ($P < 0.001$). Upon QA program implementation, in-hospital mortality ($P < 0.001$), hospital LOS ($P < 0.001$), and 30-day mortality ($P < 0.001$) improved.

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The authors have no potential conflicts of interest to disclose.

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Conclusion: Continuing QA program is effective in improving the clinical outcomes of hospitalized CAP.

Keywords: Community-Acquired Infections; Pneumonia; Prognosis; Quality of Health Care

INTRODUCTION

The global burden of pneumonia, which is the third leading cause of death in South Korea, is enormous.[1-3] In 2018, 45.4 patients per 100,000 populations succumbed to pneumonia, which is approximately three times higher than that of 2010.[4] Moreover, the mortality of pneumonia is steadily increasing owing to the change in the aging society.[5] Approximately 257.6 patients of 100,000 individuals succumbed to pneumonia in the ≥ 65 years-old age group in Korea in 2018.[4] Although, the social status of South Korea has evolved from a developing country to a developed country, pneumonia still remains a tremendous burden both on the socioeconomic status and public health.[6]

Most pneumonia are acquired in the community, so-called community-acquired pneumonia (CAP).[7-10] Among them, the patients who need hospitalization were main burden of poor outcomes of CAP, such as mortality.[11-14] In order to improve the clinical outcomes of CAP, the Health Insurance Review and Assessment Service (HIRA) of South Korea managed a nationwide quality assessment (QA) program for hospitalized CAP care since 2013. Until 2019, three times of QA period were successfully conducted, and related data was collected prospectively by the HIRA. The objective of this study was to evaluate the changes of clinical outcomes and to investigate the risk factors which are associated with poor outcomes by using the hospitalized CAP QA database.

METHODS

Data sources

The HIRA collaborated with the Korean Academy of Tuberculosis and Respiratory Diseases in developing the QA program.[15] An official assignment of Joint Project on Quality Assessment Research was procured from the HIRA, and we were granted access to the QA database for analyzing the factors associated with the prognosis of CAP in South Korea. The QA database was collected and manipulated by the HIRA. The QA data tables contain demographic information of the patients with CAP as follows. 1) Age, 2) sex, 3) hospital type, 4) first visited route, 5) type of admitted room, 6) type of severity assessment tools of pneumonia and its scores (e.g., CURB-65 and pneumonia severity index), 7) smoking status and whether perform smoking cession education or not, 8) vaccination status of pneumococcus, 9) lists of antibiotics and its duration, and 10) treatment outcomes (hospital length of stay [LOS], in-hospital mortality, and 30-day mortality). They also contain several core measure scores for CAP.[15]

The HIRA is also responsible for evaluating all the Korean citizens' medical claims data.[16] South Korea has a well-established mandatory nationwide medical claims system, which included most of the medication and comorbidities. These are matched by anonymized join-key with QA database. We analyzed the comorbidities of patients from one year before the index time of admission owing to CAP in the HIRA database.

Study population

The QA database included the data reported from the three rounds of QA; 1st QA (October 2014–December 2014), 2nd QA (April 2016–June 2016), and 3rd QA (October 2017–December 2017). The patients who met the criteria of hospitalized CAP were enrolled. Inclusion and exclusion criteria were as follows.[15]

Inclusion criteria

1) Patients aged ≥ 18 years
2) Patients who had at least one diagnosis code of pneumonia (J10.x–J18.x and J20.x as primary or diagnosis within 2nd position) from the International Classification of Disease, Tenth Revision (ICD-10)
3) Patients who were treated using intravenous (IV) antibiotics for more than 3 days
4) Hospitals which claimed at least five cases of hospitalized CAP

Exclusion criteria

1) Patients who had the following conditions not meeting the criteria of CAP: a) hospital acquired pneumonia, b) ventilator-associated pneumonia, c) postoperative pneumonia, d) patients who had transferred from other health care facilities, and e) patients who were admitted to the hospital for more than 2 days in the recent 90 days
2) Patients who were not treated with IV antibiotics first at the hospitals, such as those who were transferred from other hospital with previous antibiotics use or who were not administered antibiotics within 72 hours of admission
3) Patients who were delayed appropriate treatment owing to inevitable causes such as emergent operation
4) Patients who had the following conditions: a) patients who were recently diagnosed with malignant cancer (≤ 3 months), b) patients who received chemo- or radiation therapy within 3 months, c) patients who take immunosuppressant agents, d) patients who were treated with high dose steroids with a composition greater than 20 mg/day (≥ 14 days), e) patients who regularly underwent dialysis, and f) patients who have human immunodeficiency virus or acquired immune deficiency syndrome
5) Hospitals which claimed less than 5 cases of hospitalized CAP
6) Patients who are in or transferred from nursing hospitals

