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Impact of financial incentives for infection prevention and management on antibiotic use: A Korea National Health Insurance cohort study

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ABSTRACT

Background: The Korean government implemented financial incentives to enhance infection prevention and management within general hospital settings. This study aimed to evaluate the impact of infection control compensation on antibiotic usage using a controlled interrupted time series analysis.
Methods: The main unit of analysis was 270,901 inpatient episodes extracted from the Korean National Health Insurance Service Cohort Database from 2013 to 2019. The 96-month period was examined before and after the intervention, which was set to September 1, 2017, by applying a 1-year lag time after the incentive was introduced. Segmented regression was used to estimate the effects of interventions in a controlled interrupted time series. Hospitals that received nationwide financial incentives for infection prevention and management were included in the analysis. The study's primary outcome was the use of antibiotics based on the WHO Access, Watch, and Reserve (AWaRe) classification of antibiotics, and the secondary outcome was the number of days of antibiotic use as days of therapy (DOTs) per patient day (PD).
Results: The probability of overall antibiotic use decreased between incentivized and unincentivized hospitals (odds ratio [OR], 0.922; 95% confidence interval [CI], 0.859–1.000). The difference in level change in the use of third-generation cephalosporins (OR,0.894; 95% CI, 0.817–0.977) and carbapenem (OR,0.790; 95% CI, 0.630–0.992) was significantly reduced between incentivized and unincentivized hospitals. The difference in slope change on DOTs/PD of glycopeptides was −0.005 DOT/PDs, and that of carbapenem was −0.003 between incentivized and unincentivized hospitals.
Conclusion: We observed that incentives for infection prevention and management have had a positive impact on some aspects of antibiotic usage. A partial decrease was observed in antibiotic use, accompanied by a modest reduction in DOTs/PD, particularly for antibiotics aimed at addressing multidrug-resistant pathogens. Further investigation is necessary to establish evidence for extending these incentives.

Introduction

The rise of multidrug-resistant bacteria (MDRB) has resulted in a significant public health challenge. [1] It not only limits the available treatment options for antibiotics but also raises concerns about their potential spread. [2,3] The development of antibiotic resistance leads to higher rates of illness and death from infections and contributes significantly to escalating healthcare costs due to additional hospital stays and the necessity for expensive medications. [4,5] The overuse of antibiotics by medical professionals in hospitals and the transmission of resistant bacteria within healthcare facilities through cross-contamination among patients via the hands of healthcare

Abbreviations: MDRB, multidrug-resistant bacteria; ASP, Antimicrobial Stewardship Program; WHO, World Health Organization; IPC, infection prevention and control; NHIS, National Health Insurance (NHI) Service; NHID, National Health Insurance Data; EDI, electronic data interchange; DOTs, days of therapy; PD, patient day; AWaRe, WHO Access, Watch, and Reserve; PFP, pay-for-performance; CI, confidence interval; OR, odds ratio; ICU, intensive care unit; CCI, Charlson Comorbidity Index

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staff have been identified as major factors contributing to the growing problem of antibiotic resistance. [5] Effectively managing antibiotic resistance and monitoring antibiotic usage are crucial aspects of infection prevention and control in hospitals.

To address the harmful effects of antibiotic resistance, the Antimicrobial Stewardship Program (ASP) has been introduced globally. [6] Many hospitals in different countries have successfully implemented this program, resulting in benefits, such as reduced antibiotic usage, healthcare costs, and hospital stays. [7–10] However, in Korea, despite the implementation of ASPs in several major hospitals since the 2000 s, their programs have primarily relied on modified preauthorization-of-antibiotic use programs that involve restrictive measures specifically targeting certain antibiotics. [11] Previous studies showed that the challenges in implementing the ASP in Korea include low clinician compliance, lack of expertise, and absence of suitable incentives. [12].

To curb the spread of antimicrobial resistance, the World Health Organization (WHO) implemented a global action plan. [13] In Korea, the Ministry of Health and Welfare established the Korean National Action Plan on Antimicrobial Resistance in 2016. In September 2016, the Korean government introduced an infection prevention and control fee to enhance compensation for hospital infection control activities. The fee, ranging from 1650 to 4060 KRW per patient per day, is applicable under certain conditions, such as creating infection prevention and control (IPC) teams, recruiting professionals for infection control, certifying medical institutions, participating in nationwide infection monitoring, and implementing infection control measures. [14,15].

