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ORIGINAL ARTICLE

Impact of Hospital Specialization on Hospital Charge, Length of Stay and Mortality for Lumbar Spine Disease Inpatients

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Background: This study investigates association modified category medical specialization (CMS) and hospital charge, length of stay (LOS), and mortality among lumbar spine disease inpatients.
Methods: This study used National Health Insurance Service–cohort sample database from 2002 to 2013, using stratified representative sampling released by the National Health Insurance Service. A total of 56,622 samples were analyzed. The primary analysis was based on generalized estimating equation model accounting for correlation among individuals within each hospital.
Results: Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a shorter LOS (estimate, -1.700; 95% confidence interval [CI], -1.886 to -1.514; $p<0.0001$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a lower mortality rate (odds ratio, 0.635; 95% CI, 0.521 to 0.775; $p<0.0001$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher hospital cost per case (estimate, 192,658 Korean won; 95% CI, 125,701 to 259,614; $p<0.0001$). However, inpatients admitted with lumbar spine surgery patients at hospitals with higher modified CMS had lower hospital cost per case (estimate, -152,060 Korean won; 95% CI, -287,236 to -16,884; $p=0.028$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher hospital cost per diem (estimate, 55,694 Korean won; 95% CI, 46,205 to 65,183; $p<0.0001$).
Conclusion: Our results showed that increase in hospital specialization had a substantial effect on decrease in hospital cost per case, LOS, and mortality, and on increase in hospital cost per diem among lumbar spine disease surgery patients.

Keywords: Hospital; Specialization; Mortality

INTRODUCTION

Over the last few decades, hospitals in South Korea have undergone dramatic changes of health care market conditions such as separation of prescription and drug dispensing in 2000 and implementation of diagnosis related groups (DRGs) in 2013. Thus, Korean hospitals traditionally have provided a broad range of health care services in the health care market for competitive advantage. However, recently, many hospitals have faced increasing financial challenges [1] due to an increase in the number of small general hospitals, from 581 in 2000 to 1,064 in 2008 [2], and increasing competition between hospitals.

In response to various changes of health care market conditions, hospitals adopted various cost-saving strategies and changed their medical health behavior through exploring and planning hospital specialization strategies for competitive advantage, to attract more patients. Small general hospitals increasingly specialized in certain medical services to better compete with other small and mid-

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sized hospitals as "specialty hospitals," and an effort emerged among these institutions to promote the development of "superb small general hospitals" through investment in high-tech equipment [2]. Thus, in recent times in Korea, a rapid rise in the number of small hospitals specializing in spinal, cardiac, orthopedic, and surgery services occurred [3].

In this situation, precise, valid, and reliable measures of hospital specialization have become increasingly necessary. Traditionally, the most common of these measures in the hospital context has been the Information Theory Index (ITI) [4-6] and inner Herfindahl–Hirschman Index (IHI) [7] interpreting "specialization" used by Eastaugh [8,9], Linna and Häkkinen [10], Lee et al. [1], Herwartz and Strumann [11], and Baumgardner and Marder [7]. Both measures analyze hospital caseloads based on patient proportions, independent of patient volumes. This means that the total number of patients treated is effectively normalized to 100%. However, both IHI and ITI fail to account for important issues. First, relying solely on patient proportions might be problematic for larger hospitals that provide a high number of diagnosis categories, as the patient proportions in each category are naturally relatively smaller in such hospitals. Thus, measuring specialization at these hospitals based on the patient proportions in each category, as with IHI and ITI, may lead to a result showing inappropriately low specialization for a practice as a whole in cases where several physicians are providing a heterogeneous range of specialties. Recent study developed two novel measures of hospital specialization for solving the problem as above mentioned: category medical specialization (CMS) and inner category medical specialization (ICMS); these are based on patient volumes including patient proportions [12], which were measured by both IHI and ITI.

However, to date, hospital specialization measures as a case-mix index of hospital level, could not identify the extent of specialization in a specific medical category within a hospital [13]. To address this issue, this study developed "modified category medical specialization" (modified CMS) and investigated association modified CMS and hospital charge, length of stay (LOS), and mortality among lumbar spine disease inpatients.

METHODS

1. Study sample

This study used Korean National Health Insurance Service–cohort sample data (NHIS-CSD) from 2002 to 2013, released by the Korean NHIS. Initial NHIS-CSD cohort members (n=1,025,340, approximately 2.2% of the entire population in 2002) were established by stratified random sampling using a systematic sampling method to generate a representative sample of the 46,605,433 Korean residents recorded in 2002.

The present study utilized data on healthcare utilization claims, including patient specifications such as hospital cost per case, hospital cost per diem, and LOS and mortality. In order to analyze the relationship between hospital specialization for lumbar spine disease specialization, hospital costs (per case and per diem), LOS and mortality, this study used the International Classification of Diseases, tenth revision (ICD-10) codes of all inpatients within each hospital by year (Appendices 1, 2).

This study developed a separate individual database for each hospital, including the calendar years and transposing claim data into a longitudinal design for repeated measurement. The hospitals allowed us to study the associations between hospital specialization and outcomes during a 12-year follow-up.

To measure hospital specialization for all hospitals, there were no exclusion criteria in these regards. The exception was for lumbar spine disease specialization, where our exclusion criterion was one or more case of lumbar spine disease per year per hospital.

2. Study methods

In this study, the nationwide cohort sample data over 12 years used for this study was investigated in three parts, to meet the study objectives. First, we identified the distribution of hospital specialization scores according to scale of hospital to identify limitations of hospital specialization measures such as IHI, ITI, CMS, and ICMS for measuring specialization in specific diseases (such as lumbar spine disease).

Second, given that IHI, ITI, CMS, and ICMS tend to return decreasing hospital specialization scores when measuring specialization in a specific disease (Appendix 3), we developed implemented modified CMS. New methods for measuring hospital specialization through modified CMS for lumbar spine disease inpatients are as follow: to extract lumbar spine disease patients within each hospital, diseases were classified into 267 categories based on the ICD-10. It takes a log transformation to the denominator of CMS to reduce between-hospital variation of number of medical categories, because maximum disease category is up to three to extract specific disease regardless of the scale of the hospital (type, number of beds, etc.).

$$\text{Modified CMS} = \frac{\sum_{i=1}^{I} \varsigma_{ij}}{\ln(\sum_{i=1}^{I} \eta_{ij})}$$

Where

ln(*) = natural log of what hospital has a valid diagnosis category η_{ij} if the proportion of treated patients is greater than 1/267 (number of disease categories).

Third, to verify its validity in the Korean health care environment, we examined hospital distribution by proportion and absolute number of lumbar spine patients (Appendices 4, 5). In addition, we conducted correlation analysis between hospital specialization and absolute number and proportion of lumbar spine disease patients (Appendix 6). As a result, unlike other measures, modified CMS shows the highest correlation (0.611, $p < 0.0001$) with absolute number of lumbar spine disease patients. Finally, we conducted subgroup analysis by proportion of lumbar spine disease patients. As a result of subgroups analysis, only modified CMS shows positive correlation with absolute number of lumbar spine disease patients (Appendix 7).

3. Independent variables

This study incorporated individual- and hospital-level variables including age, sex, residential region, surgery, death, hospital type, organization type, region of hospital, number of beds, number of doctors, presence of computed tomography (CT), presence of magnetic resonance imaging (MRI), presence of positron emission tomography (PET), and a year dummy.

Lists of individual-level and hospital-level variables are in Table 1. The age variable is categorized into three groups: ≤29, 30–39, 40–49, 50–59, 60–69, and ≥70 years. The sex variable is categorized into two groups: male and female. Residential region is categorized into three groups: metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan), and rural (everywhere else). Surgery and death variables are categorized into two groups: yes and no.

The hospital type variable is categorized into three groups: tertiary hospital, general hospital, and hospital. The organization type variable was categorized into three groups: public, corporate, and private. The region of hospital variable was categorized into three groups: metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan), and rural (everywhere else). The number of beds variable was categorized into nine groups: ≤199, 200–299, 300–399, 400–499, 500–599, 600–699, 700–799, 800–899, and ≥900. The number of doctors variable was categorized into seven groups: ≤49, 50–99, 100–149, 150–199, 200–249, 250–299, and ≥300. In addition, presence of CT, presence of MRI, and presence of PET were categorized into two groups: yes or no. Finally, a year dummy variable was included in our analysis. We measured hospital specialization using the main independent variables: IHI, ITI, CMS, ICMS, and modified CMS, as continuous variables.