Definition of class of hospitals in South Korea

Hospitals were classified into hospital, general hospital, and tertiary hospital according to their capacity based on the number of hospital beds and specialties, as defined by the Korean Health Law. Hospital is defined by a medical institution for hospitalized patients with 30–100 beds, general hospitals are defined as hospitals with more than 100 beds and at least seven specialty areas, and tertiary hospitals should have more than 500 beds with more than 20 specialty departments that serve as teaching hospitals to medical students and nurses.

Core Assessment of CAP score measurement

As mentioned above, the QA program include the scores that evaluate the appropriateness of pneumonia care. These scores were composed of 8 categories that represent the pattern of pneumonia treatment as follows: 1) oxygen assessment, 2) use of severity assessment of pneumonia, 3) sputum smear, 4) sputum culture, 5) blood culture before antibiotics, 6) antibiotics within 8 hours of arrival, 7) education of quit smoking, and 8) pneumococcal vaccination. These are calculated by the weighted values of each score and were summarized into total scores (0–10 points) (**Supplementary Table 1**).

Comorbidities

The Charlson comorbidity index (CCI) was calculated as stated in previous articles (**Supplementary Table 2**).[17,18] It was based on the ICD-10 diagnosis codes for predicting the prognosis.[19] The HIRA database was matched with the QA database one year prior from the incidence of each pneumonia case, and calculated from the lists of diagnosis.

Statistical analyses

We used the analysis of variance and χ^2 test for independence to compare the differences in the continuous and categorical variables between the three groups. Simple and multiple linear regression analyses were used to determine the factors affecting the hospital LOS. Univariable and multivariable logistic regression analyses were used to evaluate the factors of in-hospital and 30-day mortality. A P value of < 0.05 was considered statistically significant. Post hoc tests were performed by the Bonferroni t-test. All the statistical analyses were performed using the SAS Enterprise Guide 6.1 (SAS Institute, Cary, NC, USA) and RStudio Team (2020) (RStudio: Integrated Development for R. RStudio, PBC, Boston, MA, USA; http://www.rstudio.com/).

Ethics statement

This study was approved by the Institutional Review Board of The Catholic University of Korea Yeouido St. Mary's Hospital (approval No. SC19ZNDE0020). Informed consent was waived owing to the retrospective nature of the study.

RESULTS

Hospitalized CAP demographics

After excluding the cases based on the exclusion criteria, 54,307 patients were finally included (**Fig. 1**). Male predominance was found, and the mean age of the hospitalized CAP cases was mid-sixties with increasing upon the proceedings of the QA rounds ($P < 0.001$). Approximately 58.8% and 11.8% of the patients with CAP were admitted to general and tertiary hospitals, respectively. Severity of pneumonia was assessed by the CURB-65

