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Economic evaluation of the hospitalist care model in an acute medical unit: a benefit–cost analysis

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ABSTRACT

Objective This study aimed to assess the economic efficiency of the acute medical unit (AMU) hospitalist care model, utilising patient outcomes (length of hospital stay, emergency department (ED)-length of hospital stay, in-hospital mortality) from a previous investigation.

Design A retrospective cohort study was conducted using benefit–cost analysis from a societal perspective. Data relating to clinical factors, outcomes and medical costs were obtained from the electronic medical record database at our institution. Literature-based costing was applied to determine direct non-medical costs and indirect costs that could not be obtained directly.

Setting A tertiary care hospital in the Republic of Korea.

Participants We evaluated 6391 medical inpatients admitted through the ED from 1 June 2016 to 31 May 2017.

Interventions The study compared multiple types of costs and benefits among inpatients from the ED between a non-hospitalist group and an AMU hospitalist group.

Results
This investigation found a significant reduction in medical costs and total costs in the AMU hospitalist group compared to the non-hospitalist group (30% reduction, 95% CI: 27.6–32.1%, *P*=0.000; 29.3% reduction, 95% CI: 27.0–31.5%, *P*=0.000; respectively). Furthermore, significant reductions in direct and indirect costs were found in the AMU hospitalist group compared to the non-hospitalist group (28.6% reduction, 95% CI: 26.6–30.5%, *P*=0.000; 23.3% reduction, 95% CI: 20.9–25.5%, *P*=0.000; respectively). The net-benefit and benefit-cost ratio (BCR) of the AMU hospitalist care group were US $6846 and 1.33 per patient admission, respectively.

Conclusions The AMU hospitalist care model was associated with remarkable reductions in multiple costs. The results of the sensitivity analysis indicated that the net-benefit estimates of AMU hospitalist care were similar to the baseline estimates. Thus, the overall net-benefit of AMU hospitalist care was found to be largely positive.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ In this study, extensive cost analysis was conducted from a societal perspective.
⇒ The study encompassed all medical inpatients who were admitted from the emergency department to medical wards throughout the specified time frame from 1 June 2016 to 31 May 2017. Having such broad inclusion criteria is likely to have enhanced the validity of the findings.
⇒ Making generalisations regarding this retrospective study is challenging because of its singular institution of origin.
⇒ Expenditures apart from medical costs were not obtained directly but were calculated after consulting relevant sources; therefore, a degree of uncertainty may remain in the cost estimates.
⇒ This study could not quantify the potential benefits associated with a reduction in admissions to the intensive care unit. Therefore, the benefits determined in this study may have been undervalued.

INTRODUCTION

In South Korea, a pilot hospitalist care system was implemented from 2016 to address reduced numbers of medical personnel and improve the quality of inpatient care.[1] The pilot project was integrated within the general hospital care system after 5 years, and the number of hospitalists in Korea has increased to approximately 250.[2] Under the hospitalist care model, a dedicated specialist takes comprehensive responsibility directly and provides managed care to patients during admission, whereas under the non-hospitalist care model, a resident provides care to patients during admission under the supervision of a specialist.

Since the implementation of the hospitalist care system in Korea, research on patient outcomes has been conducted[3–9] in terms of in-hospital mortality (IHM), intensive care unit (ICU) admission, emergency department-length of stay (ED-LOS) and total length of hospital stay (LOS). Although there have been many studies on the effectiveness of the hospitalist system, few studies have been undertaken on costs or involving economic evaluations. While some studies have reported on the medical costs of hospitalist care in South Korea,[7 10] no economic evaluations from a societal perspective have been reported concerning hospitalist care in South Korea. Therefore, evaluating the economic efficiency of hospitalist care is necessary, considering both its costs and effects in terms of whether it is efficient within the overall medical system. In this study, economic efficiency was defined by a positive net-benefit and benefit–cost ratio (BCR) exceeding 1. Hence, we conducted an economic evaluation that accounted for both costs and benefits for the same patient population whose outcomes had been previously assessed.[9]

In this study, a societal-perspective economic evaluation was conducted to estimate the overall costs and benefits of the acute medical unit (AMU) hospitalist care model implemented at our institution, based on patient outcomes. We aimed to provide new evidence on the economic efficiency of the AMU hospitalist care model.

METHODS

Study participants and AMU setting

We evaluated 6391 medical inpatients admitted through the emergency department (ED) of our institution from 1 June 2016 to 31 May 2017, who were assigned to AMU hospitalist care and non-hospitalist care groups (2426 and 3965 patients, respectively). The AMU patients were evaluated and treated by four hospitalists with an average of 10 years of clinical experience in infectious diseases, pulmonology and critical care, nephrology and endocrinology.[9] Seven days per week, two AMU hospitalists were responsible for the care of the AMU patients admitted during the day. In addition, non-hospitalist inpatient care was provided by subspecialists and residents in a specialty medical ward, where residents were primarily responsible for inpatient care under the supervision of an attending physician.[9] While hospitalist care in the AMU focused on general acute care, non-hospitalist care in the specialty medical ward emphasised long-term and specialised treatment.[9]

Study design

This retrospective cohort study compared and analysed the cost-saving benefits, calculated based on costs and patient outcomes, between AMU hospitalist care and non-hospitalist care groups for patients admitted through the ED at a tertiary hospital.

We conducted a benefit–cost analysis and divided costs into medical costs, non-medical costs and time costs in terms of productivity loss.[11] This investigation was conducted in accordance with Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022).[12] A flow diagram of the study population and benefit–cost factors is presented in online supplemental 1.