However, there is currently no systematic monitoring to ensure that hospitals utilize compensation for infection control activities, and based on a previous study, experts have indicated that the compensation amount is insufficient. Although efforts are being made to extend this incentive to smaller hospitals, no impact-assessment studies have been conducted. Therefore, this study aimed to evaluate the impact of infection control compensation on antibiotic usage using a controlled interrupted time series analysis.

Methods

Data source

This study used medical claim records from the Korean National Health Insurance (NHI) Service (NHIS) National Sample Cohort from 2013 to 2019. The National Health Insurance data (NHID), which included data on clinically determined International Classification of Disease, 10th revision (ICD-10) codes, and socioeconomic status, were a nationally representative random sample of approximately one million individuals from the Korean population. [16] These data enable long-term observations and can be used to investigate causal relationships. The cessation of follow-up for individual participants in the NHIS-SC dataset was determined by their death.

Ethical approval

As the NHID is publicly available, anonymized, and de-identified, informed consent was waived by the Ethics Committee, and the study was approved by the Institutional Review Board of Yonsei University's Health System (4-−2023–0820) for academic research.

Participants and design

The main unit of analysis was inpatient episodes to a general hospital from 2013 to 2019. Patients admitted to tertiary hospitals or other hospitals were excluded because all tertiary hospitals were subject to incentives for infection prevention, and only a few hospitals received incentives for infection prevention immediately after the policy was implemented(n = 1700,276). We excluded episodes from general hospitals that either received incentives after September, 2017, or stopped receiving incentives midway through the observation period (n = 115,975) and the episodes which stayed for only one day (n = 122,494). The total number of episodes from 2013 to 2019 was 270,901.

Incentive for infection control

Since September 2016, incentives for infection prevention and management have been included in the NHI. Medical institutions must fulfill certain conditions to be recognized and receive incentives for infection prevention and management. We selected hospitals that received incentives for infection prevention and management annually from September 2017 to December 2019 and designated them as incentivized hospitals. General hospitals that started receiving incentives for infection prevention and management in September 2016, the point at which introduction for the incentive, were very limited. We selected hospitals that began receiving incentives for infection prevention and management within one year from September 2016, as they needed to establish personnel or teams for infection control to qualify for the fees. The non-incentivized group was comprised of hospitals which had never received the incentive during the study period. Hospitals that either started or stopped receiving incentives midway through the observation period were excluded from the study. We identified the incentives for infection prevention and management using electronic data interchange (EDI) transaction codes associated with each episode and categorized each episode as either a case or control based on the hospital of admission. Our study was observed on a monthly unit and classified based on the hospitalization date of the episode. And we established the criteria for hospitals receiving infection prevention management incentives from September 2016 to September 2017. Consequently, we excluded this period from consideration. To assess the impact of infection prevention management incentives, the intervention time was set to September 2017, incorporating a 1-year lag time after the introduction of the incentive.

Outcome

The primary outcome of the study was the use of antibiotics based on the WHO Access, Watch, and Reserve (AWaRe) classification of antibiotics. [17] We included the following four classes of broad-spectrum antibiotics: third- and fourth-generation cephalosporins, fluoroquinolones, beta-lactam/beta-lactamase inhibitors, and glycopeptides and carbapenems defined as antibiotics used against multidrug-resistant pathogens. These antibiotics, identified as watch antibiotics, generally have a higher potential for the selection of antimicrobial resistance and are more commonly used in sicker patients in hospital facilities. These antibiotics were recommended to be monitored to avoid overuse. [18] We coded “1” when patients used the antibiotics during the hospitalization period, and 0 if what was used was not among the six antibiotics. The secondary outcome measure was the number of days of antibiotic use as days of therapy (DOTs) per patient day (PD).