4. Control variables

To investigate our hypothesis, this study used LOS, mortality, hospital cost per case, and hospital cost per diem as dependent variables. In Korea, the fees for services (FFS) catalogue is negotiated by the government, care providers, and other stakeholders every year. This study discounted hospital charges for all inpatients on the basis of catalogue for the year 2002 using each year's negotiated FFS catalogue.

5. Analytical approach and statistics

In this study, the units of analysis are each individual and each hospital. Thus, this study employed analysis of variance; cluster analysis, to identify groups of individuals or objects that are similar to each other but different from individuals in other groups; and generalized estimating equation (GEE) regression model accounting for correlation among individuals within each hospital to investigate whether general characteristics and hospital specialization had a relationship with mortality, LOS, hospital costs per case, and hospital costs per diem. In GEE, proc genmod was used, with link identity, distribution normal. SAS ver. 9.4 (SAS Institute Inc., Cary, NC, USA) was used to estimate all calculation and our hypothesis. All statistical significance tests were two-tailed and rejected null hypothesis of no difference if p-values were less than 0.05 or equivalent.

RESULTS

Table 2 shows results for general characteristics of all variables by surgery and mortality, and Table 3 shows results for general characteristics of all variables by LOS, hospital cost per case, and hospital cost per diem. According to Table 2, of the 56,622 total cases included in our analysis, there were 21,317 surgery cases (37.7%) and 283 mortality cases (0.5%). Average LOS of total cases was 11.564 days (standard deviation [SD] = 10.139), average hospital

Table 1. Association of modified CMS on each dependent variable among total patients

Variable	Length of stay		Mortality		Hospital cost per case		Hospital cost per diem	
	Estimate	*p*-value	Odds ratio	*p*-value	Estimate	*p*-value	Estimate	*p*-value
Hospital level								
Modified CMS	-1.700	<0.0001	0.635	<0.0001	192,658	<0.0001	55,694	<0.0001
Type								
Tertiary hospital	1.072	<0.0001	0.972	0.902	36,498	0.704	34,173	0.013
General hospital	0.977	<0.0001	0.781	0.084	-136,847	0.017	-3,989	0.624
Hospital	Ref		1		Ref		Ref	
Organization type								
Public	2.135	<0.0001	2.122	0.001	39,035	0.767	-55,363	0.003
Corporate	0.732	<0.0001	1.371	0.003	50,415	0.251	-13,594	0.029
Private	Ref		1		Ref		Ref	
Region								
Metropolitan	-1.648	<0.0001	0.943	0.631	14,011	0.755	53,700	<0.0001
Urban	1.671	<0.0001	1.151	0.219	363,145	<0.0001	257	0.969
Rural	Ref		1		Ref		Ref	
Bed								
≤199	-1.679	<0.0001	1.506	0.294	113,590	0.442	5,837	0.781
200–299	-1.146	0.003	1.624	0.196	361,535	0.01	36,932	0.065
300–399	-0.175	0.664	1.669	0.176	777,216	<0.0001	24,401	0.238
400–499	-1.268	0.003	1.298	0.508	433,116	0.005	26,096	0.233
500–599	0.755	0.045	1.033	0.928	923,310	<0.0001	46,079	0.017
600–699	0.806	0.025	0.903	0.763	913,663	<0.0001	43,418	0.018
700–799	0.416	0.216	0.828	0.583	630,061	<0.0001	-13,794	0.425
800–899	1.447	<0.0001	0.946	0.828	231,736	0.03	-13,158	0.386
≥900	Ref		1		Ref		Ref	
Doctor								
≤49	1.496	0	0.651	0.272	-1,101,740	<.0001	-70,699	0.001
50–99	0.755	0.063	0.737	0.412	-1,159,576	<.0001	-27,814	0.182
100–149	0.558	0.15	0.872	0.695	-776,666	<.0001	-60,307	0.002
150–199	0.993	0.005	0.394	0.018	-688,876	<.0001	-63,345	0.001
200–249	0.307	0.361	0.461	0.031	-595,701	<.0001	-52,864	0.002
250–299	0.519	0.07	1.218	0.357	-402,449	<.0001	-46,951	0.001
≥300	Ref		1		Ref		Ref	
Computed tomography								
No	-0.19	0.305	0.925	0.677	-176,502	0.008	-29,488	0.002
Yes	Ref		1		Ref		Ref	
Magnetic resonance imaging								
No	1.578	<0.0001	1.589	0	-246,132	0	-25,261	0.006
Yes	Ref		1		Ref		Ref	
Positron emission tomography								
No	1.842	<0.0001	0.887	0.504	-94,042	0.183	-32,219	0.001
Yes	Ref		1		Ref		Ref	
Individual level								
Patient clinical complexity level								
0	-5.417	<0.0001	0.192	<0.0001	-118,002	0.328	56,699	0.001
1	-2.293	<0.0001	0.233	<0.0001	867,483	<0.0001	67,963	0
2	-0.564	0.109	0.387	<0.0001	1,374,079	<0.0001	76,577	<0.0001
3	Ref		1		Ref		Ref	

(Continued to the next page)

Table 1. Continued

Variable	Length of stay		Mortality		Hospital cost per case		Hospital cost per diem	
	Estimate	*p*-value	Odds ratio	*p*-value	Estimate	*p*-value	Estimate	*p*-value
Sex								
Male	-0.895	<0.0001	1.472	<0.0001	-92,025	0.001	13,295	0.001
Female	Ref		1		Ref		Ref	
Age (yr)								
≤29	-2.602	<0.0001	0.147	<0.0001	-946,853	<0.0001	-22,105	0.017
30–39	-2.261	<0.0001	0.157	<0.0001	-805,589	<0.0001	-28,210	0
40–49	-1.409	<0.0001	0.172	<0.0001	-656,418	<0.0001	-26,463	0
50–59	-0.704	<0.0001	0.246	<0.0001	-329,168	<0.0001	-12,070	0.064
60–69	-0.143	0.255	0.368	<0.0001	54,352	0.23	5,881	0.36
≥70	Ref		1		Ref		Ref	
Region								
Metropolitan	0.252	0.044	0.785	0.067	117,435	0.009	-7,959	0.213
Urban	0.129	0.292	0.84	0.131	-57,136	0.193	-9,528	0.126
Rural	Ref		1		Ref		Ref	
Surgery								
Yes	Ref		1		Ref		Ref	
No	-3.676	<0.0001	1.599	<0.0001	-2,008,377	<.0001	-100,115	<0.0001
Death								
Yes	Ref		NA		Ref		Ref	
No	1.875	0.001	NA		753,879	0	-30,075	0.289
Year								
2002	3.077	<0.0001	0.65	0.287	445,872	<0.0001	334	0.981
2003	2.987	<0.0001	1.46	0.122	18,560	0.832	-36,056	0.004
2004	1.369	<0.0001	1.055	0.814	-437,645	<0.0001	-4,215	0.712
2005	1.521	<0.0001	1.067	0.748	17,856	0.803	31,539	0.002
2006	2.032	<0.0001	1.718	0.002	1,845	0.979	-20,933	0.032
2007	1.827	<0.0001	1.445	0.033	181,910	0.005	-4,922	0.59
2008	2.099	<0.0001	1.203	0.281	158,788	0.01	-11,451	0.187
2009	2.207	<0.0001	1.39	0.036	349,137	<0.0001	-12,424	0.136
2010	1.473	<0.0001	1.387	0.033	325,841	<0.0001	-12,264	0.126
2011	0.6	<0.0001	1.257	0.127	-30,054	0.578	-14,884	0.054
2012	0.368	0.012	1.307	0.064	80,687	0.123	6,921	0.351
2013	Ref		1		Ref		Ref	

CMS, category medical specialization; Ref, reference; NA, not applicable.

costs per case of total cases were 2,941,444 (SD = 3,876,058), and average hospital costs per diem of total cases was 275,882 (SD = 483,928) (Table 3).