Outcomes and clinical variables

Outcomes and clinical variables were obtained from the electronic medical records (EMRs) at our institution. Among the outcome variables, IHM, LOS and ED-LOS were used to calculate costs and benefits as well as the time cost of productivity loss. Productivity loss is the time cost incurred as a result of mortality or disease-related restrictions on productive activities due to admission.[13]

We analysed the following clinical variables of the participants: age, sex, prior hospitalisation history, cardiopulmonary resuscitation (CPR) incidence, cause of ICU admission, referral to a specialty, consultations, surgical intervention (cases performed during the hospitalisation, not before), major diagnosis (based on the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM))), Korean Triage and Acuity Scale (KTAS), Age-adjusted Charlson Comorbidity Index (ACCI) and Acute Physiology and Chronic Health Evaluation (APACHE) II scores. The ACCI score is derived from the sum of 1, 2, 3 and 6 weighted values for 17 disease groups, ranging from 0 to 29; higher scores indicate higher severity.[14] The KTAS, which is currently applied in emergency medical centres in Korea, is a national standardised classification tool for evaluating illness severity.[15] We used the APACHE II score to compare the disease severity among ICU admissions; this score (range: 0–71) has been found to closely correlate with the risk of hospital death.[16] Baseline characteristics of the study population are presented in table 1.[9]

Cost measures

Micro-costing and gross-costing were used for cost calculation in this study. Micro-costing was applied to directly calculate the medical costs during the total hospital stay.[17] Gross-costing was used to calculate all costs other than medical costs (online supplemental 2). The costs were classified into direct costs and indirect costs,[13] with all unit costs converted to United States (US) dollars as of 2023.

Direct costs

Direct costs comprised medical costs (micro-costing), family caregiver transportation fares, paid care costs and doctor labour costs in hospitalisation (gross-costing). Healthcare in South Korea is a single-payer system organised through the National Health Insurance Service (NHIS). Nearly all citizens receive universal medical care through this system.[18] The governance of National Health Insurance in South Korea is presented in online supplemental 3. The health security system in Korea has two components: mandatory social health insurance and medical aid. In Korea, fee-for-service has been the standard payment model for outpatient care and the majority of inpatient care, leading to an increase in the volume of services that healthcare professionals can provide.[19] Medical costs in this study comprised reimbursements issued to medical providers by the NHIS and co-payments paid to medical providers by patients.

Medical cost data were obtained from hospital administrative information in the EMRs at our institution regarding consultation fee, admission fee (mainly hospital room expense, including for isolation, intensive care and general hospital room), medication fee (medication/

Table 1 Baseline characteristics of patients cared for by hospitalists and non-hospitalists (N=6391)

Baseline characteristics	Hospitalists (n=2426)	Non-hospitalists (n=3965)	P value
Sex			
Male	1387 (57.2)	2188 (55.2)	0.120
Female	1039 (42.8)	1777 (44.8)	
Age (years)	63.24±16.20	67.38±16.52	<0.001
<50	488 (20.1)	610 (15.4)	<0.001
50–59	401 (16.5)	499 (12.6)	
60–69	542 (22.3)	733 (18.5)	
70–79	632 (26.1)	1131 (28.5)	
≥80	363 (15.0)	992 (25.0)	
Prior hospitalisation	2101 (86.6)	3373 (85.1)	0.090
Number of prior hospitalisations	3.16±4.07	3.24±4.20	0.480
Korean Triage and Acuity Scale			
1 (Resuscitation)	12 (0.5)	69 (1.7)	<0.001
2 (Emergency)	324 (13.4)	941 (23.7)	
3 (Urgent)	1699 (70.0)	2511 (63.3)	
4 (Less urgent)	367 (15.1)	403 (10.2)	
5 (Non-urgent)	24 (1.0)	41 (1.0)	
Major disease			
Malignant neoplasms	845 (34.8)	890 (22.4)	<0.001
Diseases of the circulatory system	48 (2.0)	552 (13.9)	
Diseases of the respiratory system	266 (11.0)	875 (22.1)	
Diseases of the digestive system	441 (18.2)	424 (10.7)	
Diseases of the genitourinary system	202 (8.3)	375 (9.5)	
Symptoms, signs, and abnormal clinical and laboratory findings	162 (6.7)	167 (4.2)	
Certain infectious and parasitic diseases	86 (3.5)	204 (5.1)	
Endocrine, nutritional and metabolic diseases	95 (3.9)	158 (4.0)	
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	130 (5.4)	47 (1.2)	
Diseases of the musculoskeletal system and connective tissue	58 (2.4)	89 (2.2)	
Others	93 (3.8)	184 (4.6)	
Age-adjusted Charlson Comorbidity Index	3.82±2.63	3.77±2.19	
Median (IQR)	4(2–5)	4(2–5)	0.055
≤2	729 (30.0)	1018 (25.7)	0.001
3	436 (18.0)	733 (18.5)	
4	502 (20.7)	943 (23.8)	
≥5	759 (31.3)	1271 (32.1)	
Surgical intervention	282 (11.6)	560 (14.1)	0.004
CPR incidence	15 (0.6)	35 (0.9)	0.244
Consultation	1830 (75.4)	2946 (74.3)	0.312
Number of consultations	3.50±6.18	3.99±7.02	0.004
Referral to a specialty	1613 (66.5)	450 (11.3)	<0.001
Type of specialty referral (n=2063)			

Continued

Table 1 Continued

Baseline characteristics	Hospitalists (n=2426)	Non-hospitalists (n=3965)	P value
Haematology and Oncology	658 (40.8)	114 (25.3)	<0.001
Gastroenterology	360 (22.3)	20 (4.4)	
Respiratory	174 (10.8)	53 (11.8)	
Nephrology	96 (6.0)	11 (2.4)	
Infection	96 (6.0)	8 (1.8)	
Geriatrics	80 (5.0)	9 (2.0)	
Others	149 (9.2)	235 (52.2)	
Outcomes			
In-hospital mortality	117 (4.8)	361 (9.1)	<0.001
ICU admission	95 (3.9)	343 (8.7)	<0.001
Cause of ICU admission (n=438)			
Close monitoring after procedure or surgical intervention	55 (57.9)	223 (65.0)	0.077
Respiratory failure or insufficiency	23 (24.2)	78 (22.7)	
Septic shock	7 (7.4)	17 (5.0)	
Cardiovascular failure or insufficiency	7 (7.4)	12 (3.5)	
Metabolic/renal failure	0 (0.0)	8 (2.3)	
GI bleeding	3 (3.2)	2 (0.6)	
Neurogenic dysfunction	0 (0.0)	3 (0.9)	
APACHE II score at ICU admission (n=438)	25.20±10.62	21.26±12.03	0.004
Length of hospital stay (days)	10.56±11.68	11.40±12.36	
Median (IQR)	7 (4–10 47 48)	8 (5–11 47 48)	0.007
ED-LOS (hours)	11.24±8.49	13.74±10.11	
Median (IQR)	8.4 [6.1–12.7)	10.2 [6.7–19.0)	<0.001
Readmission within 10 days	117 (4.8)	177 (4.5)	0.507
Readmission within 30 days	277 (11.4)	416 (10.5)	0.248

Data are presented as the mean±SD, number (%), or median (IQR), as indicated. ‘Surgical intervention’ implies the patient underwent surgery during the hospital stay, not before.