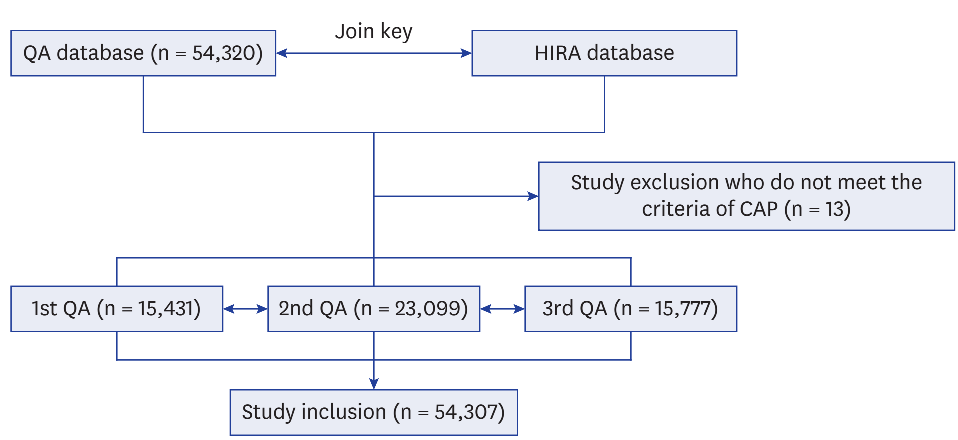

Fig. 1. Schematic diagram of the study. Both QA database and medical claims database were manipulated by the HIRA of South Korea. All the data were matched by anonymous join keys. From 1st to 3rd QA rounds, 54,307 hospitalized CAP cases were collected, after excluding the non-CAP cases.
QA = quality assessment, HIRA = Health Insurance Review and Assessment Service, CAP = community-acquired pneumonia.

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(66.2%). The mean CURB-65 scores were higher in 3rd QA than 1st and 2nd QA on post hoc analyses ($P < 0.001$). Most frequent accompanying disease was chronic pulmonary disease (59.7%). Other common comorbid conditions were described in **Supplementary Table 3**. CCI scores were higher in the 3rd QA round than others (1st QA, 2.96 ± 2.04; 2nd QA, 2.91 ± 2.01; 3rd QA, 3.10 ± 2.11; $P < 0.001$). Approximately one fourth of the patients were current or ex-smokers. The status of pneumococcal vaccination increased with the proceeding of QA program (53.2% vs. 71.5% vs. 80.5%, $P < 0.001$). Details were summarized in **Table 1** and **Supplementary Table 3**.

CAP changes by proceeding of QA program

Overall quality of CAP care, CAP scores, improved as the QA progressed (1st QA vs. 2nd QA vs. 3rd QA, 6.54 ± 2.35 vs. 7.11 ± 2.18 vs. 7.54 ± 2.03, respectively; $P < 0.001$). Antibiotic administration before 8 hours of hospital arrival (94.4%) and blood culture before

Table 1. Demographics of hospitalized CAP in Korea

Total (n = 54,307)	1st QA (n = 15,431)	2nd QA (n = 23,099)	3rd QA (n = 15,777)	*P* value
Age, yr	64.4 ± 18.9	65.2 ± 17.6	66.1 ± 17.7	< 0.001
Male sex	7,369 (47.8)	10,682 (46.2)	7,853 (49.9)	< 0.001
Hospital types				< 0.001
Tertiary	1,666 (10.8)	2,720 (11.8)	2,024 (12.8)	
General	8,809 (57.1)	13,766 (59.6)	9,351 (59.3)	
Hospital	4,956 (32.1)	6,613 (28.6)	4,402 (27.9)	
ER visit	9,793 (63.5)	14,677 (63.5)	9,323 (59.1)	< 0.001
Admission room				< 0.001
GW	14,042 (91.0)	22,087 (95.6)	14,919 (94.6)	
ICU	1,355 (8.8)	998 (4.3)	846 (5.4)	
ER	34 (0.2)	13 (0.1)	12 (0.1)	
Severity index use	8,977 (58.2)	15,592 (67.5)	11,890 (75.4)	< 0.001
CURB	8,813 (57.1)	15,442 (66.9)	11,723 (74.3)	< 0.001
Score	1.10 ± 1.05	1.11 ± 0.98	1.21 ± 0.99	< 0.001
Confusion	888 (10.1)	1,881 (8.2)	781 (5.0)	< 0.001
Urea > 20 mg/dL	2,232 (14.5)	5,333 (23.1)	3,894 (24.7)	< 0.001
RR > 30 count/hour	264 (1.7)	590 (2.6)	261 (1.7)	0.687
SBP < 90 mmHg or DBP < 60 mmHg	547 (3.5)	1,216 (5.3)	1,024 (6.5)	< 0.001
PSI	92 (0.6)	97 (0.4)	106 (0.7)	0.351
Score	85.87 ± 37.82	66.95 ± 30.44	81.96 ± 29.69	< 0.001
CCI, points	2.96 ± 2.04	2.91 ± 2.01	3.10 ± 2.11	< 0.001
Smoking status				0.022
Current	1,348 (12.9)	2,093 (11.5)	1,503 (11.6)	
Ex (≤ 1 yr)	217 (2.1)	323 (1.8)	213 (1.6)	
Ex (> 1 yr)	1,098 (10.5)	1,920 (10.5)	1,586 (12.2)	
Never	7,758 (74.5)	13,889 (76.2)	9,691 (74.6)	
Pneumococcal vaccination	4,663 (53.2)	9,590 (71.5)	7,665 (80.5)	< 0.001
Antibiotics				
Triple	181 (1.2)	219 (1.0)	198 (1.3)	0.476
Dual	4,653 (30.2)	6,988 (30.3)	5,173 (32.8)	< 0.001
Single	10,590 (68.7)	15,883 (68.8)	10,404 (66.0)	< 0.001
CAP scores, points	6.54 ± 2.35	7.11 ± 2.18	7.54 ± 2.03	< 0.001
Hospital LOS, days	10.50 ± 6.88	9.68 ± 6.10	9.78 ± 6.07	< 0.001
Outcome				< 0.001
Improved	13,372 (87.0)	21,081 (91.4)	14,155 (89.8)	
Transfer	1,042 (6.8)	1,223 (5.3)	975 (6.2)	
Death + Hopeless discharge	960 (6.2)	774 (3.4)	637 (4.0)	
30-day mortality	912 (5.9)	666 (2.9)	607 (3.9)	< 0.001