Table 1 shows the results for the adjusted effect of the association between modified CMS and LOS, mortality, hospital case per case, and hospital cost per diem among total patients, including both surgery and non-surgery lumbar spine disease patients, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, patient clinical complexity level (PCCL), age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a shorter LOS (estimate, -1.700; 95% confidence interval [CI], -1.886 to -1.514; $p < 0.0001$). LOS was 1.072 days longer (95% CI, 0.548 to 1.595; $p < 0.0001$) in tertiary hospital compared with hospitals. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a lower mortality rate (odds ratio, 0.635; 95% CI, 0.521 to 0.775; $p < 0.0001$): 2.122 times higher (95% CI, 1.389 to 3.243; $p = 0.001$) in public hospitals and 1.371 times higher (95% CI, 1.110 to 1.694; $p = 0.003$) in corporate hospitals as compared with private hospitals. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS

Table 2. General characteristics of all variables for analysis (surgery, mortality)

Characteristic	Total	Surgery			Mortality		
		Yes	No	*p*-value	Yes	No	*p*-value
Hospital level							
Type				< 0.0001			< 0.0001
Tertiary hospital	6,593 (11.6)	2,639 (40.0)	3,954 (60.0)		55 (0.8)	6,538 (99.2)	
General hospital	14,257 (25.2)	4,954 (34.8)	9,303 (65.3)		78 (0.6)	14,179 (99.5)	
Hospital	35,772 (63.2)	13,724 (38.4)	22,048 (61.6)		150 (0.4)	35,622 (99.6)	
Organization type				< 0.0001			< 0.0001
Public	725 (1.3)	176 (24.3)	549 (75.7)		14 (1.9)	711 (98.1)	
Corporate	21,369 (37.7)	7,619 (35.7)	13,750 (64.4)		161 (0.8)	21,208 (99.3)	
Private	34,528 (61.0)	13,522 (39.2)	21,006 (60.8)		108 (0.3)	34,420 (99.7)	
Region				< 0.0001			0.0002
Metropolitan	18,800 (33.2)	8,030 (42.7)	10,770 (57.3)		64 (0.3)	18,736 (99.7)	
Urban	17,022 (30.1)	6,870 (40.4)	10,152 (59.6)		87 (0.5)	16,935 (99.5)	
Rural	20,800 (36.7)	6,417 (30.9)	14,383 (69.2)		132 (0.6)	20,668 (99.4)	
Bed				< 0.0001			< 0.0001
≤ 199	26,886 (47.5)	10,186 (37.9)	16,700 (62.1)		103 (0.4)	26,783 (99.6)	
200–299	12,986 (22.9)	5,260 (40.5)	7,726 (59.5)		56 (0.4)	12,930 (99.6)	
300–399	2,895 (5.1)	774 (26.7)	2,121 (73.3)		26 (0.9)	2,869 (99.1)	
400–499	1,319 (2.3)	331 (25.1)	988 (74.9)		11 (0.8)	1,308 (99.2)	
500–599	1,696 (3.0)	541 (31.9)	1,155 (68.1)		10 (0.6)	1,686 (99.4)	
600–699	1,387 (2.5)	462 (33.3)	925 (66.7)		8 (0.6)	1,379 (99.4)	
700–799	1,198 (2.1)	450 (37.6)	748 (62.4)		4 (0.3)	1,194 (99.7)	
800–899	1,424 (2.5)	609 (42.8)	815 (57.2)		9 (0.6)	1,415 (99.4)	
≥ 900	6,831 (12.1)	2,704 (39.6)	4,127 (60.4)				
Doctor				0.002			< 0.0001
≤ 49	42,870 (75.7)	15,952 (37.2)	26,918 (62.8)		194 (0.5)	42,676 (99.6)	
50–99	3,025 (5.3)	1,144 (37.8)	1,881 (62.2)		12 (0.4)	3,013 (99.6)	
100–149	1,347 (2.4)	505 (37.5)	842 (62.5)		10 (0.7)	1,337 (99.3)	
150–199	1,444 (2.6)	575 (39.8)	869 (60.2)		2 (0.1)	1,442 (99.9)	
200–249	1,116 (2.0)	426 (38.2)	690 (61.8)		3 (0.3)	1,113 (99.7)	
250–299	1,490 (2.6)	577 (38.7)	913 (61.3)		15 (1.0)	1,475 (99.0)	
≥ 300	5,330 (9.4)	2,138 (40.1)	3,192 (59.9)		47 (0.9)	5,283 (99.1)	
Computed tomography				0.707			0.4946
No	2,907 (5.1)	1,104 (38.0)	1,803 (62.0)		12 (0.4)	2,895 (99.6)	
Yes	53,715 (94.9)	20,213 (37.6)	33,502 (62.4)		271 (0.5)	53,444 (99.5)	
Magnetic resonance imaging				< 0.0001			< 0.0001
No	3,283 (5.8)	443 (13.5)	2,840 (86.5)		45 (1.4)	3,238 (98.6)	
Yes	53,339 (94.2)	20,874 (39.1)	32,465 (60.9)		238 (0.5)	53,101 (99.6)	
Positron emission tomography				< 0.0001			0.0007
No	43,956 (77.6)	16,307 (37.1)	27,649 (62.9)		196 (0.5)	43,760 (99.6)	
Yes	12,666 (22.4)	5,010 (39.6)	7,656 (60.5)		87 (0.7)	12,579 (99.3)	
Individual level							
Patient clinical complexity level				< 0.0001			< 0.0001
0	39,143 (69.1)	13,595 (34.7)	25,548 (65.3)		108 (0.3)	39,035 (99.7)	
1	11,424 (20.2)	5,208 (45.6)	6,216 (54.4)		66 (0.6)	11,358 (99.4)	
2	5,261 (9.3)	2,233 (42.4)	3,028 (57.6)		73 (1.4)	5,188 (98.6)	
3	794 (1.4)	281 (35.4)	513 (64.6)		36 (4.5)	758 (95.5)	

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Table 2. Continued

Characteristic	Total	Surgery			Mortality		
		Yes	No	*p*-value	Yes	No	*p*-value
Sex				0.810			0.2458
Male	26,666 (47.1)	10,053 (37.7)	16,613 (62.3)		143 (0.5)	26,523 (99.5)	
Female	29,956 (52.9)	11,264 (37.6)	18,692 (62.4)		140 (0.5)	29,816 (99.5)	
Age (yr)				< 0.0001			< 0.0001
≤ 29	4,316 (7.6)	1,266 (29.3)	3,050 (70.7)		1 (0.0)	4,315 (100.0)	
30–39	7,309 (12.9)	2,227 (30.5)	5,082 (69.5)		2 (0.0)	7,307 (100.0)	
40–49	9,993 (17.7)	3,440 (34.4)	6,553 (65.6)		6 (0.1)	9,987 (99.9)	
50–59	12,712 (22.5)	4,926 (38.8)	7,786 (61.3)		27 (0.2)	12,685 (99.8)	
60–69	12,114 (21.4)	5,433 (44.9)	6,681 (55.2)		59 (0.5)	12,055 (99.5)	
≥ 70	10,178 (18.0)	4,025 (39.6)	6,153 (60.5)		188 (1.9)	9,990 (98.2)	
Region				0.553			0.0017
Metropolitan	9,962 (17.6)	3,791 (38.1)	6,171 (62.0)		30 (0.3)	9,932 (99.7)	
Urban	13,339 (23.6)	4,983 (37.4)	8,356 (62.6)		60 (0.5)	13,279 (99.6)	
Rural	33,321 (58.9)	12,543 (37.6)	20,778 (62.4)		193 (0.6)	33,128 (99.4)	
Death				< 0.0001			
Yes	283 (0.5)	59 (20.9)	224 (79.2)		283 (100.0)	-	
No	56,339 (99.5)	21,258 (37.7)	35,081 (62.3)		-	56,339 (100.0)	
Year				< 0.0001			0.111
2002	1,453 (2.6)	589 (40.5)	864 (59.5)		-	1,453 (100.0)	
2003	1,964 (3.5)	810 (41.2)	1,154 (58.8)		9 (0.5)	1,955 (99.5)	
2004	2,372 (4.2)	992 (41.8)	1,380 (58.2)		10 (0.4)	2,362 (99.6)	
2005	3,276 (5.8)	1,437 (43.9)	1,839 (56.1)		14 (0.4)	3,262 (99.6)	
2006	3,523 (6.2)	1,485 (42.2)	2,038 (57.9)		26 (0.7)	3,497 (99.3)	
2007	4,148 (7.3)	1,776 (42.8)	2,372 (57.2)		23 (0.6)	4,125 (99.5)	
2008	4,818 (8.5)	1,904 (39.5)	2,914 (60.5)		22 (0.5)	4,796 (99.5)	
2009	5,482 (9.7)	2,185 (39.9)	3,297 (60.1)		33 (0.6)	5,449 (99.4)	
2010	6,204 (11.0)	2,388 (38.5)	3,816 (61.5)		35 (0.6)	6,169 (99.4)	
2011	7,259 (12.8)	2,553 (35.2)	4,706 (64.8)		37 (0.5)	7,222 (99.5)	
2012	8,133 (14.4)	2,689 (33.1)	5,444 (66.9)		44 (0.5)	8,089 (99.5)	
2013	7,990 (14.1)	2,509 (31.4)	5,481 (68.6)		30 (0.4)	7,960 (99.6)	
Total	56,622 (100.0)	21,317 (37.7)	35,305 (62.4)		283 (0.5)	56,339 (99.5)	

Values are presented as number (%).

had higher hospital cost per case (estimate, 192,658 Korean won; 95% CI, 125,701 to 259,614; $p < 0.0001$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher hospital cost per diem (estimate, 55,694 Korean won; 95% CI, 46,205 to 65,183; $p < 0.0001$).