. APACHE, Acute Physiology and Chronic Health Evaluation; CPR, cardiopulmonary resuscitation; ED-LOS, emergency department-length of stay; GI bleeding, Gastrointestinal bleeding; ICU, intensive care unit; IQR, interquartile range.

injection/anaesthesia/whole blood and blood product), treatment and surgery fee, medical examination fee (inspection/medical imaging/CT/MRI/positron emission tomography/ultrasonography), therapeutic materials and other factors (prosthetics, orthodontics/rehabilitation and physiotherapy/ psychotherapy).

The family caregiver transportation fare in relation to hospitalisation was estimated by multiplying referenced costs (2017 Korea Health Panel Study[20] and the 2017 Consumer Price Index[21]) by individual patient’s LOS. The term ‘family caregiver transportation costs’ referred to the mean expenses for round-trip transportation for each visit of a family caregiver to a medical facility during the patient’s hospitalisation.[20] The paid care cost was calculated by multiplying the referenced average costs[22] by individual patient’s LOS. During the day, hospitalists administer care to patients in the hospitalist care group while residents provide care under the direction of a subspecialist. During the night, residents care for patients in both groups. The daytime doctor labour costs were estimated and analysed separately for residents, subspecialists and hospitalists (online supplemental files 2 and 4). Resident doctor labour costs per patient were estimated using the following variables: the average after-tax salary (2017 resident training environment evaluation survey results[23]), four major social insurance scheme classifications (national pension, health insurance, employment insurance and workers’ compensation insurance[24]) and tax (income tax and resident tax[25]), the number of inpatients per physician[26] and the total patient days (the total number of days for all inpatients) in the non-hospitalist care group. Subspecialist labour costs were calculated using a referenced average labour cost,[27] the number of inpatients per physician[28 29] and the total patient days in the non-hospitalist care group.

The AMU hospitalist labour costs per patient were calculated using a referenced average labour cost,[30] the number of AMU hospitalists and AMU-LOS in the hospitalist care group. In addition, doctor labour costs for night shifts were estimated by reflecting the number of patients under the charge of residents,[31] residents' average wage and total patient days in the non-hospitalist care group.

Indirect costs

Indirect costs (time costs) were calculated by applying the gross-costing method. Patient productivity loss during hospitalisation (time costs) was calculated by multiplying the average daily wage by gender and age,[32] by individual LOS and by the labour force participation rate.[33] Family caregiver productivity loss was calculated by multiplying the average daily wage of all workers[32] by individual LOS. Patient productivity loss due to ED-LOS was calculated by multiplying the average hourly wage by gender and age,[32] by individual ED-LOS and by the labour force participation rate.[33] Patient productivity loss due to death in hospitalisation was calculated by multiplying the average annual wage by gender and age,[32] by the labour force participation rate[33] and by individual life years gained in relation to death.[34] Individual life years gained were estimated by subtracting life expectancy reduced by major diseases from life expectancy by gender and age, in reference to life tables available from the Korean Statistical Information Service (KOSIS, 2017).[34]

Benefit measure

In this study, the human capital approach was used as a method of evaluating the value of 'health' or 'life' in monetary units.[17] Benefits, in the form of cost savings, were then estimated based on direct and indirect costs.

Economic evaluation: benefit–cost analysis

In benefit–cost analysis, the BCR and net-benefit are used as indicators for decision indices. Net-benefit refers to the benefit minus the cost, with a larger net-benefit indicating a more favourable benefit–cost situation.[17] Therefore, we used BCR and net-benefit as indicators in terms of decision indices.

Sensitivity analysis

This study is a retrospective study of costs incurred. As the study period comprised only 1 year, a discount rate was not applied to the costs and a sensitivity analysis was performed on uncertain variables.[35] The results of the sensitivity analysis are presented in a tornado diagram (figure 1).

First, a sensitivity analysis was conducted on LOS and ED-LOS, which showed a skewed distribution. We analysed the 1%-trimmed mean by calculating the average of the remaining values while excluding some (1%) from the extremes of the data.

Second, a sensitivity analysis was conducted on paid care costs among the direct non-medical costs that were considered to have high uncertainty. Assuming that no caregiver was hired, the baseline paid care costs were set at $53,[22] and the maximum daily paid care costs for hospitalised patients were set at $122.[22]

Third, a sensitivity analysis was conducted on doctor labour costs among the direct non-medical costs that were considered to have high uncertainty, with both one-way and two-way sensitivity analyses conducted. Resident labour costs were set at $44 180 as a baseline, with a minimum value of $37 350 and a maximum value of $52,669.[23] Hospitalist and specialist labour costs were set at $115 452 as a baseline,[27 30] with a minimum value of $76 458 and a maximum value of $152 917.

Statistical analysis

Categorical variables are reported as percentages and continuous variables as mean±SD. Groups were compared by conducting Pearson's χ^2 tests or t-tests, as appropriate. ACCI, LOS and ED-LOS were expressed as the median and IQR. For these variables, groups were compared by conducting the Mann-Whitney U test, owing to their skewed distributions. We performed subgroup analyses of costs and benefits according to age, the severity of the patient's condition (based on the KTAS score), the degree of comorbidity (based on the ACCI score) and the major disease category (based on the ICD-10). Natural log-transformed multivariable regression analysis was conducted in relation to the costs. As the unit cost was large, using a natural logarithm can increase normality and enable accurate values to be obtained during analysis as well as reduce skewness and kurtosis of the data. Regression analysis for the costs was used to adjust for the following factors: age, sex, prior hospitalisation, referral to specialty, consultation, CPR, KTAS score, ACCI score, surgical intervention, major disease, ICU admission, IHM, LOS and ED-LOS. Using the estimates from the regression models, we presented differences between AMU hospitalised and non-hospitalised groups in terms of medical, direct, indirect, and total costs.

