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Analysis of Hospital Volume and Factors Influencing Economic Outcomes in Cancer Surgery: Results from a Population-based Study in Korea

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Objectives: To evaluate associations between hospital volume, costs, and length of stay (LOS), and clinical and demographic outcome factors for five types of cancer resection. The main dependent variables were cost and LOS; the primary independent variable was volume.

Methods: Data were obtained from claims submitted to the Korean National Health Insurance scheme. We identified patients who underwent the following surgical procedures: pneumonectomy, colectomy, mastectomy, cystectomy, and esophagectomy. Hospital volumes were divided into quartiles.

Results: Independent predictors of high costs and long LOS included old age, low health insurance contribution, non-metropolitan residents, emergency admission, Charlson score > 2, public hospital ownership, and teaching hospitals. After adjusting for relevant factors, there was an inverse relationship between volume and costs/LOS. The highest volume hospitals had the lowest procedure costs and LOS. However, this was not observed for cystectomy.

Conclusion: Our findings suggest an association between patient and clinical factors and greater costs and LOS per surgical oncologic procedure, with the exception of cystectomy. Yet, there were no clear associations between hospitals' cost of care and risk-adjusted mortality.

Key Words: neoplasms, surgical procedures, operative, hospital costs, length of stay, hospitalization

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INTRODUCTION

Numerous studies have demonstrated a volume–outcome relationship for medical and surgical care, whereby outcomes improve as the number of procedures performed at a particular hospital increases [1–5]. Some reports attribute this association to a "practice makes perfect" effect [1,2], the effect of improving outcomes by repetitively performing the same procedures [6]. Within the corporate sector, a similar effect has been described, known as the volume–cost relationship. In this instance, the average cost of unit production decreases as total production increases. This association is thought to rely on the learning effect and economies of scale [7].

The volume–outcome relationship in health services has been thoroughly studied; however, few studies have examined the volume–cost relationship. Whereas the former focuses on aspects of health service quality, the latter has potential to support the regionalization of health services, an important concept gaining substantial interest. Glasgow et al [8] reported that the identification of hospitals with superior patient outcomes for particular procedures could enable the regionalization of complex operations to provide the most efficacious and cost-effective care. For example, in cases of complex surgical procedures that require expensive medical equipment and specialized skills, such as coronary artery bypass surgery and bone marrow or solid organ transplantation, the quality of care can be improved and costs can be reduced if certain hospitalizes specialize in those particular procedures, thereby accumulating more procedure-specific experience and knowledge. In support of this notion, hospitals that frequently perform complex surgical procedures have been shown to have lower associated costs [4,9].

Several studies have identified a trend of surgery costs decreasing as the number of performed procedures increases, and this trend remains constant across demographic variables and diseases [2–4]. Furthermore, some reports have shown that the length of stay (LOS) per operation, a factor closely related with total cost, also decreases as the number of operations increases [3,4]. While studies of this nature have been conducted in the past, they either focused only on one type of cancer surgery or were regionally limited to the United States or Europe. A recent study examined the volume–cost relationship for lung cancer resection in Asia [10]. However, that report considered only one type of procedure, making it difficult to generalize the relationship across cancer treatments.

Carey reported that costs per patient were determined by certain factors, including several major diagnoses, characteristics of hospitals and patients, and LOS. However, for any one disease, costs were most affected by LOS [11]. Thus, in this study, we examined five major types of cancer surgical procedures and various factors that affect procedural costs and LOS.

MATERIALS AND METHODS

1. Databases

Using National Health Insurance (NHI) claim data, which covers almost the entire Korean population, we identified patients who underwent the following cancer resections between 2002 and 2005: major pneumonectomy, colectomy, mastectomy, cystectomy, or esophagectomy. These data included the payments for insurance-covered services, as well as patient sociodemographic information (gender, age, monthly insurance contribution, the residential area of all health service providers, and disease comorbidity) and other health-related information, such as specific surgical procedures performed and course of admission. Prior to analysis, the personal identification number used for data linkage was deleted. In addition, this study was a secondary data analysis. For these reasons, the human research ethics committee of our institution did not have to review this study.

2. Patients and procedures

Admissions for each of the five cancer surgical procedures in our analysis were identified using appropriate procedural codes from the International Classification of Disease (ICD), 9th revision, Clinical Modification (ICD-9-CM) [12]. In addition, ICD-9-CM codes for major cancer surgical procedures were modified for the Korean Electronic Data Interchange.

To ensure our data included only cancer resections and to increase the homogeneity of the study sample, we excluded patients whose file did not contain an accompanying cancer code related to the indexed procedure in the primary diagnosis. Secondary diagnostic codes were extracted to enumerate comorbidity conditions, according to the Charlson comorbidity index, which has been validated as a good instrument to predict clinical outcomes, costs, and use of resources [13]. The monthly NHI contribution is income-based and serves as a reasonable proxy for income. Depending on whether the patients were admitted to the emergency department or the outpatient department, routes of admission were divided into emergency or non-emergency cases, respectively. All variables were either coded as categorical or dummy variables.

3. Outcome measures

The outcome variables were mean costs and LOS. These variables were used to compare the relative use of resources among hospitals with differing volumes of cancer procedures. Using the National Health Insurance Corporation Input Price Indices, costs were defined as the cost per episode for surgery and were adjusted for inflation to 2005 premiums. LOS was defined as the period from index procedure to hospital discharge for the index admission. We also examined hospital standardized mortality ratios (HSMR) as an outcome variable of quality care for cancer procedures. The ratio was adjusted for other factors that affected mortality, such as age, gender, hospital stay duration, admission course, principal diagnosis, and comorbidities [14].