Table 4 shows the results for the adjusted effect of the association between modified CMS and LOS, mortality, hospital cost per case, and hospital cost per diem among lumbar spine disease surgery patients adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a shorter LOS (estimate, -2.539; 95% CI, -2.859 to -2.220; $p < 0.0001$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had an association 0.972 times lower (95% CI, 0.837 to 1.130; $p = 0.715$). Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had lower hospital cost per case (estimate, -152,060 Korean won; 95% CI, -287,236 to -16,884; $p = 0.028$): -556,111 Korean won lower (95% CI, -941,978 to -170,243; $p = 0.005$) in tertiary hospitals and -607,487 Korean won lower (95% CI, -847,311 to -367,662; $p < 0.0001$) in general hospitals compared with hospitals. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher hospital cost per diem (estimate: 42,362 Korean won; 95% CI, -29,180 to 55,544; $p < 0.0001$).

Table 3. General characteristics of all variables (length of stay, hospital cost)

Characteristic	Length of stay (day)		Hospital cost per case (Korean won)		Hospital cost per diem (Korean won)	
	Mean ± SD	*p*-value	Mean ± SD	*p*-value	Mean ± SD	*p*-value
Hospital level						
Type		<0.0001		<0.0001		0.0004
Tertiary hospital	12.340 ± 10.258		4,073,357 ± 4,827,482		365,897 ± 821,742	
General hospital	12.965 ± 12.214		3,084,961 ± 4,351,142		277,903 ± 513,120	
Hospital	10.863 ± 9.083		2,675,627 ± 3,409,682		258,568 ± 374,123	
Organization type		<0.0001		0.2109		<0.0001
Public	16.039 ± 15.975		3,226,527 ± 5,510,078		216,969 ± 493,928	
Corporate	12.772 ± 10.539		3,369,909 ± 4,475,030		288,624 ± 583,690	
Private	10.722 ± 9.616		2,670,286 ± 3,379,137		269,304 ± 410,536	
Region		<0.0001		<0.0001		<0.0001
Metropolitan	9.715 ± 9.017		3,109,011 ± 3,847,805		341,082 ± 518,786	
Urban	13.258 ± 10.889		3,271,190 ± 4,042,084		266,172 ± 521,540	
Rural	11.849 ± 10.189		2,520,137 ± 3,722,206		224,726 ± 406,041	
Bed		<0.0001		<0.0001		<0.0001
≤199	10.470 ± 8.901		2,515,714 ± 3,197,653		247,930 ± 349,336	
200–299	11.507 ± 11.036		3,009,791 ± 3,699,586		310,114 ± 493,649	
300–399	14.210 ± 11.155		2,885,936 ± 5,506,214		207,580 ± 407,818	
400–499	13.324 ± 11.529		2,670,602 ± 3,557,473		226,261 ± 426,559	
500–599	15.242 ± 11.927		3,469,678 ± 4,187,909		272,043 ± 742,036	
600–699	14.610 ± 14.011		3,821,565 ± 5,230,944		296,492 ± 519,921	
700–799	13.573 ± 10.702		3,896,925 ± 5,895,635		268,919 ± 280,308	
800–899	14.580 ± 12.535		3,857,991 ± 3,879,661		296,764 ± 345,553	
≥900	12.005 ± 9.283		3,894,471 ± 4,652,814		353,465 ± 807,264	
Doctor		<0.0001		<0.0001		<0.0001
≤49	11.272 ± 9.798		2,692,606 ± 3,556,071		256,485 ± 386,024	
50–99	11.728 ± 14.138		2,965,897 ± 3,954,385		351,910 ± 664,742	
100–149	14.520 ± 11.693		3,802,614 ± 4,607,958		281,665 ± 741,486	
150–199	13.755 ± 11.325		3,713,833 ± 5,007,180		278,344 ± 384,235	
200–249	13.258 ± 10.068		3,706,323 ± 5,108,694		288,947 ± 342,877	
250–299	12.736 ± 9.136		3,534,084 ± 3,982,408		299,960 ± 592,477	
≥300	11.796 ± 9.356		4,176,295 ± 4,938,677		378,279 ± 851,768	
Computed tomography		0.2753		0.0005		<0.0001
No	10.073 ± 7.327		2,392,039 ± 2,901,786		232,260 ± 287,055	
Yes	11.645 ± 10.263		2,971,177 ± 3,919,712		278,250 ± 492,258	
Magnetic resonance imaging		<0.0001		<0.0001		<0.0001
No	13.030 ± 10.030		1,773,690 ± 2,570,092		162,979 ± 389,843	
Yes	11.474 ± 10.139		3,013,319 ± 3,931,032		282,815 ± 488,269	
Positron emission tomography		<0.0001		0.0043		<0.0001
No	11.342 ± 10.230		2,690,128 ± 3,570,272		259,464 ± 424,430	
Yes	12.334 ± 9.781		3,813,610 ± 4,684,820		333,393 ± 647,519	
Individual level						
Patient clinical complexity level		<0.0001		<0.0001		<0.0001
0	9.918 ± 8.513		2,366,234 ± 3,124,208		262,627 ± 482,602	
1	14.381 ± 11.015		4,084,060 ± 4,426,943		306,522 ± 354,896	
2	16.822 ± 14.123		4,706,630 ± 5,982,440		315,587 ± 685,841	
3	17.355 ± 15.086		3,162,558 ± 3,921,545		224,798 ± 508,493	

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Table 3. Continued

Characteristic	Length of stay (day)		Hospital cost per case (Korean won)		Hospital cost per diem (Korean won)	
	Mean ± SD	*p*-value	Mean ± SD	*p*-value	Mean ± SD	*p*-value
Sex		< 0.0001		0.3495		< 0.0001
Male	10.637 ± 9.713		2,591,159 ± 3,671,664		267,903 ± 441,874	
Female	12.390 ± 10.436		3,253,258 ± 4,023,822		282,977 ± 518,372	
Age (yr)		< 0.0001		< 0.0001		< 0.0001
≤ 29	8.308 ± 7.240		1,369,066 ± 1,794,441		220,628 ± 378,160	
30–39	8.592 ± 7.160		1,508,280 ± 1,743,870		210,589 ± 337,449	
40–49	10.302 ± 9.628		2,116,664 ± 2,616,372		233,283 ± 506,684	
50–59	11.763 ± 9.974		3,090,064 ± 3,654,968		284,153 ± 448,818	
60–69	13.366 ± 10.336		4,043,988 ± 4,731,798		332,486 ± 549,210	
≥ 70	13.926 ± 12.191		3,949,300 ± 4,929,566		310,534 ± 535,593	
Region		0.0731		0.0021		0.0003
Metropolitan	9.990 ± 10.100		2,935,998 ± 4,537,192		306,564 ± 441,434	
Urban	12.692 ± 10.225		3,022,640 ± 3,902,546		257,350 ± 550,549	
Rural	11.583 ± 10.055		2,910,568 ± 3,643,598		274,136 ± 466,803	
Death		< .0001		< 0.0001		< 0.0001
Yes	12.781 ± 11.222		2,817,350 ± 3,848,167		296,535 ± 668,160	
No	11.558 ± 10.133		2,942,068 ± 3,876,222		275,779 ± 482,838	
Year		< 0.0001		< 0.0001		0.7751
2002	12.424 ± 9.530		3,311,334 ± 3,952,227		313,640 ± 559,053	
2003	12.823 ± 11.648		2,856,296 ± 3,288,238		264,448 ± 330,068	
2004	12.637 ± 14.212		2,727,633 ± 3,266,189		291,371 ± 430,242	
2005	12.533 ± 12.838		3,232,273 ± 4,000,586		340,784 ± 562,475	
2006	12.789 ± 11.187		3,124,003 ± 3,665,188		282,838 ± 383,053	
2007	12.397 ± 10.011		3,236,505 ± 3,875,078		292,414 ± 408,736	
2008	12.531 ± 10.207		3,097,829 ± 3,814,858		277,667 ± 510,071	
2009	12.665 ± 11.377		3,321,143 ± 4,521,166		276,274 ± 434,815	
2010	11.740 ± 9.008		3,165,761 ± 4,665,550		266,456 ± 320,008	
2011	10.630 ± 9.001		2,683,059 ± 3,378,635		256,839 ± 430,593	
2012	10.334 ± 8.483		2,708,282 ± 3,833,982		271,484 ± 660,299	
2013	10.037 ± 8.616		2,548,756 ± 3,456,698		256,028 ± 507,837	
Total	11.564 ± 10.139		2,941,444 ± 3,876,058		275,882 ± 483,928	