Patient and public involvement

This was a non-interventional study conducted retrospectively. Consequently, no patients participated directly in the study's conception, formulation of research objectives and queries, or execution. In addition, patients were not involved in the interpretation of results or production of the manuscript. It is not currently in our intentions to disseminate the findings to the study participants.

RESULTS

Costs

All costs are presented as costs per patient admission in this study. The estimated costs [36] between the hospitalist group and the non-hospitalist group are presented in table 2. The total costs were significantly lower in the hospitalist group than in the non-hospitalist group, with a difference of more than $6000 (20570±91024 vs

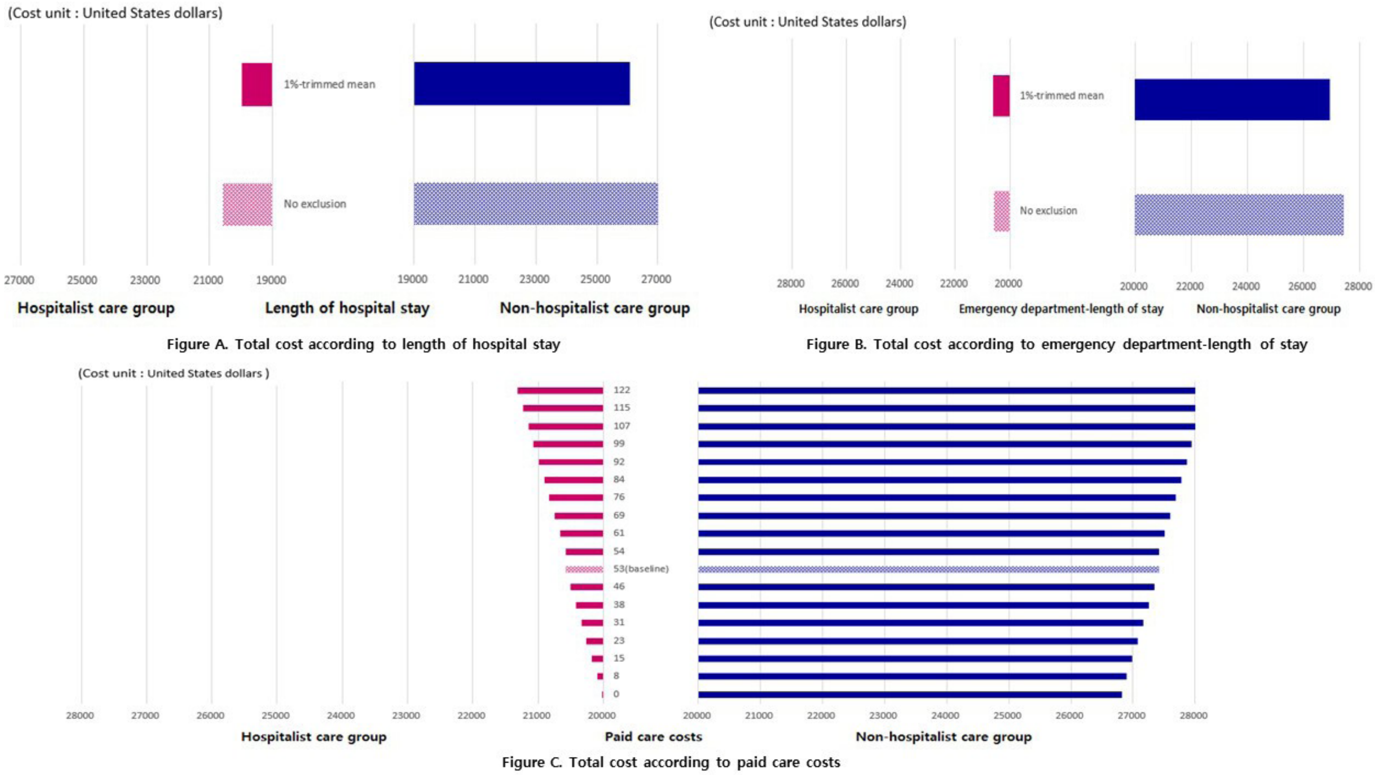

Figure 1 One-way sensitivity analysis for the length of hospital stay, emergency department-length of stay and paid care costs. Supplementary Materials: online supplemental 1: Flow diagram of the study population and benefit–cost factors; online supplemental 2: Type of costs, cost estimation formula and data source; online supplemental 3: Governance of National Health Insurance in South Korea; online supplemental 4: Doctor labour cost estimation by patient flow and timeline; online supplemental 5: Cost analysis for urgent and non-urgent cases treated by hospitalists or non-hospitalists (N=6391); online supplemental 6: Cost analysis for patients with different comorbidity severities treated by hospitalists or non-hospitalists (N=6391); online supplemental 7: Cost analysis according to major diseases between hospitalist and non-hospitalist groups (N=6391); online supplemental 8: Cost analysis according to age between hospitalist and non-hospitalist groups (N=6391); online supplemental 9: Natural log-transformed multivariable regression analysis for medical costs and total costs (N=6391); online supplemental 10: Natural log-transformed multivariable regression analysis for direct costs and indirect costs (N=6391); online supplemental 11: One-way sensitivity analysis for resident labour costs; online supplemental 12: One-way sensitivity analysis for hospitalist labour costs; online supplemental 13: One-way sensitivity analysis for specialist labour costs; online supplemental file 14: Two-way sensitivity analysis for hospitalist and resident labour costs; online supplemental 15: Two-way sensitivity analysis for hospitalist and specialist labour costs.

27416±102360, p=0.007). The direct medical costs were significantly lower in the hospitalist group than in the non-hospitalist group, with a difference of more than \$900 (4075±6504 vs 5050±7255, p=0.000).

Among the subcategories of medical costs, the biggest difference was found in relation to the admission fee and medical examination fee (886±1661 vs 1167±1697, p=0.003; 1269±1629 vs 1565±1676, p=0.000; respectively). Among the direct non-medical costs, the family caregiver transportation fare, paid care costs and doctor labour costs were significantly lower in the hospitalist group than in the non-hospitalist group (p=0.007, p=0.007 and p=0.000; respectively).