Values are presented as number of patients (%) or mean ± standard deviation.
QA = quality assessment, ER = emergent room, GW = general ward, ICU = intensive care unit, RR = respiration rate, SBP = systolic blood pressure, DBP = diastolic blood pressure, PSI = pneumonia severity index, CCI = Charlson comorbidity index, CAP = community-acquired pneumonia, LOS = length of stay.

Table 2. Core measures of QA of hospitalized CAP in South Korea

Core assessment	1st QA (n = 15,431)	2nd QA (n = 23,099)	3rd QA (n = 15,777)	*P* value
Oxygenation assessment (≤ 24 hr)	10,481 (67.9)	17,249 (74.7)	12,800 (81.1)	< 0.001
Use of severity assessment tool (≤ 24 hr)	7,975 (51.7)	14,362 (62.2)	11,312 (71.7)	< 0.001
Sputum smear (≤ 24 hr)	10,234 (66.3)	17,397 (75.3)	12,085 (76.6)	< 0.001
Sputum cultures (≤ 24 hr)	10,538 (68.3)	17,887 (77.4)	12,571 (79.7)	< 0.001
Blood cultures prior to first antibiotics	14,121 (91.5)	21,662 (93.8)	14,992 (95.0)	< 0.001
First antibiotics administration (≤ 8 hr)	14,241 (92.3)	21,870 (94.7)	15,147 (96.0)	< 0.001
Smoking cessation education	1,565 (10.1)	2,416 (10.5)	1,716 (10.9)	0.034
Screening of vaccination	4,663 (30.2)	9,590 (41.5)	7,665 (48.6)	< 0.001
CAP scores, points	6.54 ± 2.35	7.11 ± 2.18	7.54 ± 2.03	< 0.001

QA = quality assessment; CAP = community-acquired pneumonia.

initial administration of IV antibiotics (93.5%) were performed in most cases. Moreover, examination of the oxygen saturation (74.6%), sputum smear (73.1%), and sputum culture (75.5%) were assessed in more than 70% of the cases. However, the use of severity assessment tools (62.0%) and the evaluation of vaccination status (40.4%) were not performed frequently. Most of the hospitalized patients with CAP had not been educated regarding smoking cessation (10.5%) (**Table 2**).

Change of in-hospital mortality

Univariate and multivariate logistic regression analyses were performed to evaluate the effect of the variables in in-hospital mortality. Sex, hospital types, CURB-65 scores, CCI scores, CAP scores, and QA rounds were selected as variables. In the univariate analyses, all the variables demonstrated statistical difference on the in-hospital mortality. Male sex, higher CCI scores, higher CURB-65 scores, and higher CAP scores were associated with higher in-hospital mortality ($P < 0.001$). The hospital types showed higher in-hospital mortality in general or tertiary hospital than hospital ($P = 0.005$ and $P < 0.001$, each). After adjusting for the confounding factors in multivariate analyses, male sex (odds ratio [OR], 1.730; 95% confidence interval [CI], 1.635–1.831; $P < 0.001$) and higher CURB-65 scores (OR, 2.559; 95% CI, 2.479–2.641; $P < 0.001$) were associated with poor in-hospital mortality for hospitalized CAP. Higher level of hospital type (general hospital vs. hospital [OR, 1.315; 95% CI, 1.188–1.434; $P = 0.001$] and tertiary hospital vs. hospital [OR, 1.395; 95% CI, 1.242–1.568; $P < 0.001$]) was associated with poor in-hospital mortality also. Proceeding of QA rounds (2nd QA vs. 1st QA [OR, 0.586; 95% CI, 0.546–0.628; $P < 0.001$] and 3rd QA vs. 1st QA [OR, 0.426; 95% CI, 0.395–0.459; $P < 0.001$]) was associated with lower in-hospital mortality (**Table 3**).