Values are presented as mean ± standard deviation.

DISCUSSION

In this study, our primary purpose was to modify medical specialization in Korea by category for lumbar spine disease hospital inpatients by taking log transformation to the denominator of CMS and to determine the effects of specialization on LOS, mortality, hospital cost per case, and hospital cost per diem after adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year, applying a longitudinal model to a nationally representative cohort sample data from 2002 to 2013. Under the assumption that hospitals can provide treatments in several different diagnosis categories [12] and may be medically specialized in each of them, independently of the hospital's degree of diversification, we classified a hospital as specialized if the number of treated cases in a given diagnosis category exceeded a defined threshold (mean number of patients treated nationally in each disease category). In short, we focused on the volume as well as the proportion of patients within specific diagnosis category.

To our knowledge, this is the first study anywhere in the world to develop a measure for hospital specialization in a specific disease based on patient volumes and patient proportions. As can be seen in Appendix 3, modified CMS shows a U-shaped trend from small to large hospitals, associated with higher hospital specialization. Our measures are therefore the first to capture our experi-

Table 4. Association of modified CMS on each dependent variable among surgery patients

Variable	Length of stay		Mortality		Hospital cost per case		Hospital cost per diem	
	Estimate	*p*-value	Odds ratio	*p*-value	Estimate	*p*-value	Estimate	*p*-value
Hospital level								
Modified CMS	-2.539	<0.0001	0.972	0.715	-152,060	0.028	42,362	<0.0001
Type								
Tertiary hospital	-0.174	0.708	1.054	0.805	-556,111	0.005	-13,852	0.471
General hospital	0.105	0.716	0.934	0.612	-607,487	<0.0001	-40,224	0.001
Hospital	Ref		1.000		Ref		Ref	
Organization type								
Public	6.398	<0.0001	0.888	0.755	1,088,659	0.001	-99,631	0.002
Corporate	1.030	<0.0001	1.095	0.384	242,019	0.013	-14,342	0.129
Private	Ref		1.000		Ref		Ref	
Region								
Metropolitan	-2.291	<0.0001	1.003	0.974	-242,075	0.005	70,206	<0.0001
Urban	1.714	<0.0001	1.053	0.59	436,402	<0.0001	-98	0.991
Rural	Ref		1.000		Ref		Ref	
Bed								
≤199	-2.083	0.005	1.164	0.659	383,062	0.217	85,483	0.005
200–299	-0.997	0.149	1.155	0.656	894,820	0.002	120,529	<0.0001
300–399	0.580	0.427	1.367	0.350	2,105,382	<0.0001	140,659	<0.0001
400–499	0.073	0.926	1.083	0.827	1,021,570	0.002	71,297	0.028
500–599	1.112	0.089	0.922	0.794	1,615,999	<0.0001	81,848	0.003
600–699	1.140	0.070	1.060	0.837	1,487,516	<0.0001	47,037	0.070
700–799	0.616	0.270	0.888	0.654	1,123,535	<0.0001	14,678	0.525
800–899	0.576	0.229	1.048	0.824	83,899	0.68	-7,969	0.688
≥900	Ref		1.000		Ref		Ref	
Doctor								
≤49	0.517	0.478	0.960	0.905	-1,822,744	<0.0001	-117,550	<0.0001
50–99	0.870	0.225	1.036	0.915	-1,580,249	<0.0001	-12,031	0.685
100–149	0.163	0.802	1.134	0.666	-1,227,326	<0.0001	-79,750	0.003
150–199	1.515	0.009	0.925	0.775	-1,056,423	<0.0001	-102,637	<0.0001
200–249	0.935	0.095	0.855	0.557	-720,735	0.002	-72,211	0.002
250–299	1.344	0.005	1.209	0.350	-270,308	0.181	-72,847	0.000
≥300	Ref		1.000		Ref		Ref	
Computed tomography								
No	-0.898	0.004	0.997	0.983	-394,287	0.003	-41,399	0.001
Yes	Ref		1.000		Ref		Ref	
Magnetic resonance imaging								
No	3.65	<0.0001	0.919	0.719	498,394	0.013	-72,968	0.000
Yes	Ref		1.000		Ref		Ref	
Positron emission tomography								
No	2.824	<0.0001	0.930	0.638	115,532	0.425	-71,770	<0.0001
Yes	Ref		1.000		Ref		Ref	
Individual level								
Patient clinical complexity level								
0	-3.12	<0.0001	0.570	0.006	1,297,466	<0.0001	85,335	0.000
1	-0.513	0.383	0.569	0.007	2,280,018	<0.0001	96,686	<0.0001
2	1.396	0.021	0.730	0.142	2,978,026	<0.0001	107,110	<0.0001
3	Ref		1.000		Ref		Ref	

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Table 4. Continued

Variable	Length of stay		Mortality		Hospital cost per case		Hospital cost per diem	
	Estimate	*p*-value	Odds ratio	*p*-value	Estimate	*p*-value	Estimate	*p*-value
Sex								
Male	-1.363	<0.0001	1.028	0.662	-204,567	0.000	8,607	0.127
Female	Ref		1.000		Ref		Ref	
Age (yr)								
≤29	-3.557	<0.0001	0.776	0.106	-1,489,142	<0.0001	20,318	0.136
30–39	-3.053	<0.0001	0.781	0.055	-1,297,855	<0.0001	2,101	0.853
40–49	-1.871	<0.0001	0.784	0.027	-1,121,956	<0.0001	-24,467	0.013
50–59	-1.177	<0.0001	0.820	0.035	-627,865	<0.0001	-11,936	0.168
60–69	-0.98	<0.0001	0.855	0.077	-319,843	0.000	-535	0.949
≥70	Ref		1.000		Ref		Ref	
Region								
Metropolitan	0.618	0.002	0.921	0.390	379,186	<0.0001	4,398	0.599
Urban	0.526	0.007	0.904	0.270	-23,903	0.772	-15,319	0.057
Rural	Ref		1.000		Ref		Ref	
Death								
Yes	Ref		NA		Ref		Ref	
No	1.398	0.263	NA		192,243	0.716	-109,424	0.035
Year								
2002	1.424	0.002	0.985	0.945	353,426	0.069	-3,158	0.868
2003	0.894	0.029	1.025	0.901	-603,129	0.001	-58,710	0.001
2004	-0.863	0.022	0.966	0.849	-1,218,983	<0.0001	-25,643	0.099
2005	-0.164	0.618	0.978	0.887	-285,711	0.041	54,176	<0.0001
2006	0.228	0.479	1.188	0.235	-462,273	0.001	-38,413	0.004
2007	0.127	0.675	1.048	0.74	-215,000	0.093	-30,744	0.014
2008	0.658	0.025	1.011	0.935	-207,560	0.096	-56,316	<0.0001
2009	0.965	0.001	1.023	0.861	13,720	0.909	-58,672	<0.0001
2010	0.641	0.020	1.056	0.669	210,149	0.072	-38,254	0.001
2011	0.407	0.134	1.079	0.546	-259,622	0.024	-50,741	<0.0001
2012	0.368	0.167	1.039	0.759	122,582	0.277	-8,038	0.464
2013	Ref		1.000		Ref		Ref	

Adjusted for primary diagnosed code.
CMS, category medical specialization; Ref, reference; NA, not applicable.

ence, professional expertise and technical equipment as well as the concentration of diagnoses within each diagnosis category, and also to show that, on balance, modified CMS provides an intuitively reasonable characterization of hospital specialization reflecting the Korean health care environment. The results of our repeated cross-sectional regression analysis over time (i.e., the GEE methodology) provide insightful scientific evidence into the associations between the modified CMS and LOS, mortality, hospital cost per case, and hospital cost per diem in current practice in Korea. This is a very flexible approach to the analysis of correlated data from the same subject (i.e., person) over time [14,15].