Covariates

Variables included sociodemographic factors, socioeconomic status, health status, and treatment. Sociodemographic factors consisted of age (20–29, 30–39, 40–49, 50–59, 60–69, ≥70), sex, and region (capital city, urban, or rural). Socioeconomic status was defined by income level (low, low-mid, mid-high, and high) and medical aid beneficiary status (yes or no). Health status consisted of Charlson Comorbidity Index(CCI)(0–1, 2–3, or ≥4). Medical utilization consisted of the utilization of the ICU (yes or no), and the length of stay was classified by quarters: low group, < 3 days; low-mid, 4–6 days; mid-high, 7–13 days; and high, > 13 days. Hospital-related variables included the location of the hospital (capital city, urban, or rural) and the total number of beds was divided into quarters. The low, low-mid, mid-high, and high groups had < 270 beds, 271–391, 392–576, and > 576 beds, respectively. The ratio of the number of beds to the number of nurses was defined by Grade of the Nursing Management Fee. The nurse-to-bed ratio categorized into grades ranging from 1 to 7. Grade 1 signifies the lowest nurse-to-patient ratio, where each nurse cares for the fewest number of patients, while Grade 7 represents the highest nurse-to-patient ratio, indicating that each nurse attends to the highest number of patients (levels 1, 2, 3, 4, 5, 6, and 7 and unknown).

Statistical analysis

Statistical significance was set at $P < 0.05$. significant. The 96-month periods were examined before and after the intervention

Table 1
General characteristics of the study population.

Variable	Incentive for infection control					
	Total		Incentivized hospital		Unincentivized hospital	
	N	%	N	%	N	%
Hospital	258	100.0	120	46.5	138	53.5
Episodes of hospitalization	270,901	100.0	199,522	73.7	71,379	26.3
Sex						
Male	126103	46.5	93317	46.8	32786	45.9
Female	144798	53.5	106205	53.2	38593	54.1
Age						
20-29	17167	6.3	12545	6.3	4622	6.5
30-39	24757	9.1	19069	9.6	5688	8.0
40-49	34212	12.6	25220	12.6	8992	12.6
50-59	52985	19.6	38526	19.3	14459	20.3
60-69	52151	19.3	38901	19.5	13250	18.6
70≤	89629	33.1	65261	32.7	24368	34.1
Medical-aid beneficiary						
Yes	24489	9.0	16449	8.2	8040	11.3
No	246412	91.0	183073	91.8	63339	88.7
Income level						
Low	47750	17.6	33348	16.7	14402	20.2
Low-mid	54910	20.3	40352	20.2	14558	20.4
Mid_high	69842	25.8	51444	25.8	18398	25.8
High	98399	36.3	74378	37.3	24021	33.7
Disability status						
Yes	43301	16.0	31273	15.7	12028	16.9
No	227600	84.0	168249	84.3	59351	83.1
Region						
Capital city	41847	15.4	35704	17.9	6143	8.6
Urban	122089	45.1	97694	49.0	24395	34.2
Rural	106965	39.5	66124	33.1	40841	57.2
Charlson Comorbidity Index						
0–1	112000	41.3	81722	41.0	30278	42.4
2–3	65457	24.2	47163	23.6	18294	25.6
4~	93444	34.5	70637	35.4	22807	32.0
Utilization of Intensive care						
Yes	21377	7.9	17432	8.7	3945	5.5
No	249524	92.1	182090	91.3	67434	94.5
Length of stay						
Low	71077	26.2	53628	26.9	17449	24.4
Low-mid	70472	26.0	53665	26.9	16807	23.5
Mid-high	65433	24.2	47377	23.7	18056	25.3
High	63919	23.6	44852	22.5	19067	26.7
Season						
Spring	68505	25.3	50549	25.3	17956	25.2
summer	68659	25.3	50361	25.2	18298	25.6
autumn	65142	24.0	48352	24.2	16790	23.5
winter	68595	25.3	50260	25.2	18335	25.7
Location of hospital						
Metropolitan	49939	18.4	43476	21.8	6463	9.1
City	129430	47.8	104663	52.5	24767	34.7
Rural	91532	33.8	51383	25.8	40149	56.2
Level of nursing staff						
Lv1	35219	13.0	31475	15.8	3744	5.2
Lv2	69892	25.8	65275	32.7	4617	6.5
Lv3	50105	18.5	39224	19.7	10881	15.2
Lv4	16704	6.2	9021	4.5	7683	10.8
Lv5	8228	3.0	4662	2.3	3566	5.0
Lv6	21431	7.9	8173	4.1	13258	18.6
Lv7	23176	8.6	3826	1.9	19350	27.1
unknown	46146	17.0	37866	19.0	8280	11.6
Total number of Bed						
Low	68143	25.2	23495	11.8	44648	62.6
Low-mid	68039	25.1	49356	24.7	18683	26.2
Mid-high	67180	24.8	64837	32.5	2343	3.3
High	67539	24.9	61834	31.0	5705	8.0