4. Hospital volume

The number of procedures performed at each hospital was determined using a unique hospital identification code. For each procedure, the hospitals were first ranked in order of increasing total volume as a continuous variable, after which volume cut-off points were selected to create volume groups with approximately equal numbers of patients. Hospital volume was stratified into quartiles (very high-, high-, low-, and very low-volume).

5. Statistical analyses

Descriptive analyses were performed to clarify the distributions of patient demographics, hospital volume, and economic outcomes. The differences in patient characteristics were compared across hospital volume groups using the chi-squared statistic for categorical variables. Bivariate analyses of covariance (ANCOVA) were performed to determine differences in costs and LOS between the four groups.

We used multiple linear regressions to examine the relationship between hospital volume and economic outcome, after adjusting for patient demographics and clinical information [15]. All statistical analyses pertaining to costs and LOS were based on the log-transformed data. The *p*-values < 0.05 indicated statistical significance. Data analyses were performed using the IBM SPSS Statistics software (ver. 22.0; IBM Co., Armonk, NY, USA).

RESULTS

1. Patient characteristics and clinical information

Between 2002 and 2005, 62,549 patients underwent the specified types of cancer-related procedures at 535 hospitals. Table 1 shows the distribution of patient characteristics by hospital vol-

Table 1. Characteristics of patients who underwent cancer surgery according to hospital volume

Variable	Hospital volume[a]					*p*-value[b]
	Total	Very low	Low	High	Very high	
Pneumonectomy[c] (n = 7,720)		(< 26)	(26–50)	(51–133)	(> 133)	
Female gender	2,340 (30.31)	582 (30.81)	565 (29.99)	457 (27.48)	736 (32.22)	< 0.05
Age (y)						< 0.001
< 50	1,738 (22.51)	471 (24.93)	453 (24.04)	280 (16.84)	534 (23.38)	
50–59	1,781 (23.07)	391 (20.70)	444 (23.57)	395 (23.75)	551 (24.12)	
60–69	2,935 (38.02)	688 (36.42)	698 (37.05)	697 (41.91)	852 (37.30)	
> 69	1,266 (16.40)	339 (17.95)	289 (15.34)	291 (17.50)	347 (15.19)	
Contribution[d]						< 0.001
< 28,010	1,781 (23.07)	558 (29.54)	480 (25.48)	387 (23.27)	356 (15.59)	
28,010–74,720	3,942 (51.06)	944 (49.97)	1,030 (54.67)	861 (51.77)	1,107 (48.47)	
> 74,720	1,997 (25.87)	387 (20.49)	374 (19.85)	415 (24.95)	821 (35.95)	
Residential area						< 0.001
Metropolitan	5,048 (65.39)	1,177 (62.31)	1,176 (62.42)	1,112 (66.87)	1,583 (69.31)	
Urban	1,838 (23.81)	473 (25.04)	493 (26.17)	387 (23.27)	485 (21.23)	
Rural	834 (10.80)	239 (12.65)	215 (11.41)	164 (9.86)	216 (9.46)	
Routine admission	6,537 (84.68)	1,571 (83.17)	1,432 (76.01)	1,485 (89.30)	2,049 (89.71)	< 0.001
Charlson score						< 0.001
0	3,277 (42.45)	784 (41.50)	907 (48.14)	693 (41.67)	893 (39.10)	
1	1,786 (23.13)	556 (29.43)	522 (27.71)	387 (23.27)	321 (14.05)	
> 2	2,657 (34.42)	549 (29.06)	455 (24.15)	583 (35.06)	1,070 (46.85)	
Private ownership	7,653 (99.13)	1,822 (96.45)	1,884 (100)	1,663 (100)	2,284 (100)	< 0.001
Hospital location						< 0.001
Metropolitan	7,206 (93.34)	1,476 (78.14)	1,783 (94.64)	1,663 (100)	2,284 (100)	
Urban	338 (4.38)	338 (17.89)	0 (0)	0 (0)	0 (0)	
Rural	176 (2.28)	75 (3.97)	101 (5.36)	0 (0)	0 (0)	
Hospital size (beds)						< 0.001
< 500	371 (4.81)	185 (9.79)	0 (0)	186 (11.18)	0 (0)	
500–699	1,118 (14.48)	612 (32.40)	0 (0)	506 (30.43)	0 (0)	
> 699	6,231 (80.71)	1,092 (57.81)	1,884 (100)	971 (58.39)	2,284 (100)	