The major findings of our study are as follows. First, our modified CMS shows the highest correlation with absolute number of lumbar spine disease patients (Appendix 6). In particular, subgroup analysis by proportion of total patients who are lumbar spine disease patients reflects the results of correlation analysis between hospital specialization measures and absolute hospital volume of lumbar spine disease patients. As can be seen in Appendix 7, IHI, ITI, CMS, and ICMS have negative associations with absolute number of lumbar spine patients, and only modified CMS has a positive association with it. Second, results of the adjusted effects of the associations between modified CMS and LOS, mortality, total cost per case, and total cost per diem among lumbar spine disease surgery patients show that inpatients at hospitals with higher modified CMS had lower LOS, lower mortality (although not significantly), and lower total cost per case, while inpatients at hospitals with higher modified CMS had higher total cost per diem.

Given the decreases in LOS, morality (although not significant) and total cost per case of lumbar spine disease surgery patients and the increase in total cost per diem of lumbar spine disease surgery patients, specialization can be considered to improve the health outcomes of these patients, reflecting the use of the very complex and sophisticated medical technologies and of the efficient and effective care and operating procedures adopted at more specialized hospitals. As a result of our study, it can be concluded that hospital specialization has a substantial effect on hospital performance in the areas of LOS, mortality, and total cost.

Whereas previous studies, for example by Luft et al. [16] and Melnick et al. [17] found that hospitals have a tendency to imitate competitors, they also found that hospital competition tended to increase hospital specialization, resulting in increasing efficiency by reducing the costs associated with the prior service mix. In addition, several hospitals within more competitive markets had less specialized service mix, suggesting that they provide a wider range of services. These findings imply that hospitals tend to adopt some high-visibility services offered by their competitors for competitive purposes at the same time that they focus on filling selected market niches.

According to many researchers, there are two opposite perspectives on hospital specialization. The first perspective argues that hospital specialization improves quality of care and efficiency of hospital management by increasing productivity [18,19] and has a positive effect on hospital performance [20]. In addition, as shown by Schneider et al. [21], specialized hospitals are associated with higher operating margins and lower operating costs. However, contrary to the expectation that specialized hospitals reduce the overall operating profits of general hospitals, general hospital residing in markets with at least one specialized hospital have higher profit and operating margins than those that do not compete with specialized hospitals. This is consistent with prevailing economic theory, which suggests that firms will enter markets in which profit margins will be comparatively higher. In addition, economic theory predicts that competition eventually should lead hospitals to reduce the range of services they offer [22] and concentrate on services in which they have a comparative advantage [22]. In this way, each hospital finds a way to most efficiently provide given services. The other implication of this perspective is that general hospitals are threatened by specialized hospitals, because specialized hospitals tend to focus on services with high profit margins and to avoid health care services with high expenses related to admitting patients in severe condition [23,24].

Based on the results of previous studies showing that hospital specialization brings a reduction of production costs and results in improved efficiency of hospital operation [8,25], our results show that hospital specialization supports the achievement of hospital efficiency and increased quality of care in areas such as LOS and mortality.

Our results have several major implications for health care policymakers and hospital administrators, in Korea and elsewhere. First, this study may help hospital policymakers and hospital administrators to understand the effects of hospital specialization strategy on hospital cost and quality of care under recent changes in the Korean health care environment such as the initiation of the specialty hospital designation and prospective payment systems (e.g., DRG) and to evaluate the internal and external environments of the hospital before implementing a new hospital management strategy [26]. Thus, our results can help hospitals improve performance and operations. Second, with increasing competition, economic crisis, and recent policy changes made by the Korean government, hospitals have to become more competitive to survive and have to seek to improve cost efficiency in the face of increasing national health expenditures and to have the desire to provide high-quality. Therefore, our findings add to the evidence of associations between hospital specialization and hospital cost per case, hospital cost per diem, LOS, and mortality, through the use of "modified CMS"; and these results enhance the evidentiary documentation for hospital specialization. However, to strengthen the reliability and generalizability of our findings of this study, replication of this work using other countries' data could be necessary and further study of our modified CMS is needed.

This study has several limitations worth noting, and caution must be taken when interpreting the study's results or attempting to generalize our findings. First, although this study analyzed nationwide cohort sample data to measure hospital specialization during a defined period, international generalizability is limited as a result. Second, this study analyzed hospital cost, LOS, and mortality to find out whether hospital specialization is associated with hospital performance. However, it was not able to measure the direct management achievements of hospitals because of lack of information. Therefore, if data to measure financial performance of hospitals can be collected and analyzed, meaningful conclusions for policymakers and hospital administrators can be drawn. Third, when participants were selected for our study, ICD coding was employed. However, because the hospital specialization variable relied on ICD coding of principal diagnosis, it is difficult to validate individual ICD codes, because our data are anonymized database, making them susceptible to errors related to coding. Fourth, as this is a large, longitudinal, nationwide sample, there may be significant heterogeneity in the care provided both in the field and at receiving hospitals, although we limited our analysis to lumbar spine disease patients with surgery. Fifth, several unmeasured confounders exist, including hospital factors that could contribute to differences in hospital cost, mortality, and LOS, such as better management of health resources, a well-selected care team, and presence of clinical pathways; lack of data on these means that we could not obtain information regarding unmeasured hospital characteristics. Therefore, further research is required to explore their respective contributions, because the evidence at present is inadequate and unclear.

Our results showed that increase in hospital specialization had a substantial effect on decrease in hospital cost per case, LOS, and mortality, and on increase in hospital cost per diem among lumbar spine disease surgery patients. With increasing competition among Korean hospitals and recent policy changes by the Korean government, considered above, our results may help hospital policymakers better understand the effects of hospital specialization strategies on hospital operations and quality of care.

In conclusion, our findings also provide unique evidentiary documentation of the effectiveness of our modified CMS. Thus, to strengthen the reliability and generalizability of our findings of this study, replication of this work using other countries' data could be necessary and further study of our modified CMS is needed.