Table 3. Univariate and multivariate logistic analyses of in-hospital mortality of hospitalized CAP in Korea

Characteristics	Univariate		Multivariate	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Male sex	1.903 (1.831–1.977)	< 0.001	1.730 (1.635–1.831)	< 0.001
Hospital types				
Hospital	Ref.	Ref.	Ref.	Ref.
General hospital	1.126 (1.078–1.176)	0.005	1.315 (1.188–1.434)	0.001
Tertiary hospital	1.423 (1.335–1.516)	< 0.001	1.395 (1.242–1.568)	< 0.001
CCI scores	1.246 (1.234–1.258)	< 0.001	1.149 (1.134–1.164)	< 0.001
CURB-65 scores	2.875 (2.794–2.958)	< 0.001	2.559 (2.479–2.641)	< 0.001
CAP scores	1.054 (1.045–1.063)	< 0.001	1.005 (0.981–1.031)	0.505
QA				
1st QA	Ref.	Ref.	Ref.	Ref.
2nd QA	0.603 (0.577–0.630)	< 0.001	0.586 (0.546–0.628)	< 0.001
3rd QA	0.518 (0.493–0.545)	< 0.001	0.426 (0.395–0.459)	< 0.001

OR = odds ratio, CI = confidence interval, CCI = Charlson comorbidity index, CAP = community-acquired pneumonia, QA = quality assessment.

Change in hospital stays

Simple and multiple linear regression analyses were performed to evaluate the associated factors with hospital LOS in hospitalized CAP. Sex, hospital type, CCI, CURB-65 scores, CAP scores, and QA rounds were selected as variables. Multi-collinearity between variables was not observed and significance was set at $P < 0.001$ in the analyses. In the simple linear regression analyses, all the variables were significantly associated with hospital LOS. However, the hospital type was not consistently associated with hospital LOS in the multiple linear regression analyses (general hospital vs. hospital [OR, 1.709; 95% CI, 1.411–2.070; $P < 0.001$] and tertiary hospital vs. hospital [OR, 0.766; 95% CI, 0.571–1.026; $P = 0.074$]). Male sex (exponentiation of the β coefficient [exp(β)], 0.761; 95% CI, 0.658–0.881; $P < 0.001$), higher CAP scores (exp(β), 0.866; 95% CI, 0.813–0.922; $P < 0.001$), and proceeding of QA program (2nd QA vs. 1st QA [exp(β), 0.590; 95% CI, 0.491–0.708; $P < 0.001$] and 3rd QA vs. 1st QA [exp(β), 0.577; 95% CI, 0.476–0.700; $P < 0.001$]) were associated with shorter hospital LOS. Higher CCI scores (exp(β), 1.190; 95% CI, 1.148–1.233; $P < 0.001$) and higher CURB-65 scores (exp(β), 3.551; 95% CI, 3.290–3.829; $P < 0.001$) were significantly associated with longer hospital LOS (**Table 4**).