Table 1. Continued

Variable	Hospital volume[a]					*p*-value[b]
	Total	Very low	Low	High	Very high	
Teaching hospital	6,944 (89.95)	1,810 (95.82)	1,884 (100)	966 (58.09)	2,284 (100)	< 0.001
Colectomy[c] (n = 16,085)		(< 33)	(33–52)	(53–100)	(> 100)	
Female gender	7,117 (44.25)	1,562 (42.90)	1,960 (46.74)	1,789 (43.68)	1,806 (43.47)	< 0.01
Age (y)						< 0.001
< 50	4,411 (27.42)	1,077 (29.58)	1,170 (27.90)	1,057 (25.81)	1,107 (26.64)	
50–59	3,022 (18.79)	622 (17.08)	782 (18.65)	739 (18.04)	879 (21.16)	
60–69	4,627 (28.77)	934 (25.65)	1,150 (27.43)	1,249 (30.49)	1,294 (31.14)	
> 69	4,025 (25.02)	1,008 (27.68)	1,091 (26.02)	1,051 (25.66)	875 (21.06)	
Contribution[d]						< 0.001
< 28,010	3,921 (24.38)	1,007 (27.66)	1,082 (25.80)	1,035 (25.27)	797 (19.18)	
28,010–74,720	8,064 (50.13)	1,823 (50.07)	2,156 (51.42)	2,092 (51.07)	1,993 (47.97)	
> 74,720	4,100 (25.49)	811 (22.27)	955 (22.78)	969 (23.66)	1,365 (32.85)	
Residential area						< 0.001
Metropolitan	10,486 (65.19)	2,141 (58.80)	2,683 (63.99)	2,792 (68.16)	2,870 (69.07)	
Urban	3,909 (24.30)	988 (27.14)	1,134 (27.05)	851 (20.78)	936 (22.53)	
Rural	1,690 (10.51)	512 (14.06)	376 (8.97)	453 (11.06)	349 (8.40)	
Routine admission	11,194 (69.59)	2,726 (74.87)	2,742 (65.39)	2,723 (66.48)	3,003 (72.27)	< 0.001
Charlson score						< 0.001
0	8,165 (50.76)	1,985 (54.52)	2,053 (48.96)	2,174 (53.08)	1,953 (47.00)	
1	3,580 (22.26)	977 (26.83)	987 (23.54)	898 (21.92)	718 (17.28)	
> 2	4,340 (26.98)	679 (18.65)	1,153 (27.50)	1,024 (25.00)	1,484 (35.72)	
Private ownership	15,810 (98.29)	3,463 (95.11)	4,096 (97.69)	4,096 (100)	4,155 (100)	< 0.001
Hospital location						< 0.001
Metropolitan	13,763 (85.56)	2,461 (67.59)	3,222 (76.84)	3,925 (95.83)	4,155 (100)	
Urban	1,976 (12.28)	1,099 (30.18)	706 (16.84)	171 (4.17)	0 (0)	
Rural	346 (2.15)	81 (2.22)	265 (6.32)	0 (0)	0 (0)	
Hospital size (beds)						< 0.001
< 500	3,207 (19.94)	2,348 (64.49)	637 (15.19)	222 (5.42)	0 (0)	
500–699	3,091 (19.22)	1,011 (27.77)	1,462 (34.87)	215 (5.25)	403 (9.70)	
> 699	9,787 (60.85)	282 (7.75)	2,094 (49.94)	3,659 (89.33)	3,752 (90.30)	
Teaching hospital	13,530 (84.12)	2,094 (57.51)	3,588 (85.57)	4,096 (100)	3,752 (90.30)	< 0.001
Mastectomy[c] (n = 33,225)		(< 70)	(70–142)	(142–357)	(> 357)	
Female gender	31,394 (94.49)	7,120 (84.59)	7,725 (96.42)	7,934 (97.87)	8,615 (99.15)	< 0.001
Age (y)						< 0.001
< 50	21,266 (64.01)	5,452 (64.77)	5,216 (65.10)	5,057 (62.38)	5,541 (63.77)	
50–59	7,170 (21.58)	1,546 (18.37)	1,709 (21.33)	1,883 (23.23)	2,032 (23.39)	
60–69	3,618 (10.89)	1,009 (11.99)	817 (10.20)	915 (11.29)	877 (10.09)	
> 69	1,171 (3.52)	410 (4.87)	270 (3.37)	252 (3.11)	239 (2.75)	
Contribution[d]						< 0.001
< 28,010	8,049 (24.23)	2,466 (29.30)	1,967 (24.55)	1,956 (24.13)	1,660 (19.10)	
28,010–74,720	16,423 (49.43)	4,267 (50.70)	4,042 (50.45)	4,012 (49.49)	4,102 (47.21)	
> 74,720	8,753 (26.34)	1,684 (20.01)	2,003 (25.00)	2,139 (26.38)	2,927 (33.69)	