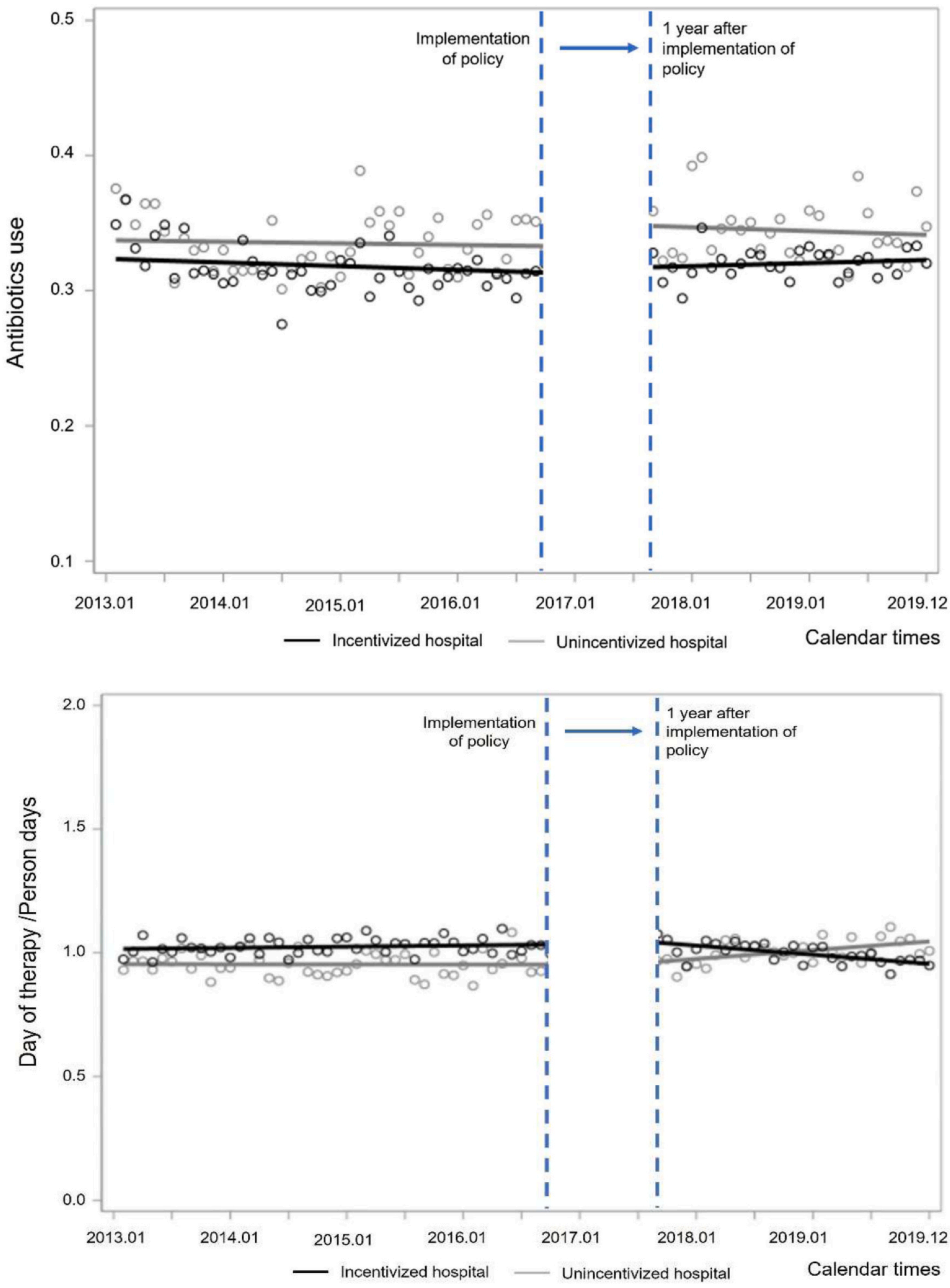

Fig. 1. Segmented regression of interrupted time series analysis before and after implementation of policy.