The indirect costs were significantly lower in the hospitalist group than in the non-hospitalist group, with a difference of more than \$5000 (14988±89 375 vs 20719±1 00 689, p=0.021). Among the indirect costs, family caregiver productivity loss according to LOS and patient productivity loss according to ED-LOS and IHM were significantly lower in the hospitalist group than in the non-hospitalist group (p=0.007, p=0.000 and p=0.023, respectively). However, there were no significant differences between the two groups in terms of patient productivity loss according to LOS (560±782 vs 549±788, p=0.570).

Subgroup cost differences according to KTAS scores, comorbidity severity, major disease and age

Cost analysis was performed according to subgroups of patients stratified by KTAS scores, ACCI scores, major disease and age to determine differences between the two groups (online supplemental 5–8). Compared with the non-hospitalist group, the hospitalist group's overall costs for more urgent cases were significantly reduced by more than \$8000 (p=0.002). In low-to-moderate comorbidity groups (ACCI=0–2, 3 and 4 points), there was a greater cost reduction in the hospitalist group than in the

Table 2 Costs of patients cared for by hospitalists and non-hospitalists (N=6391)

Cost per patient admission (USD)	HG (n=2426)	NHG (n=3965)	P value
Total costs	20570±91 024	27416±1 02 360	0.007
Direct costs	5582±8003	6697±8729	0.000
Direct medical costs	4075±6504	5050±7255	0.000
Consultation fee	251±221	269±238	0.003
Admission fee	886±1661	1167±1697	0.000
Medication fee	907±2345	889±2324	0.774
Treatment and surgery fee	266±1092	432±1720	0.000
Medical examination fee	1269±1629	1565±1676	0.000
Therapeutic materials	304±866	552±1477	0.000
Others	191±596	176±467	0.249
Direct non-medical costs	1508±1688	1647±1786	0.002
Family caregiver transportation fare in hospitalisation	198±219	213±231	0.007
Paid care cost in hospitalisation	556±614	600±650	0.007
Doctor's labour cost	754±855	834±904	0.000
Indirect costs	14988±89 375	20719±1 00 689	0.021
Patient productivity loss according to LOS	560±782	549±788	0.570
Family caregiver productivity loss according to LOS	1124±1243	1213±1316	0.007
Patient productivity loss according to ED-LOS	76±75	86±90	0.000
Patient productivity loss according to IHM	13228±88 992	18871±1 00 401	0.023

Data are presented as mean±SD. Cost unit: USD (US$), ($1=1307.9 KRW, year: 2023)
ED-LOS, emergency department-length of stay; HG, hospitalist group; IHM, in-hospital mortality; LOS, length of hospital stay; NHG, non-hospitalist group.

non-hospitalist group ($12941, p=0.033; $10017, p=0.152; $8199, p=0.016; respectively).

Among the major diseases, in all but three disease types, the overall cost in the hospitalist group decreased compared with the non-hospitalist group (online supplemental 7). In a subgroup analysis by age, total costs in the hospitalist group decreased in almost all age groups (p=0.248, p=0.004, p=0.000, p=0.002, p=0.001, respectively).

Natural log-transformed multivariable regression analysis of costs

We performed natural log-transformed multivariable regression analysis to adjust for clinical variables and outcome variables potentially associated with costs, namely, medical, direct, indirect and total costs (online supplemental 9 and 10). Regression analysis revealed a significant 30% reduction in medical costs and a 29.3% reduction in total costs in the hospitalist group compared with the non-hospitalist group ($e^{-0.355}$=0.701, p=0.000; $e^{-0.346}$=0.707, p=0.000; respectively). Furthermore, there was a significant reduction of 28.6% in direct costs and a 23.3% reduction in indirect costs in the hospitalist group compared with the non-hospitalist group ($e^{-0.336}$=0.714, p=0.000; $e^{-0.265}$=0.767, p=0.000; respectively).

Benefit–cost analysis

Net-benefit and BCR analysis were conducted according to the total group and subgroups of patients stratified by clinical variables, KTAS scores, ACCI scores, major diagnoses and age (table 3). Among the total group of patients, the net-benefit and BCR of the AMU hospitalist care group were $6846 and 1.33 per patient admission, respectively; overall net-benefit of AMU hospitalist care was found to be largely positive. Among the patients stratified by clinical variables, net-benefit and BCR of AMU hospitalist care were found to be largely positive in all but five subgroups (less urgent; ACCI ≥5; diseases of the circulatory system; diseases of the genitourinary system and endocrine, nutritional and metabolic diseases).

Sensitivity analysis

The sensitivity analysis results for LOS and ED-LOS are shown in figure 1A,B. We analysed the 1%-trimmed mean and excluded patients with extreme values, as noted. After excluding extreme values related to LOS, the results were stable (net-benefit: $7162 to $8067, BCR: 1.31 to 1.33) and showed no significant difference from the baseline analysis. Sensitivity analysis for ED-LOS revealed that the results were similar to (net-benefit: $6311 to $6846, BCR: 1.31 to 1.33) the baseline analysis. After varying paid care costs from $0 to $122, the sensitivity analysis results were stable, with the net-benefit ranging from $8013 to

Table 3 Benefit–cost analysis

Total cost per patient admission (USD)	HG (A)	NHG (B)	Net-benefit (B–A)	B/A ratio (benefit–cost ratio, BCR)
Total (N=6391)	20570	27416	6846	1.33
KTAS				
More urgency (n=5556)	20334	29074	8740	1.43
Less urgency (n=835)	21801	14269	−7532	0.65
ACCI				
ACCI≤2 (n=1747)	16700	29640	12941	1.77
ACCI=3 (n=1169)	24948	34965	10017	1.40
ACCI=4 (n=1445)	14346	22545	8199	1.57
ACCI≥5 (n=2030)	25890	24894	−996	0.96
Major disease				
Malignant neoplasms (n=1735)	37059	63186	26127	1.71
Diseases of the circulatory system (n=600)	21568	10963	−10604	0.51
Diseases of the respiratory system (n=1141)	12369	18568	6199	1.50
Diseases of the digestive system (n=865)	10408	19732	9324	1.90
Diseases of the genitourinary system (n=577)	14018	11979	−2039	0.85
Symptoms, signs, and abnormal clinical and laboratory findings (n=329)	6724	10762	4038	1.60
Certain infectious and parasitic diseases (n=290)	5411	22358	16947	4.13
Endocrine, nutritional, and metabolic diseases (n=253)	13906	5765	−8142	0.41
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism (n=177)	12512	65460	52948	5.23
Diseases of the musculoskeletal system and connective tissue (n=147)	9269	19916	10647	2.15
Others (n=277)	19377	28223	8846	1.46
Age (years)				
<50 (n=1098)	34234	46473	12238	1.36
50–59 (n=900)	36276	66967	30691	1.85
60–69 (n=1275)	14345	22699	8354	1.58
70–79 (n=1763)	11861	15868	4007	1.34
≥80 (n=1355)	9310	12453	3143	1.34