Table 1. Continued

Variable	Hospital volume[a]					p-value[b]
	Total	Very low	Low	High	Very high	
Residential area						< 0.001
Metropolitan	23,219 (69.88)	4,978 (59.14)	6,059 (75.62)	5,940 (73.27)	6,242 (71.84)	
Urban	7,485 (22.53)	2,500 (29.70)	1,424 (17.77)	1,658 (20.45)	1,903 (21.90)	
Rural	2,521 (7.59)	939 (11.16)	529 (6.61)	509 (6.28)	544 (6.26)	
Routine admission	28,404 (85.49)	7,091 (84.25)	7,106 (88.69)	7,652 (94.39)	6,555 (75.44)	< 0.001
Charlson score						< 0.001
0	21,404 (64.42)	5,526 (65.65)	5,480 (68.40)	5,998 (73.99)	4,400 (50.64)	
1	2,883 (8.68)	994 (11.81)	864 (10.78)	581 (7.17)	444 (5.11)	
> 2	8,938 (26.90)	1,897 (22.54)	1,668 (20.82)	1,528 (18.85)	3,845 (44.25)	
Private ownership	32,889 (98.99)	8,081 (96.01)	8,012 (100)	8,107 (100)	8,689 (100)	< 0.001
Hospital location						<0.001
Metropolitan	30,441 (91.62)	5,937 (70.54)	7,708 (96.21)	8,107 (100)	8,689 (100)	
Urban	2,156 (6.49)	2,156 (25.61)	0 (0.00)	0 (0.00)	0 (0.00)	
Rural	628 (1.89)	324 (3.85)	304 (3.79)	0 (0.00)	0 (0.00)	
Hospital size (beds)						< 0.001
< 500	5,993 (18.04)	3,207 (38.10)	711 (8.87)	661 (8.15)	1,414 (16.27)	
500–699	5,265 (15.85)	2,761 (32.80)	1,095 (13.67)	1,409 (17.38)	0 (0.00)	
> 699	21,967 (66.12)	2,449 (29.10)	6,206 (77.46)	6,037 (74.47)	7,275 (83.73)	
Teaching hospital	28,939 (87.10)	6,337 (75.29)	7,215 (90.05)	6,698 (82.62)	8,689 (100)	< 0.001
Cystectomy[c] (n = 1,688)		(< 25)	(25–42)	(42–72)	(> 72)	
Female gender	347 (20.56)	67 (18.72)	88 (19.38)	88 (19.64)	104 (24.30)	NS
Age (y)						<0.001
< 50	264 (15.64)	59 (16.48)	50 (11.01)	61 (13.62)	94 (21.96)	
50–59	270 (16.00)	42 (11.73)	79 (17.40)	79 (17.63)	70 (16.36)	
60–69	616 (36.49)	111 (31.01)	167 (36.78)	178 (39.73)	160 (37.38)	
> 69	538 (31.87)	146 (40.78)	158 (34.80)	130 (29.02)	104 (24.30)	
Contribution[d]						< 0.001
< 28,010	427 (25.30)	105 (29.33)	123 (27.09)	122 (27.23)	77 (17.99)	
28,010–74,720	860 (50.95)	181 (50.56)	235 (51.76)	227 (50.67)	217 (50.70)	
> 74,720	401 (23.76)	72 (20.11)	96 (21.15)	99 (22.10)	134 (31.31)	
Residential area						NS
Metropolitan	1,122 (66.47)	219 (61.17)	295 (64.98)	312 (69.64)	296 (69.16)	
Urban	378 (22.39)	90 (25.14)	104 (22.91)	94 (20.98)	90 (21.03)	
Rural	188 (11.14)	49 (13.69)	55 (12.11)	42 (9.38)	42 (9.81)	
Routine admission	1,381 (81.81)	307 (85.75)	378 (83.26)	341 (76.12)	355 (82.94)	< 0.01
Charlson score						< 0.001
0	818 (48.46)	185 (51.68)	194 (42.73)	230 (51.34)	209 (48.83)	
1	475 (28.14)	101 (28.21)	142 (31.28)	144 (32.14)	88 (20.56)	
> 2	395 (23.40)	72 (20.11)	118 (25.99)	74 (16.52)	131 (30.61)	
Private ownership	1,673 (99.11)	346 (96.65)	451 (99.34)	448 (100)	428 (100)	< 0.001
Hospital location						< 0.001
Metropolitan	1,521 (90.11)	265 (74.02)	380 (83.70)	448 (100)	428 (100)	

Table 1. Continued

Variable	Hospital volume[a]					p-value[b]
	Total	Very low	Low	High	Very high	
Urban	134 (7.94)	60 (16.76)	74 (16.30)	0 (0)	0 (0)	
Rural	33 (1.95)	33 (9.22)	0 (0)	0 (0)	0 (0)	
Hospital size (beds)						< 0.001
< 500	162 (9.60)	117 (32.68)	6 (1.32)	39 (8.71)	0 (0)	
500–699	304 (18.01)	151 (42.18)	82 (18.06)	71 (15.85)	0 (0)	
> 699	1,222 (72.39)	90 (25.14)	366 (80.62)	338 (75.45)	428 (100)	
Teaching hospital	1,590 (94.19)	321 (89.66)	451 (99.34)	390 (87.05)	428 (100)	< 0.001
Esophagectomy[c] (n = 3,831)		(<13)	(13–36)	(37–94)	(>94)	
Female gender	337 (8.80)	86 (9.36)	84 (8.77)	78 (8.29)	89 (8.79)	NS
Age (y)						NS
< 50	411 (10.73)	111 (12.08)	109 (11.38)	83 (8.82)	108 (10.66)	
50–59	915 (23.88)	205 (22.31)	242 (25.26)	224 (23.80)	244 (24.09)	
60–69	1,872 (48.86)	431 (46.90)	466 (48.64)	484 (51.43)	491 (48.47)	
> 69	633 (16.52)	172 (18.72)	141 (14.72)	150 (15.94)	170 (16.78)	
Contribution[d]						<0.001
< 28,010	1,061 (27.70)	319 (34.71)	298 (31.11)	255 (27.10)	189 (18.66)	
28,010–74,720	2,059 (53.75)	452 (49.18)	490 (51.15)	537 (57.07)	580 (57.26)	
> 74,720	711 (18.56)	148 (16.10)	170 (17.75)	149 (15.83)	244 (24.09)	
Residential area						< 0.001
Metropolitan	2,223 (58.03)	529 (57.56)	583 (60.86)	518 (55.05)	593 (58.54)	
Urban	986 (25.74)	233 (25.35)	252 (26.30)	239 (25.40)	262 (25.86)	
Rural	622 (16.24)	157 (17.08)	123 (12.84)	184 (19.55)	158 (15.60)	
Routine admission	3,180 (83.01)	735 (79.98)	838 (87.47)	734 (78.00)	873 (86.18)	< 0.001
Charlson score						< 0.001
0	1,320 (34.46)	286 (31.12)	398 (41.54)	245 (26.04)	391 (38.60)	
1	1,408 (36.75)	293 (31.88)	321 (33.51)	444 (47.18)	350 (34.55)	
>2	1,103 (28.79)	340 (37.00)	239 (24.95)	252 (26.78)	272 (26.85)	
Private ownership	3,791 (98.96)	879 (95.65)	958 (100)	941 (100)	1,013 (100)	< 0.001
Hospital location						< 0.001
Metropolitan	3,586 (93.60)	722 (78.56)	910 (94.99)	941 (100)	1,013 (100)	
Urban	163 (4.25)	163 (17.74)	0 (0)	0 (0)	0 (0)	
Rural	82 (2.14)	34 (3.70)	48 (5.01)	0 (0)	0 (0)	
Hospital size (beds)						< 0.001
< 500	288 (7.52)	53 (5.77)	0 (0)	235 (24.97)	0 (0)	
500–699	610 (15.92)	237 (25.79)	48 (5.01)	325 (34.54)	0 (0)	
> 699	2,933 (76.56)	629 (68.44)	910 (94.99)	381 (40.49)	1,013 (100)	
Teaching hospital	3,400 (88.75)	890 (96.84)	881 (91.96)	616 (65.46)	1,013 (100)	< 0.001