The 30-day mortality improvement

The 30-day mortality was defined by the index date of admission owing to hospitalized CAP, which was evaluated by the univariate and multivariate logistic regression analyses. Sex, hospital types, CURB-65, CCI, CAP scores, and QA rounds were selected as variables. Most variables, except comparing hospital type between general hospital and hospital, demonstrated the association with 30-day mortality in the univariate analyses ($P < 0.001$). In the multivariate analyses, male sex (OR, 1.214; 95% CI, 1.077–1.370; $P < 0.001$), hospital types (general hospital vs. hospital [OR, 1.302; 95% CI, 1.045–1.622; $P = 0.019$] and tertiary hospital vs. hospital [OR, 1.353; 95% CI, 1.056–1.734; $P = 0.017$]), CCI scores (OR, 1.035; 95% CI, 1.009–1.062, $P = 0.008$), CURB-65 scores (OR, 2.881; 95% CI, 2.725–3.045; $P < 0.001$), and proceeding QA program (2nd QA vs. 1st QA [OR, 0.596; 95% CI, 0.515–0.688; $P < 0.001$] and 3rd QA vs. 1st QA [OR, 0.725; 95% CI, 0.627–0.838; $P < 0.001$]) were still associated with the 30-day mortality (**Table 5**).

Table 4. Simple and multiple linear regression analyses for the hospital length of stay in hospitalized CAP in Korea

Characteristics	Simple linear			Multiple linear		
	β	Exp(β) (95% CI)	*P* value	β	Exp(β) (95% CI)	*P* value
Male sex	−0.452	0.636 (0.572–0.708)	< 0.001	−0.273	0.761 (0.658–0.881)	< 0.001
Hospital types						
Hospital	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
General hospital	0.358	1.430 (1.207–1.695)	< 0.001	0.536	1.709 (1.411–2.070)	< 0.001
Tertiary hospital	−0.421	0.656 (0.546–0.788)	< 0.001	−0.267	0.766 (0.571–1.026)	0.074
CCI scores	0.324	1.382 (1.343–1.423)	< 0.001	0.175	1.190 (1.148–1.233)	< 0.001
CURB-65 scores	1.369	3.930 (3.686–4.190)	< 0.001	1.280	3.551 (3.290–3.829)	< 0.001
CAP scores	0.0002	1.046 (1.021–1.072)	< 0.001	−0.164	0.866 (0.813–0.922)	< 0.001
QA						
1st QA	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
2nd QA	−0.823	0.439 (0.386–0.499)	< 0.001	−0.528	0.590 (0.491–0.708)	< 0.001
3rd QA	−0.719	0.487 (0.423–0.560)	< 0.001	−0.549	0.577 (0.476–0.700)	< 0.001

Exp(β) = exponentiation coefficient β, CI = confidence interval, CCI = Charlson comorbidity index, CAP = community-acquired pneumonia, QA = quality assessment.

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Table 5. Univariate and multivariate logistic analyses of 30-day mortality of hospitalized CAP in Korea

Characteristics	Univariate		Multivariate	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Male sex	1.413 (1.296–1.540)	< 0.001	1.214 (1.077–1.370)	< 0.001
Hospital types				
Hospital	Ref.	Ref.	Ref.	Ref.
General hospital	1.212 (0.987–1.489)	0.067	1.302 (1.045–1.622)	0.019
Tertiary hospital	1.560 (1.241–1.960)	< 0.001	1.353 (1.056–1.734)	0.017
CCI scores	1.134 (1.112–1.155)	< 0.001	1.035 (1.009–1.062)	0.008
CURB-65 scores	3.010 (2.862–3.165)	< 0.001	2.881 (2.725–3.045)	< 0.001
CAP scores	1.066 (1.045–1.088)	< 0.001	0.987 (0.936–1.041)	0.635
QA				
1st QA	Ref.	Ref.	Ref.	Ref.
2nd QA	0.473 (0.427–0.523)	< 0.001	0.596 (0.515–0.688)	< 0.001
3rd QA	0.637 (0.573–0.708)	< 0.001	0.725 (0.627–0.838)	< 0.001

OR = odds ratio, CI = confidence interval, CCI = Charlson comorbidity index, CAP = community-acquired pneumonia, QA = quality assessment.

DISCUSSION

Pneumonia is the most common infectious disease with enormous socioeconomic burden.[2] Many efforts have been taken to enhance the quality of care for improving the clinical outcomes.[20-22] This QA program was developed for these reasons. However, there is a lack of evidence supporting the importance of continuing QA program for hospitalized CAP.