REFERENCES

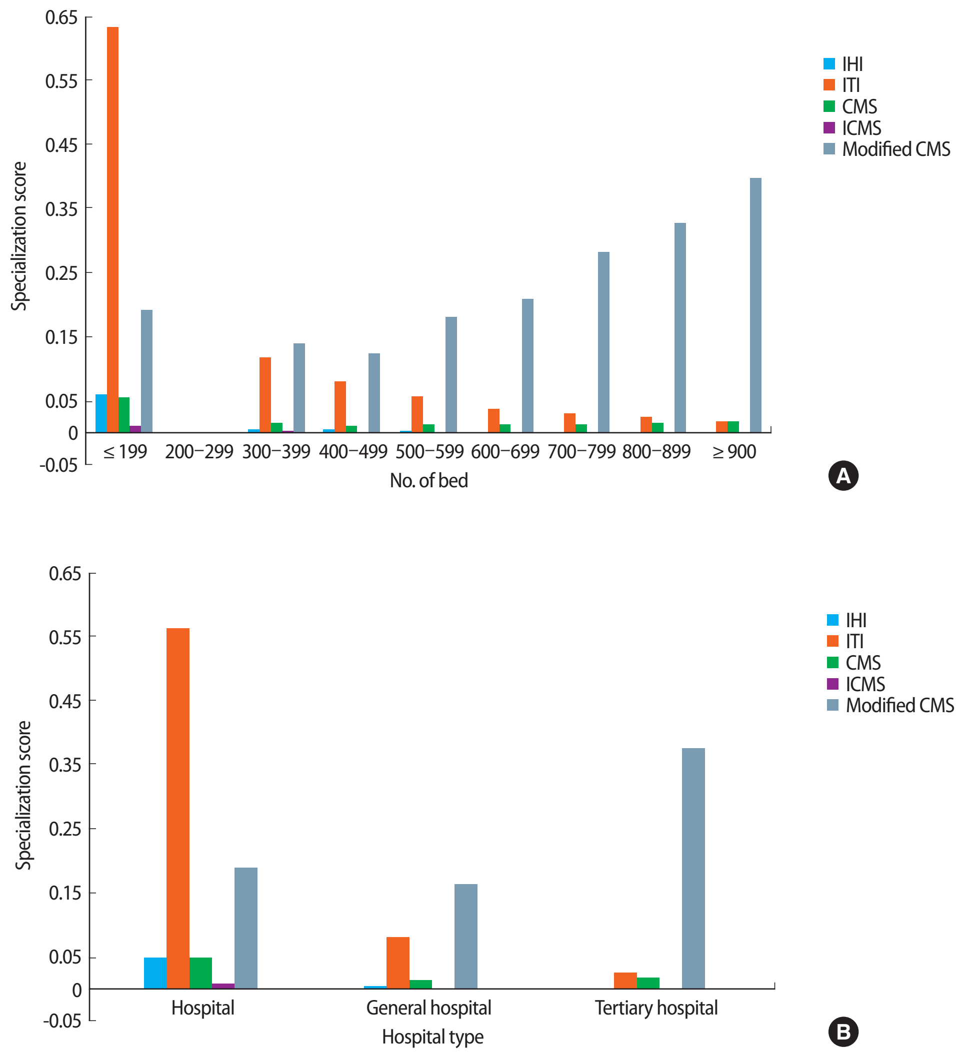
1. Lee KS, Chun KH, Lee JS. Reforming the hospital service structure to improve efficiency: urban hospital specialization. Health Policy 2008; 87(1):41-49. DOI: https://doi.org/10.1016/j.healthpol.2007.10.003.
2. Kim SJ, Park EC, Jang SI, Lee M, Kim TH. An analysis of the inpatient charge and length of stay for patients with joint diseases in Korea: specialty versus small general hospitals. Health Policy 2013;113(1-2):93-99. DOI: https://doi.org/10.1016/j.healthpol.2013.09.013.
3. Carey K, Burgess JF Jr, Young GJ. Specialty and full-service hospitals: a comparative cost analysis. Health Serv Res 2008;43(5 Pt 2):1869-1887. DOI: https://doi.org/10.1111/j.1475-6773.2008.00881.x.
4. Theil H. Economics and information theory. Chicago (IL): Rand McNally and Company; 1967.
5. Farley DE. Measuring casemix specialization and the concentration of diagnoses in hospitals using information theory. J Health Econ 1989; 8(2):185-207. DOI: https://doi.org/10.1016/0167-6296(89)90003-9.
6. Farley DE, Hogan C. Case-mix specialization in the market for hospital services. Health Serv Res 1990;25(5):757-783.
7. Baumgardner JR, Marder WD. Specialization among obstetrician/gynecologists: another dimension of physician supply. Med Care 1991;29(3): 272-282. DOI: https://doi.org/10.1097/00005650-199103000-00008.
8. Eastaugh SR. Hospital costs and specialization: benefits of limiting the number of product lines. J Health Care Finance 2009;36(2):24-34.
9. Eastaugh SR. Hospital specialization: product-line planning during the market reformation. J Health Care Finance 2011;38(1):71-82.
10. Linna M, Hakkineu U. Determinants of cost efficiency of Finnish hospitals: a comparison of DEA and SFA [Internet]. Espoo: Helsinki University of Technology; 1999 [cited 2018 Jan 20]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.16.3374&rep=rep1&type=pdf.
11. Herwartz H, Strumann C. On the effect of prospective payment on local hospital competition in Germany. Health Care Manag Sci 2012;15(1):48-62. DOI: https://doi.org/10.1007/s10729-011-9180-9.
12. Lindlbauer I, Schreyogg J. The relationship between hospital specialization and hospital efficiency: do different measures of specialization lead to different results? Health Care Manag Sci 2014;17(4):365-378. DOI: https://doi.org/10.1007/s10729-014-9275-1.
13. Kim WJ, Lee YC, Kang SH. Specialization of small and medium-size hospitals and managerial performance. Korean J Hosp Manag 1999;4(2):85-105.
14. Homish GG, Edwards EP, Eiden RD, Leonard KE. Analyzing family data: a GEE approach for substance use researchers. Addict Behav 2010;35(6): 558-563. DOI: https://doi.org/10.1016/j.addbeh.2010.01.002.
15. Liang KY, Zeger SL. Regression analysis for correlated data. Annu Rev Public Health 1993;14:43-68.
16. Luft HS, Robinson JC, Garnick DW, Maerki SC, McPhee SJ. The role of specialized clinical services in competition among hospitals. Inquiry 1986;23(1):83-94.
17. Melnick GA, Zwanziger J, Bradley T. Competition and cost containment in California: 1980-1987. Health Aff (Millwood) 1989;8(2):129-136. DOI: https://doi.org/10.1377/hlthaff.8.2.129.
18. Choudhry S, Choudhry NK, Brennan TA. Specialty versus community hospitals: what role for the law? Health Aff (Millwood) 2005;24(Suppl W5):361-372. DOI: https://doi.org/10.1377/hlthaff.w5.361.
19. Kher U, Dawson P, Hylton H. The hospital wars. Time 2006;168(24):64-66, 68.
20. Kim HS, Kim YH, Woo JS, Hyun SJ. An analysis of organizational performance based on hospital specialization level and strategy type. PLoS One 2015;10(7):e0132257. DOI: https://doi.org/10.1371/journal.pone.0132257.
21. Schneider JE, Ohsfeldt RL, Morrisey MA, Li P, Miller TR, Zelner BA. Effects of specialty hospitals on the financial performance of general hospitals, 1997-2004. Inquiry 2007;44(3):321-334. DOI: https://doi.org/10.5034/inquiryjrnl_44.3.321.
22. Dayhoff DA, Cromwell J. Measuring differences and similarities in hospital caseloads: a conceptual and empirical analysis. Health Serv Res 1993; 28(3):293-312.
23. Herzlinger RE. Let's put consumers in charge of health care. Harv Bus Rev 2002;80(7):44-50, 52-55, 123.
24. Dobson A, Haught R. The rise of the entrepreneurial physican. Health Aff (Millwood) 2005;24(Suppl W5):494-497.
25. Barro JR, Huckman RS, Kessler DP. The effects of cardiac specialty hospitals on the cost and quality of medical care. J Health Econ 2006;25(4): 702-721. DOI: https://doi.org/10.1016/j.jhealeco.2005.11.001.
26. Daft RL. Organization theory and design. St. Paul (MN): West Publishing Company; 1995.