Values are presented as number (%).
NS, not significant.
[a]To estimate average total hospital volume, we divided the observed Medicare volume (per year) by the proportion of Medicare patients undergoing each procedure (as determined by the Nationwide Inpatient Sample).
[b]All *p*-values reflect two-sided comparisons within hospital volume groups, and were calculated using the chi-squared test.
[c]Cutoffs for hospital volume quartiles are reported in parentheses.
[d]Contribution unit Korean Won/month.

ume group. The criteria used to define the four strata of hospital volume varied noticeably according to procedure.

For all procedures with the exception of mastectomies, the majority of the patients were male. According to the hospital volume strata, most patients underwent procedures at very high-volume hospitals for cystectomies, whereas fewest patients underwent procedures at very low-volume hospitals for mastectomies. Regarding age, a large number of patients were aged 60–69 years for all procedures, except mastectomies, which had a high number of patients from the < 50 years age group. For cystectomies, there was a high number of very high-volume procedures in the lower age group. For most procedures, patients with lower monthly NHI contributions were more likely to undergo surgery at lower-volume hospitals. Similarly, residents of rural areas were more likely to have surgery at a low-volume hospital than residents of more metropolitan areas. A comorbidity index score of > 2 tended to be more prevalent at high-volume hospitals. Finally, most patients who underwent tumor resection at teaching hospitals were in metropolitan areas and private hospitals with more than 699 beds.

2. Costs

Costs also varied widely across procedures by hospital volume (Table 2). The mean cost was lowest for mastectomies (1,934,027 Korean Won [KRW]) and highest for esophagectomies (8,825,781 KRW). There were also statistically significant associations between volume and costs for all five procedures ($p < 0.001$). The mean cost for esophagectomies, pneumonectomies, and mastectomies were significantly higher at very low-volume hospitals as opposed to very high-volume hospitals (8,494,271 vs. 7,428,923 KRW, 5,466,067 vs. 4,788,979 KRW, 2,014,838 vs. 1,934,027 KRW, respectively; $p < 0.001$). Costs were lower in very high-volume hospitals than in very low-, low-, and high-volume hospitals for the three procedures (pneumonectomies, mastectomies, andesophagectomies), but higher in very high- and high-volume hospitals for the two other procedures (colectomies and cystectomies).

Table 3 shows regression estimates of the cost differences for each cancer procedure by hospital volume, adjusting for patient and hospital characteristics. Low-, high-, and very high-volume hospitals performed pneumonectomies at lower costs than very low-volume hospitals ($p < 0.001$). Likewise, very high-volume hospitals performed mastectomies and esophagectomies at lower costs than very low-volume hospitals ($p < 0.001$).

Regression analysis revealed that independent predictors of higher costs included female gender, older age, lower health insurance contribution, non-metropolitan residence, emergency admission, a Charlson score > 2, public ownership, teaching hospitals, and hospitals with many beds (Table 4). In the cost regression model, hospital volume continually showed significant effects.

Table 2. Hospital costs and length of stay (LOS) for cancer surgery types by hospital volume

	Annual hospital volume					p-value[a]
	Total	Very low	Low	High	Very high	
Costs (10,000 KRW)						
Pneumonectomy	5.04 ± 2.23	5.47 ± 2.49	4.97 ± 2.34	4.99 ± 1.81	4.79 ± 2.14	< 0.001
Colectomy	4.14 ± 2.57	3.75 ± 2.35	4.41 ± 2.73	4.38 ± 2.74	3.96 ± 2.34	< 0.001
Mastectomy	2.07 ± 0.99	2.01 ± 1.29	2.22 ± 1.16	2.10 ± 0.77	1.93 ± 0.56	< 0.001
Cystectomy	4.65 ± 2.81	4.04 ± 2.86	4.88 ± 2.77	4.84 ± 2.55	4.73 ± 3.00	< 0.001
Esophagectomy	8.10 ± 3.53	8.49 ± 3.87	8.83 ± 4.06	7.72 ± 3.06	7.43 ± 2.85	< 0.001
LOS (day)						
Pneumonectomy	20.9 ± 10.1	24.8 ± 11.1	21.6 ± 10.6	20.4 ± 8.5	17.5 ± 8.6	< 0.001
Colectomy	20.1 ± 10.5	20.0 ± 11.4	21.9 ± 11.0	20.2 ± 10.5	18.2 ± 8.7	< 0.001
Mastectomy	13.4 ± 8.5	14.3 ± 11.1	15.0 ± 9.5	13.0 ± 6.5	11.3 ± 5.1	< 0.001
Cystectomy	23.0 ± 13.4	21.2 ± 13.3	24.0 ± 13.0	25.1 ± 13.9	21.3 ± 13.1	< 0.001
Esophagectomy	27.1 ± 13.1	30.9 ± 13.4	29.4 ± 14.5	26.3 ± 11.8	22.1 ± 10.5	< 0.001

Values are presented as mean ± standard deviation.
KRW, Korean Won.
[a]ANCOVA with Bonferroni multiple comparison.