Data are presented as mean. Cost unit: USD (US Dollar), ($1=1307.9 KRW, year: 2023)
ACCI, Age-adjusted Charlson Comorbidity Index; HG, hospitalist group; KTAS, Korean Triage and Acuity Scale; NHG, non-hospitalist group.

$8138 and the BCR from 1.32 to 1.34 (figure 1C). One-way sensitivity analysis results showed comparative values of resident, specialist and hospitalist labour costs (online supplemental 11–13), with resident labour costs ranging from $37 350 to $52,669, which indicated a net-benefit ranging from $6841 to $6851 (BCR, 1.33) (online supplemental 11). After varying specialist labour costs from $76 458 to $152,917, the results were similar to baseline estimates, with net-benefit ranging from $6764 to $6924 (BCR, 1.33) (online supplemental 12).

After varying hospitalist labour costs from $76 458 to $152,917, the results were stable, with the net-benefit ranging from $6784 to $6910 (BCR, 1.33) (online supplemental 13).

Two-way sensitivity analysis results on hospitalist and resident labour costs showed that net-benefit ranged from $6779 to $6916 and BCR from 1.33 to 1.34 (online supplemental 14). Moreover, two-way sensitivity analysis results on hospitalist and specialist labour costs showed that net-benefit ranged from $6703 to $6988 and BCR from 1.33 to 1.34 (online supplemental 15).

DISCUSSION

Study summary

This study is the first to report on the economic efficiency of a Korean AMU hospitalist care model while controlling for clinical factors. We found a notable cost reduction with AMU hospitalist care compared with non-hospitalist care in all areas: medical costs, direct costs, indirect costs and total costs. In this study, medical costs included hospitalist care fees. The same trend towards cost reduction was observed in the subgroup and regression analyses. In this study, the cost of doctor labour was estimated separately for each hospitalisation flow and day and night shifts (online supplemental 4).

The net-benefit and BCR analysis results of the AMU hospitalist care group were $6846 and 1.33 per patient admission, respectively; overall, the net-benefit of AMU hospitalist care was found to be largely positive. Sensitivity analysis showed that the net-benefit and BCR results of AMU hospitalist care were similar to baseline analysis.

In the present resident training system, which lacks a structured curriculum, training has taken the form of encountering more patients and accumulating experience over time. Many institutions still use the apprenticeship model of training to become specialists. The Medical Resident Act has been enacted to address this issue; however, the situation remains ambiguous in the field.[37] Moreover, residents who rotate annually or monthly will inevitably experience strained relationships with other professional teams, and medical treatment is frequently interrupted due to complications such as doctor–nurse disputes.[2] However, direct, real-time communication among our multidisciplinary team members, which enables appropriate and quick decision-making on treatments for patients with acute diseases, is a key component of our AMU care.[3]

Furthermore, consultation, formulation and implementation of treatment plans and the treatment itself are responsibilities shared among residents, fellows and attending specialists in the context of resident/attending specialist care. However, hospitalists carry the sole responsibility for all these tasks.[38] Moreover, hospitalists have extensive knowledge and proficiency in managing patients who are hospitalised. Their level of professionalism is unparalleled compared with that of residents with 1–2 years of experience, as evidenced by their critical thinking skills, patient communication capabilities and accountability for treatment.[38] Consequently, these characteristics are believed to help reduce overall costs, including medical costs.

Furthermore, our previous study reported that AMU hospitalist care improved patient outcomes in terms of IHM, ICU admission rate, LOS and ED-LOS.[9] This enhanced performance may have led to a reduction in indirect expenses and productivity loss.

Direct medical costs

Some previous studies that investigated the costs of hospitalist care have reported reduced medical costs in hospitalist care.[10 39–46] In contrast, other studies have reported no significant difference in total medical costs between patients treated by hospitalists and those treated by non-hospitalists[7 47] and that the costs of care for hospitalists were more than those for specialists but less than those for generalists.[48] Our study showed that there was a marked cost reduction in consultation, admission, treatment and surgery, medical examination and therapeutic materials fees among the medical cost subcategories. Even when hospitalist care fees were included in medical costs, the hospitalist group's medical costs were lower, which indicates that the difference would be even greater if hospitalist care fees were excluded. Among the previous studies, one study that evaluated Korean hospitalists reported that medical costs reduced by $208 in terms of hospitalist care.[10] However, in our study, medical expenses per admission decreased by nearly $1000 in the hospitalist care group. Both research findings regarding medical cost reduction are comparable, but our study's findings on cost-reduction suggest a more substantial reduction is involved.

The patient group in our study consisted of patients with acute medical conditions admitted through the ED of a tertiary general hospital, with their disease severity being higher than that among those in the total group of patients, which may explain the difference in study results. However, the regression analyses showed a significant 30% reduction in medical costs in the hospitalist group after adjusting for clinical factors. Despite the conflicting results reported in earlier studies, our research findings offer compelling evidence supporting the effectiveness of the AMU hospitalist care model in reducing medical costs.

Direct non-medical costs compared with indirect costs

Studies are lacking on the economic implications of hospitalist care from a societal perspective. Hence, we conducted an estimation and analysis of non-medical expenses to assess the economic feasibility of AMU hospitalist care from a societal perspective.

In a previous study, we reported that AMU hospitalist care considerably improved patient outcomes in terms of IHM, ICU admission rate, LOS and ED-LOS.[9] In this study, we used patient outcomes from that study to estimate the following costs: family caregiver transportation fares in hospitalisation, paid care costs in hospitalisation, patient productivity loss based on LOS, family caregiver productivity loss based on LOS, patient productivity loss based on ED-LOS and patient productivity loss based on IHM.