Appendix 1. Diagnosed code of lumbar spine disease patients

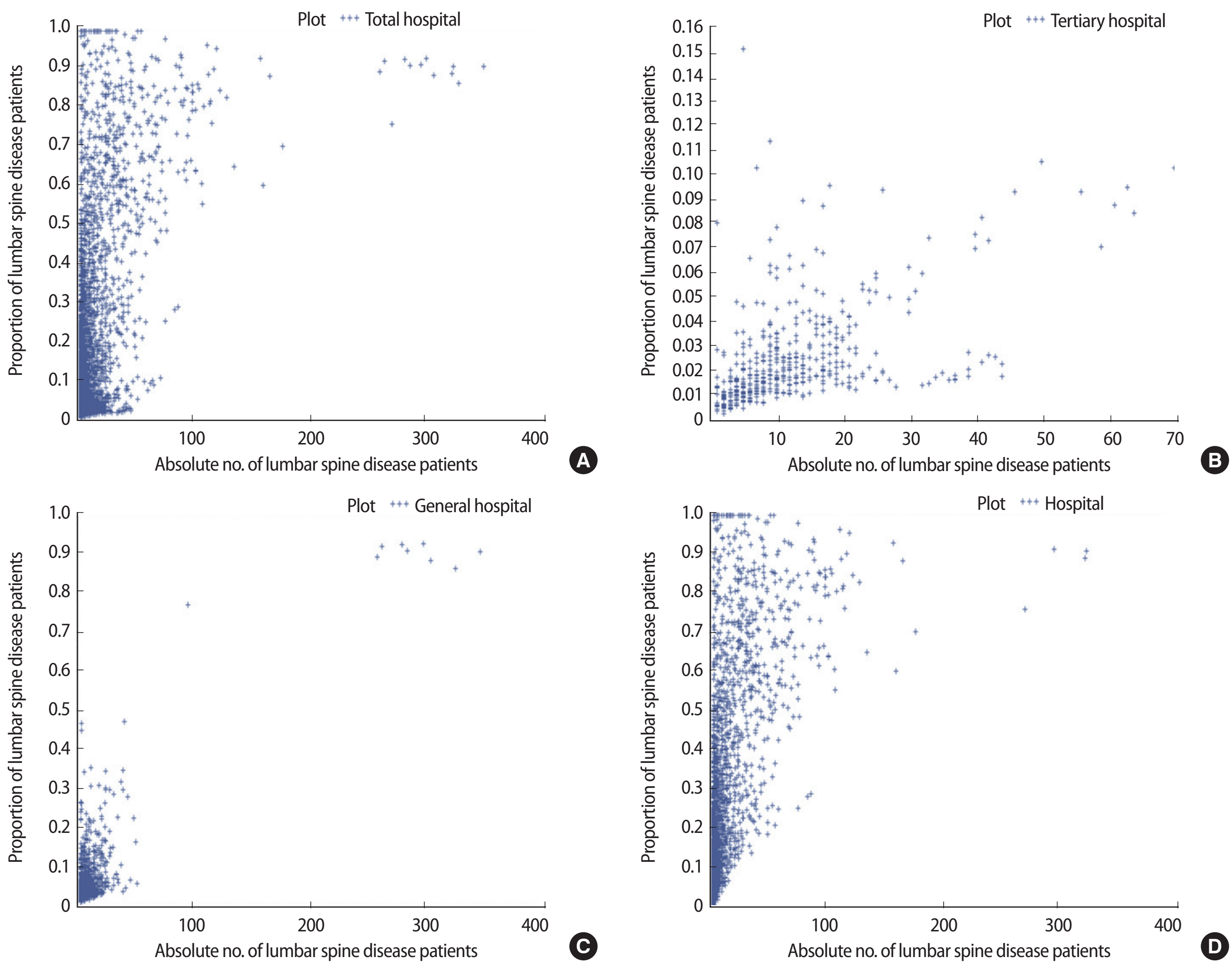
Diagnosed code	Diagnosis
M43	Other deforming dorsopathies
M430	Spondylolysis
M4300	Spondylolysis, multiple sites in spine
M4305	Spondylolysis, thoracolumbar region
M4306	Spondylolysis, lumbar region
M4307	Spondylolysis, lumbosacral region
M4308	Spondylolysis, sacral and sacrococcygeal region
M4309	Spondylolysis, site unspecified
M431	Spondylolisthesis
M4310	Spondylolisthesis, multiple sites in spine
M4315	Spondylolisthesis, thoracolumbar region
M4316	Spondylolisthesis, lumbar region
M4317	Spondylolisthesis, lumbosacral region
M4318	Spondylolisthesis, sacral and sacrococcygeal region
M4319	Spondylolisthesis, site unspecified
M432	Other fusion of spine
M4320	Other fusion of spine, multiple sites in spine
M4325	Other fusion of spine, thoracolumbar region
M4326	Other fusion of spine, lumbar region
M4327	Other fusion of spine, lumbosacral region
M4328	Other fusion of spine, sacral and sacrococcygeal region
M4329	Other fusion of spine, site unspecified
M438	Other specified deforming dorsopathies
M4380	Other specified deforming dorsopathies, multiple sites in spine
M4385	Other specified deforming dorsopathies, thoracolumbar region
M4386	Other specified deforming dorsopathies, lumbar region
M4387	Other specified deforming dorsopathies, lumbosacral region
M4388	Other specified deforming dorsopathies, sacral and sacrococcygeal region
M4389	Other specified deforming dorsopathies, site unspecified
M439	Deforming dorsopathy, unspecified
M4390	Deforming dorsopathy, unspecified, multiple sites in spine
M4395	Deforming dorsopathy, unspecified, thoracolumbar region
M4396	Deforming dorsopathy, unspecified, lumbar region
M4397	Deforming dorsopathy, unspecified, lumbosacral region
M4398	Deforming dorsopathy, unspecified, sacral and sacrococcygeal region
M4399	Deforming dorsopathy, unspecified, site unspecified
M48	Other spondylopathies
M480	Spinal stenosis
M4800	Spinal stenosis, multiple sites in spine
M4805	Spinal stenosis, thoracolumbar region
M4806	Spinal stenosis, lumbar region
M4807	Spinal stenosis, lumbosacral region
M4808	Spinal stenosis, sacral and sacrococcygeal region
M4809	Spinal stenosis, site unspecified
M488	Other specified spondylopathies
M4880	Other specified spondylopathies, multiple sites in spine
M4885	Other specified spondylopathies, thoracolumbar region
M4886	Other specified spondylopathies, lumbar region
M4887	Other specified spondylopathies, lumbosacral region
M4888	Other specified spondylopathies, sacral and sacrococcygeal region
M4889	Other specified spondylopathies, site unspecified
M489	Spondylopathy, unspecified
M4890	Spondylopathy, unspecified, multiple sites in spine
M4895	Spondylopathy, unspecified, thoracolumbar region
M4896	Spondylopathy, unspecified, lumbar region
M4897	Spondylopathy, unspecified, lumbosacral region
M4898	Spondylopathy, unspecified, sacral and sacrococcygeal region
M4899	Spondylopathy, unspecified, site unspecified
M51	Other intervertebral disc disorders
M510	Lumbar and other intervertebral disc disorders with myelopathy
M511	Lumbar and other intervertebral disc disorders with radiculopathy
M512	Other specified intervertebral disc displacement
M513	Other specified intervertebral disc degeneration
M514	Schmorl's nodes
M518	Other specified intervertebral disc disorders
M519	Intervertebral disc disorder, unspecified

Appendix 2. Surgery code of lumbar spine disease patients

Surgery	Category	Procedure code
Arthrodesis for spinal deformity	Anterior technique Posterior technique	N0444, N0445 N0446, N0447
Arthrodesis of spine	Anterior technique (lumbar spine) Posterior technique (lumbar spine)	N0466 N0469
Diskectomy	Invasive (lumbar spine) Endoscopy	N1493 N1494
Injection procedure	Chemonucleolysis	N1495
Aspiration procedure	Nucleus pulposus of intervertebral disk	N1496
Laminectomy	Lumbar spine	N1499



Appendix 3. (A, B) Hospital specialization trend by number of beds and hospital type. ITI, Information Theory Index; IHI, inner Herfindahl–Hirschman Index; CMS, category medical specialization; ICMS, inner category medical specialization.



Appendix 4. Proportion and absolute number by hospital type. (A) Total hospital. (B) Tertiary hospital. (C) General hospital. (D) Hospital.

Appendix 5. Correlation between proportion and absolute number by hospital type

Hospital type	Total	Tertiary hospital	General hospital	Hospital
Correlation	0.512	0.511	0.811	0.574
p-value	<0.0001	<0.0001	<0.0001	<0.0001

Appendix 6. Correlation between hospital specialization and absolute number and proportion of lumbar spine disease patients

	Inner Herfindahl–Hirschman Index		Information Theory Index		CMS		Inner CMS		Modified CMS	
	Proportion*	Absolute†	Proportion*	Absolute†	Proportion*	Absolute†	Proportion*	Absolute†	Proportion*	Absolute†
Correlation	0.892	0.378	0.991	0.489	0.815	0.449	0.373	0.025	0.701	0.611
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.045	<0.0001	<0.0001

CMS, category medical specialization.
*Proportion of lumbar spine patients. †Absolute number of lumbar spine patients.

Appendix 7. Correlation between hospital specialization and absolute number by proportion

Variable	Inner Herfindahl–Hirschman Index		Information Theory Index		CMS		Inner CMS		Modified CMS	
	Correlation	*p*-value	Correlation	*p*-value	Correlation	*p*-value	Correlation	*p*-value	Correlation	*p*-value
≥80% of lumbar spine disease patients	-0.420	<0.0001	-0.391	<0.0001	-0.236	0.001	-0.335	<0.0001	0.187	0.011
≥70% of lumbar spine disease patients	-0.344	<0.0001	-0.230	0.000	-0.123	0.042	-0.277	<0.0001	0.232	0.000
≥60% of lumbar spine disease patients	-0.246	<0.0001	-0.092	0.072	-0.033	0.523	-0.227	<0.0001	0.281	<0.0001

CMS, category medical specialization.