Table 3. Costs and length of stay (LOS) of cancer surgical procedures according to hospital volume

	Costs[a]			LOS[a]		
	β	t	p	β	t	p
Pneumonectomy						
Low-volume	−0.161	−10.336	< 0.001	−0.152	−10.023	< 0.001
High-volume	−0.108	−6.687	< 0.001	−0.151	−9.587	< 0.001
Very high-volume	−0.214	−13.344	< 0.001	−0.376	−24.097	< 0.001
Colectomy						
Low-volume	0.086	8.098	< 0.001	0.095	8.501	< 0.001
High-volume	0.035	2.838	0.005	0.017	1.325	0.185
Very high-volume	−0.024	−1.889	0.059	−0.061	−4.572	< 0.001
Mastectomy						
Low-volume	0.024	3.504	< 0.001	0.034	4.827	< 0.001
High-volume	0.063	9.192	< 0.001	0.035	5.023	< 0.001
Very high-volume	−0.084	−11.713	< 0.001	−0.132	−17.878	< 0.001
Cystectomy						
Low-volume	0.193	5.298	< 0.001	0.137	3.735	< 0.001
High-volume	0.187	5.141	< 0.001	0.154	4.220	< 0.001
Very high-volume	0.155	3.920	< 0.001	0.015	0.385	0.700
Esophagectomy						
Low-volume	0.051	2.370	0.018	−0.053	−2.506	0.012
High-volume	−0.039	−1.636	0.102	−0.122	−5.268	< 0.001
Very high-volume	−0.148	−6.847	< 0.001	−0.355	−16.726	< 0.001

[a]Adjusted for age, gender, contribution, residential area, inpatient course, comorbidity, ownership, hospital location, beds, teaching hospital status, and year. The reference group for hospital volume was very low-volume hospitals.

3. Length of stay

LOS varied widely according to procedure (Table 2). The mean LOS was the shortest for mastectomies and longest for esophagectomies. In general, patients who underwent more complex cancer surgical procedures had a longer mean LOS than those who underwent less complex cancer surgical procedures. There were statistically significant associations between volume and LOS for all five procedures ($p < 0.001$). Mean LOS decreased across volume strata for three procedures (pneumonectomies, mastectomies, and esophagectomies).

Volume was associated with meaningful differences in LOS for only a limited number of procedures. The largest differences occurred in esophagectomies and pneumonectomies, with a mean LOS of 8.9 days and 7.3, respectively, in very high-volume hospitals as compared to very low-volume hospitals. The mean LOS at very low-volume versus very high-volume hospitals differed by more than one day for four procedures (pneumonectomies, colectomies, mastectomies, and esophagectomies). LOS was shorter in high-volume hospitals for four procedures (pneumonectomies, colectomies, mastectomies, and esophagectomies), but longer in high-volume hospitals for the other procedure (cystectomies).

Table 3 shows regression estimates of LOS differences for each cancer procedure according to hospital volume, after adjusting for patient and hospital characteristics. Patients who underwent pneumonectomy and esophagectomy surgical procedures had shorter stays in low-, high-, and very high-volume hospitals than in very low-volume hospitals ($p < 0.001$). Likewise, mastectomy patients had shorter stays in very high-volume hospitals than in very low-volume hospitals ($p < 0.001$).

Multiple regression analysis revealed that independent predictors of longer LOS included female gender, older age, lower health insurance contribution, non metropolitan residents, emergency admission, Charlson score > 2, public ownership, teaching hospitals, and hospitals with fewer beds (Table 4). The differences

Table 4. Multiple regression analysis of costs and length of stay (LOS) according to clinical and demographic predictors

	Costs[a]			LOS[a]		
	β	t	*p*	β	t	*p*
Gender						
Female	0.071	20.107	< 0.001	0.110	24.406	< 0.001
Age	0.160	54.146	< 0.001	0.161	42.615	< 0.001
Monthly contribution						
< 28,010	0.036	10.892	< 0.001	0.058	13.715	< 0.001
28,010–74,720	0.033	9.970	< 0.001	0.056	13.315	< 0.001
Residential area						
Urban	0.017	6.104	< 0.001	0.028	7.762	< 0.001
Rural	0.009	3.478	0.001	0.018	5.064	< 0.001
Admission route						
Routine	−0.051	−18.424	< 0.001	−0.034	−9.607	< 0.001
Charlson score						
1	0.065	22.760	< 0.001	0.074	20.398	< 0.001
> 2	0.148	51.797	< 0.001	0.162	44.601	< 0.001
Ownership						
Public	0.004	1.486	0.137	0.021	6.024	< 0.001
Location						
Urban	−0.014	−4.524	< 0.001	−0.020	−5.113	< 0.001
Rural	−0.016	−6.040	< 0.001	−0.006	−1.635	0.102
Hospital size (beds)						
< 500	−0.050	−15.033	< 0.001	0.036	8.511	< 0.001
500–699	0.010	3.153	0.002	0.047	11.844	< 0.001
Teaching status						
Teaching	0.110	35.273	< 0.001	0.126	31.783	< 0.001
Year						
2003	0.013	3.622	< 0.001	−0.023	−5.211	< 0.001
2004	0.018	5.140	< 0.001	−0.053	−11.646	< 0.001
2005	0.048	13.044	< 0.001	−0.079	−16.973	< 0.001
Procedure						
Pneumonectomy	−0.229	−52.694	< 0.001	−0.127	−22.901	< 0.001
Colectomy	−0.467	−86.398	< 0.001	−0.215	−31.141	< 0.001
Mastectomy	−1.013	−150.065	< 0.001	−0.600	−69.686	< 0.001
Cystectomy	−0.166	−53.088	< 0.001	−0.063	−15.751	< 0.001
Volume						
Low	0.037	10.149	< 0.001	0.036	7.808	< 0.001
High	0.051	13.623	< 0.001	0.021	4.422	< 0.001
Very high	−0.032	−8.173	< 0.001	−0.103	−20.470	< 0.001

[a]The reference groups for categorical variables were male gender, monthly contribution > 74,720, metropolitan residential area, emergency admission, Charlson score = 0, private hospital ownership, metropolitan hospital location, beds > 699, non-teaching hospital, year 2002, esophagectomy procedure, very low-volume.