The hospitalist care group's decreased LOS resulted in a notable reduction in expenses related to family caregiver transportation and paid care during patient hospitalisation.

With the exception of patient productivity loss based on LOS, substantial reductions in expenses were shown for family caregiver productivity loss based on LOS and patient productivity loss based on ED-LOS and IHM. The hospitalist group exhibited a considerably reduced LOS in comparison to the non-hospitalist group.[9] However, it is possible that the lower age of the patients in the hospitalist group may account for the larger patient productivity loss based on the LOS observed in this group. Nevertheless, AMU hospitalist care resulted in notable reductions in the indirect costs, surpassing $7000 in savings when compared with the non-hospitalist group. This improvement in patient outcomes played a pivotal role in achieving these cost reductions. Therefore, the overall costs in relation to the AMU hospitalist care group showed a notable decrease in comparison to the non-hospitalist group.

Benefit–cost analysis

The net-benefit and BCR analysis of the AMU hospitalist care group yielded results of $6846 and 1.33 per patient admission, respectively, indicating that the overall net-benefit of AMU hospitalist care was found to be largely positive. However, variations in net-benefit and BCR analysis ranges were seen across different subgroups (-$10 604 to $52948, 0.41 to 5.23; respectively). This indicates that the economic efficacy of AMU hospitalist care varies based on the clinical characteristics of patients. Nevertheless, in terms of net-benefit and BCR results, the overall net-benefit of AMU hospitalist care was found to be largely positive in 17 subgroups and negative in five subgroups (less urgent; ACCI ≥5; diseases of the circulatory system; diseases of the genitourinary system; and endocrine, nutritional and metabolic diseases). It is possible that this population has a greater demand for specialised care; furthermore, treatment modalities and expenses can vary substantially based on the reason for admission even for the same disease. In our study, clinical variables were adjusted for factors such as age, severity, the major disease and KTAS. To determine the precise reason for the negative results reported in these five groups, more research into the variables leading to hospitalisation or disease-specific clinical outcomes is required.

These findings might potentially serve as a valuable reference for the development of a more efficient hospitalist care paradigm in further research.

A one-way sensitivity analysis was conducted to examine the impact of variations in the LOS, ED-LOS, paid care costs and doctor labour costs. The net-benefit and BCR analysis results of AMU hospitalist care were stable based on a one-way sensitivity analysis using these four variables. The results of a two-way sensitivity analysis indicated that the net-benefit and BCR results of AMU hospitalist care were similar to the baseline estimates despite fluctuations in labour costs for the resident, specialist and hospitalist.

Limitations

This study had some limitations. First, it employed a retrospective design, which posed challenges in mitigating the effect of confounding factors and discerning whether the observed results were attributable to the AMU environment or the treatment administered by the hospitalists. Second, the study was conducted at a single site, which limits the extent to which our findings may be generalised. Third, other expenditures, excluding medical expenses, were not directly obtained but rather calculated by consulting relevant sources, which introduced a degree of uncertainty into the cost estimations. Fourth, the present study could not provide a quantifiable assessment of the potential benefits associated with the reduction of ICU admissions. Five, the value and benefits of teaching services were not evaluated in this study. Even if costs are higher for teaching services than for non-teaching services, training future physicians is a valuable goal. Hence, further investigation to ascertain the value and benefits of teaching services from a societal perspective is required.

CONCLUSION

This study showed that AMU hospitalist care significantly reduced costs in nearly all categories, including medical costs, direct costs, indirect costs and total costs. Moreover, in the benefit–cost analysis, the net-benefit and BCR results of the AMU hospitalist care group were shown to be greater than $6000 and 1.30 per patient admission, respectively. These results indicate that the overall net-benefit of AMU hospitalist care is largely positive. Nevertheless, further investigation is necessary to identify the factors that contribute to hospitalisation or disease-specific clinical outcomes.