Certain significant findings regarding the association between the QA program and the prognosis of hospitalized CAP were noted. First, the QA program revealed its efficacy in improving the prognosis of CAP. Clinical outcomes were improved upon the progress of the QA program even after adjusting the confounding factors. Hospital LOS was decreased with the proceeding of the QA program. The QA program contributes to reduce the mortality of hospitalized CAP in South Korea. Second, higher CAP scores were associated with better clinical outcomes. CAP score evaluates the appropriateness of medical care. It is associated with decreasing the hospital LOS after adjusting for the confounding factors. These results indicate the need for a high CAP score. Third, CAP scores improved based on the QA proceeding. It represents that the homogeneity and consistency of pneumonia care were improved in South Korea. Moreover, these results support that the well-organized management of pneumonia care is associated with improvement in the clinical outcomes of CAP. To the best of our knowledge, it is the first nationwide population-based study that reveals the importance of well-organized management in improving the prognosis of pneumonia. We anticipate this study to serve as basis for setting up public programs for pneumonia care in other countries. Fourth, pneumonia severity assessment, such as CURB-65, is a particularly important factor for estimating prognosis. Age also plays a key role; we evaluated the logistic regression analyses using two models, with CURB-65 scores or CURB scores, in the subgroup analyses; OR by CURB decreased greatly than that of CURB-65. Nevertheless, it still demonstrates the clinical significance. This indicates that aging contributes to the majority of poor prognoses. If patients were aged 1 year older, the in-hospital mortality (OR, 1.105) and 30-day mortality (OR, 1.094) were increased in the subgroup analyses (**Supplementary Tables 4** and **5**). It is well correlated with the report of Statistics Korea on the poor mortality of elderly society. Changing to aging society of super-aging society could probably continue to influence the prognosis of pneumonia in South Korea; thus, a proper guideline for hospitalized CAP in elderly patients is warranted. Fifth, we found that the tertiary or general hospital showed higher in-hospital mortality and 30-day mortality compared to that of hospital. Usually, the patients who are admitted to higher level of hospital types have more comorbidities, have more severe status of pneumonia, or were more aged people compared to those of hospital. However, current scoring system of pneumonia severity did not reflect patient factors, such as sex, CCI scores, and CURB-65 scores, that were associated with prognosis of CAP. Therefore, the severity of CAP must be classified using those variables. The development of more reasonable composite scoring systems is recommended with further supplementary research in near future.

There were several limitations to this study. First, the severe comorbid conditions that may be related to the increase of pneumonia or affected the disease severity, such as recently diagnosed caner (≤ 3 months), those treated with chemotherapy or radiation therapy recently (≤ 3 months), those with an immunodeficient condition or take immunosuppressant drugs, or those undergoing dialysis, were excluded. However, we can essentially evaluate the effect of sex, age, severity of pneumonia, and other comorbidities without the confounding conditions by excluding these factors since these conditions affect the development or prognosis of pneumonia. Second, there are no data on the microbiological findings. However, we included the patients without previous IV antibiotic use, without admission to other healthcare facilities more than two days within 3 months, and without hospital-acquired pneumonia. Therefore, the antibiogram of the patients in this study were anticipated as community-associated infection without risk of multi-drug resistant microorganisms. Considering further studies, the results of microbial culture should be included in the QA database. Third, seasonal effects can affect to the results of this study. Previous studies showed the different incidence and mortality of CAP by seasonal effect due to the different etiology, temperature, and etc.[23,24] 1st and 3rd QA were performed in fall/winter and 2nd QA was performed in spring season. Unless there are limitations from seasonal bias, we compared the clinical outcomes of 1st QA and 3rd QA (both at fall/winter) in multivariable analyses. Additional studies about seasonal effects to the clinical outcomes of CAP should be followed in upcoming QA analyses.

In conclusion, this study is the first nationwide cross-section study, which included the total hospitalized patients with CAP in South Korea. We reported the efficacy of the nationwide well-organized CAP care program in improving the prognosis of hospitalized CAP, and hope our study serves as a basis for future research.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Core assessment of CAP score measurement

Click here to view

Supplementary Table 2

Charlson weighted index of comorbidities

Click here to view

Supplementary Table 3

Post hoc analyses and details of comorbidities of hospitalized CAP in South Korea

Click here to view

Supplementary Table 4

Univariate and multivariate logistic analyses of in-hospital mortality of hospitalized CAP in Korea by CURB scores

Click here to view

Supplementary Table 5

Univariate and multivariate logistic analyses of 30-day mortality of hospitalized CAP in Korea by CURB scores

Click here to view

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