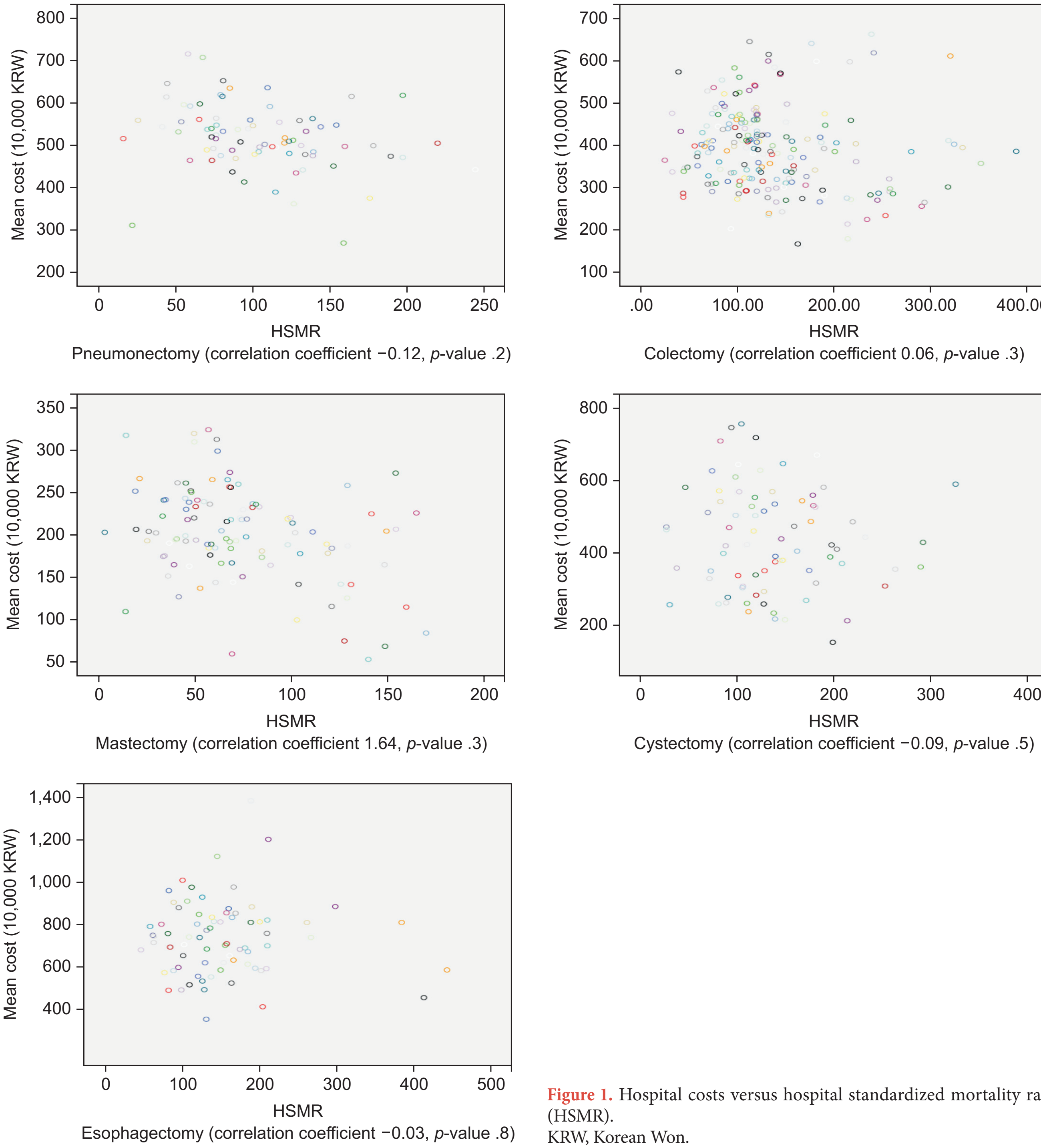

Figure 1. Hospital costs versus hospital standardized mortality ratio (HSMR).
KRW, Korean Won.

between very low-volume and very high-volume hospital were statistically significant.

4. Costs and hospital standardized mortality ratios

We examined the relationship between the mean hospital's cost and HSMR to determine whether there was a systematic relationship between cost and quality of care. We found no association (Figure 1).