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REFERENCES

1 Eom JS. Operating the hospitalist system. *J Korean Med Assoc* 2016;59:342–4.
2 Shin D-H. The vision of hospitalist system in Korea. *Korean J Med* 2021;96:1–6.
3 Ohn JH, Kim N-H, Kim ES, *et al*. An acute medical unit in a Korean tertiary care hospital reduces the length of stay and waiting time in the emergency department. *J Korean Med Sci* 2017;32:1917–20.
4 Lee JH, Kim AJ, Kyong TY, *et al*. Evaluating the outcome of multi-morbid patients cared for by Hospitalists: a report of integrated medical model in Korea. *J Korean Med Sci* 2019;34:e179.
5 Jang S-I. Korean hospitalist system implementation and development strategies based on pilot studies. *J Korean Med Assoc* 2019;62:558–63.
6 Han SJ, Jung H-W, Oh D-Y, *et al*. Comparisons of clinical outcomes between weekday-only and full-time, 24-hour/7-day coverage hospitalist systems. *J Korean Med Sci* 2020;35:e117.
7 Jung YB, Jung E-J, Lee KY. A surgical hospitalist system in Korea: a preliminary study of the effects on hospital costs and postoperative outcomes. *Ann Surg Treat Res* 2021;100:298–304.
8 Kim ES, Ohn JH, Lim Y, *et al*. Effect of active surgical co-management by medical hospitalists in urology inpatient care: a retrospective cohort study. *Yonsei Med J* 2023;64:558–65.
9 Kim HJ, Kim J, Ohn JH, *et al*. Impact of hospitalist care model on patient outcomes in acute medical unit: a retrospective cohort study. *BMJ Open* 2023;13:e069561.
10 Jang S-I, Yoon JH, Moon SD, *et al*. *A study on the implementation and the evaluation of korean hospitalist system to improve the quality of hospitalization (phase 3)*. Seoul: Institute of Health Services Research, Yonsei University, 2022.
11 Lee TJ, Kim YH, Shin SJ, *et al*. *Costing methods in healthcare*. Seoul: National Evidence-based Healthcare Collaborating Agency, 2012.
12 Husereau D, Drummond M, Augustovski F, *et al*. Consolidated health economic evaluation reporting standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. *Int J Technol Assess Health Care* 2022;38:e13.
13 Kim J, Kwon HY, Hong JH, *et al*. A Guineline for economic evaluation for Korean medicine. Guideline Center for Korean Med; 2018.
14 Charlson ME, Pompei P, Ales KL, *et al*. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
15 Lee I, Kim O, Kim C, *et al*. Validity analysis of Korean triage and acuity scale. *J Korean Soc Emerg Med* 2018;29:13–20.
16 Knaus WA, Draper EA, Wagner DP, *et al*. APACHE II: a severity of disease classification system. *Crit Care Med* 1985;13:818–29.
17 Yang BM, Kim J, Lee TJ, *et al*. Health economics (revision). *Nanam* 2015;363–6.
18 National health insurance service. Available: https://www.nhis.or.kr/english/wbheaa02300m 01.do [Accessed 19 Feb 2024].
19 Health insurance review & assessment service, Available: https://www.hira.or.kr/dummy.do?pgmid=HIRAJ010000006000 [Accessed 19 Feb 2024].
20 Moon S, Gang T, Oh H, *et al*. Korea health panel study. *NHIS* 2017.
21 2019 annual report on the consumer price index. Available: https://kosis.kr/publication/publicationThema.do [Accessed 17 Aug 2023].
22 Yi JS, Kim J. The social cost of informal nursing care and its policy implications for integrated nursing and care services. *Korean J Health Econ Policy* 2021;27:97–118.
23 2017 resident training environment evaluation survey results, Available: http://www.bosa.co.kr/news/articleView.html?idxno=2077118 [Accessed 15 Aug 2023].
24 Comparison of 4 major SIS's (social insurance schemes). Available: https://www.4insure.or.kr/ins4/ptl/Main.do [Accessed 16 Aug 2023].
25 Tax rate. Available: https://www.nts.go.kr/nts/cm/cntnts/cntntsView.do?mi=2227&cntntsId [Accessed 16 Aug 2023].
26 2020 resident training environment evaluation survey results. Available: http://www.monews.co.kr/news/articleView.html?idxno=303414 [Accessed 15 Aug 2023].
27 Specialist salary survey result. Available: https://mpak.or.kr/article/%EA%B0%84%E D%96%89%EB%AC%BC/7/60/?page= [Accessed 9 Feb 2024].
28 Seoul national University Bundang hospital: inpatient bed. Available: https://www.hira.or.kr/ [Accessed 9 Feb 2024].
29 Specialist by clinical field. Available: https://www.snubh.org/medical/deptList.do [Accessed 9 Feb 2024].
30 Jang S-I, Park E, Nam J, *et al*. *A study on the implementation and the evaluation of korean hospitalist system to improve the quality of hospitalization (phase 2)*. Seoul: Institute of Health Services Research, Yonsei University, 2018.
31 2017 resident training environment evaluation survey results. Available: http://www.Monews.co.kr/news/articleView.html?idxno=110624 [Accessed 9 Feb 2024].
32 2017 survey report on labor conditions by employment type. Available: https://kosis.kr/publication/publicationThema.do [Accessed 15 Aug 2023].
33 2017 annual report on the the economically active population survey. Available: https://kosis.kr/publication/publicationThema.do [Accessed 15 Aug 2023].
34 2017 life tables for Korea. Available: https://kosis.kr/publication/publicationThema.do [Accessed 20 Jul 2023].
35 Ko JY, Yoon JY. Economic evaluation of hospital-based home care services for the breast cancer surgery patients. *J Korean Acad Community Health Nurs* 2021;32:356–67.
36 Exchange rate. 2023. Available: https://spot.wooribank.com/pot/Dream?withyou=FXXRT0016 [Accessed 10 Feb 2024].
37 Oh SJ, Jung S-M. Development of the role of teaching hospitalists in the education of residents. *J Korean Med Assoc* 2019;62:573–6.
38 Kim HW. The current status of hospital medicine in Korea, 2019. *Korean J Med* 2019;94:139–44.
39 Manzano J-G, Park A, Lin H, *et al*. Demonstrating value: association of cost and quality outcomes with implementation of a value-driven oncology-hospitalist inpatient collaboration for patients with lung cancer. *BMJ Open Qual* 2019;8:e000381.
40 Hock Lee K, Yang Y, Soong Yang K, *et al*. Bringing generalists into the hospital: outcomes of a family medicine hospitalist model in Singapore. *J Hosp Med* 2011;6:115–21.
41 Shu C-C, Lin J-W, Lin Y-F, *et al*. Evaluating the performance of a hospitalist system in Taiwan: a pioneer study for nationwide health insurance in Asia. *J Hosp Med* 2011;6:378–82.
42 Landrigan CP, Srivastava R, Muret-Wagstaff S, *et al*. Impact of a health maintenance organization hospitalist system in academic pediatrics. *Pediatrics* 2002;110:720–8.
43 Auerbach AD, Wachter RM, Katz P, *et al*. Implementation of a voluntary hospitalist service at a community teaching hospital: improved clinical efficiency and patient outcomes. *Ann Intern Med* 2002;137:859–65.
44 Lundberg S, Balingit P, Wali S, *et al*. Cost-effectiveness of a hospitalist service in a public teaching hospital. *Acad Med* 2010;85:1312–5.
45 Hrycko A, Tiwari V, Vemula M, *et al*. A Hospitalist-led team to manage patient boarding in the emergency department: impact on hospital length of stay and cost. *South Med J* 2019;112:599–603.
46 Davis KM, Koch KE, Harvey JK, *et al*. Effects of hospitalists on cost, outcomes, and patient satisfaction in a rural health system. *Am J Med* 2000;108:621–6.
47 Rachoin J-S, Skaf J, Cerceo E, *et al*. The impact of hospitalists on length of stay and costs: systematic review and meta-analysis. In: *Database of abstracts of reviews of effects (DARE): quality-assessed reviews*. Centre for Reviews and Dissemination (UK), 2012. Available: https://www.ncbi.nl m.nih.gov/books/NBK97905/
48 Everett G, Uddin N, Rudloff B. Comparison of hospital costs and length of stay for community internists, hospitalists, and academicians. *J Gen Intern Med* 2007;22:662–7.