DISCUSSION

Consistent with previously published data, we showed that the volume of cancer surgical procedures performed by hospitals is statistically associated with costs and LOS [3–5]. Specifically, patients treated at very high-volume hospitals had lower costs and LOS as compared to very low-volume hospitals, after case-mix adjustment. When the results were analyzed for each of the different types of cancer surgeries, a consistent trend of lower costs and LOS at higher-volume hospitals was found. For four of the five procedures, LOS and costs were significantly lower in very high-volume hospitals as compared to very low-volume hospitals. However, this was not shown for cystectomies. In addition, for mastectomies and colectomies, the reverse was seen for low- and high-volume hospitals as compared to very low-volume hospitals. In our study, using the volume cut-off points approach, cancers with a high risk for surgical procedures, such as pneumonectomies and esophagectomies were associated with significantly lower costs and LOS in very high-volume hospitals as compared to very low-volume hospitals. However, in cancers with a low risk for surgical procedures, such as mastectomies and colectomies, low- and high-volume hospitals are thought to have no significant difference, with the volume cut-off points falling within the 'gray zone'. For this reason, we performed an additional p trend analysis to verify the significance of linearity. This result of a p trend < 0.05 suggests that the linear trend is statistically significant for colectomies (p for trend < 0.001), mastectomies (p for trend < 0.001), and cystectomies (p for trend = 0.088). Compared to very low-volume hospitals, pneumonectomies were 16.1%, 10.8%, and 21.4% less costly in low , high , and very high-volume hospitals, respectively, and mastectomies and esophagectomies were 8.4% and 14.8% less costly in very high-volume hospitals, respectively. In addition, relative to very low-volume hospitals, the LOS for pneumonectomies was 15.2%, 15.1%, and 37.6% shorter in low-, high-, and very high-volume hospitals, respectively. Furthermore, relative to very low-volume hospitals, the LOS for colectomies and mastectomies was 6.1% and 13.2% shorter in very high-volume hospitals, respectively, and the LOS for esophagectomies was 5.3%, 12.2%, and 35.5% shorter in low-, high-, and very high-volume hospitals, respectively.

These relationships can be explained by the learning effect theory, as presented in previous reports. This theory states that increasing the number of treatments leads to a reduction in costs and LOS because of improved efficiency in early medical decisions, leading to fewer complications and shortened LOS in high-volume hospitals [1,4,9]. However, in addition to these factors, high-volume hospitals in Korea have a tendency to encourage early discharge by switching patients to home care in an effort to increase the turnover rate of hospital beds. This tendency is a characteristic of the Korean medical system and appears to have contributed to decreased LOS at high-volume hospitals, which, in turn, lowers costs.

Multivariate regression was used to rank variables according to their strength of association with the outcome. Increased age, female sex, non metropolitan residents, emergency admission, increased Charlson score, publicly-owned hospitals, and teaching hospitals were significantly associated with higher costs and a longer LOS. These findings are generally consistent with previous studies that used clinical data to identify preoperative determinants of total or postoperative costs and LOS [4,16–18].

Initially, we expected costs and LOS to be lower for the vulnerable populations, but this study showed that costs and LOS generally increased among the vulnerable populations. This correlation seems to be because elderly and low-income families in rural areas generally have a worse health condition as compared to other groups, thereby contributing to higher medical demands. Considering this and the limited availability of family members to care for sick relatives, even an unnecessary hospitalization requires a long period of time. This could account for the increasing tendency of costs and LOS among the vulnerable populations of this study [19,20].

Contrast to the popular belief that hospital ownership is a major factor in determining the type of treatment, and that costs of treatment are cheaper at public hospitals, this study showed that costs and LOS were *higher* at public hospitals. It seems that the operation of Korean public hospitals is not very different from that of private hospitals, and the *longer* LOS indicates a problem in effective management of available beds. Further, this study considered only the health insurance payment for treatment, excluding any uncovered amounts. This could have caused the costs to be higher at public hospitals per episode, since a longer LOS may reflect an attempt to maintain hospital income by increasing bed occupation. Public hospitals have a greater probability of prolonging hospitalization for the same surgical procedures.

Although it is known that costs of hospitalization increase as the number of beds at a hospital increases, this study showed that it was not always the case in hospitals with more than a specific number of beds. After controlling for other variables and categorizing the number of beds, we found that costs decreased even when LOS increased in hospitals with fewer than 500 beds. In addition, costs increased as LOS increased in hospitals with more than 500 beds. This can be explained by economies of scale, with revenue decreasing as the average costs increase in hospitals with more than a specific number of beds. A majority of the previous studies on economies of scale have reported that there are certain economies of scale in hospitals [21,22]. In the case of Korea, the average cost increases significantly in hospitals with more than 450 beds, which, in turn, decreases revenue. Reports show that medical revenue can increase by shortening the LOS in an effort to increase the turnover rate of beds [23].

Hospitals with similar costs or LOS may differ in how resources are used during hospitalization, and intensity of care is known to differ between teaching and non teaching hospitals [15]. In general, patients treated at teaching hospitals tend to receive more diagnostic tests and spend more time in the intensive care unit [5].

As expected, patients who underwent complex cancer surgical procedures, such as esophagectomies, had significantly higher costs and a longer LOS than those who underwent less complex surgical procedures, such as colectomies and mastectomies.

Our study has some limitations. First, we excluded Medicaid beneficiaries, who account for approximately 3.1% of all Korean residents, because the NHI claims database did not provide sufficient information regarding these claimants. Second, we used an administrative claims database that lacked information about cancer specific clinical severity, such as disease stage and tumor size; thus, some residual confounding due to these covariates is possible [24,25]. However, we minimized this problem by only including patients who underwent major surgery; thus, the study population individuals were likely to be at similar cancer stages. Third, because the study was based on limited cross-sectional research using data from 2002 to 2005, there are limits to generalizing the observed relationships. Thus, there is a need to confirm our findings with additional studies across different time periods and in-depth serial research over time. Despite these limitations, our results have important implications from the health policy perspective. This is a population-level description of economic outcomes and the factors, including volume, that impact costs and LOS after cancer surgery in an Asian country. In addition, this study provide useful information about costs and treatment quality for patients selecting a hospital for a particular cancer surgery.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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