began, receiving incentives for infection control (preintervention period, January 1, 2013 to August 30, 2016; postintervention period, September 1, 2017, to December 31, 2019). We assessed the primary outcome with a binary distribution and logarithmic link function by segmented regression analysis using a generalized estimating equation. [19,20] The secondary outcome employed a generalized estimating equation with a normal distribution and identity link function among episodes using antibiotics only. Person ID was used to identify repeated subjects using the unstructured working correlation matrix for GEE model. This model can better explain the change in DOT/PDs due to the incentive for infection control with the post-implementation policy compared with that of the pre-implementation policy.

The basic model was expressed as follows:

Model 1

Table 2
Result of interrupted time series analysis of antibiotic use and DOT/PDs.

Variable	OR	95% CI		
Use of antibiotics				
Unincentivized Pre-Trend β_1	1.000	0.999	-	1.001
Unincentivized Post-Level Change β_2	1.111	1.038	-	1.192
Unincentivized Post-Trend Change β_3	1.000	0.997	-	1.004
Incentivized/Unincentivized Pre-Level Difference β_4	0.881	0.834	-	0.931
Incentivized/Unincentivized Pre-Trend Difference β_5	1.001	1.000	-	1.003
Incentivized/Unincentivized Post-Level Change Difference β_6	0.922	0.859	-	1.000
Incentivized/Unincentivized Trend Change Difference Pre- to Post- β_7	1.000	0.996	-	1.004
Variable	**adjusted estimate**	**95% CI**		
DOT/Person days				
Unincentivized Pre-Trend β_1	-0.0001	-0.0004	-	0.0003
Unincentivized Post-Level Change β_2	0.0279	0.0093	-	0.0465
Unincentivized Post-Trend Change β_3	0.0010	0.0000	-	0.0020
Incentivized/Unincentivized Pre-Level Difference β_4	-0.0202	-0.0348	-	-0.0056
Incentivized/Unincentivized Pre-Trend Difference β_5	0.0004	-0.0001	-	0.0008
Incentivized/Unincentivized Post-Level Change Difference β_6	-0.0184	-0.0404	-	0.0035
Incentivized/Unincentivized Trend Change Difference Pre- to Post- β_7	-0.0013	-0.0025	-	-0.0002

*adjusted all covariates

$$Yi\ \mathrm{t} = \beta 0 + \beta 1 \times Time + \beta 2 \times policy + \beta 3 \times time\quad after\quad policy + \beta 4 \times groupit + \beta 5 \times timet \times group\ \mathrm{t} + \beta 6 \times policy \times group\ \mathrm{t} + \beta 7 \times time\quad after\quad policy \times group\ \mathrm{t} + \beta 8 \times covariates + et$$

$\beta 0$ presents the intercept term, representing the expected outcome value when all other variables are zero, $\beta 1$ presents the pre-trend of the control group, and $\beta 4$ presents the baseline rate of antibiotic use in the control hospital. $\beta 1 + \beta 5$ presents the trend in antibiotic use in the case group. $\beta 6$ presents the immediate intervention effect that captures the difference between the intervention and control group. $\beta 7$presents the change in pre- and post-intervention trends after policy implementation. Results are presented as exponential estimates. Data were analyzed using SAS 9.4 (SAS Institute Inc., Cary, North, USA).

Results

The analysis included data from general hospitals with 270,091 hospitalizations in South Korea. A total of 120 hospitals received incentives, and 200,946 were admitted between 2013 and 2019. A total of 69,955 episodes in 138 hospitals did not receive incentives. Patients admitted to hospitals with incentives were mostly in urban areas (52.1%), whereas 57.4% of the comparison hospitals were in rural areas (Table 1).

Fig. 1 shows the monthly average rates of antibiotic use and DOT/PDs in the each group over time, with an almost linear and relatively stable trend in the use of antibiotics and DOT/PDs by hospitalized episodes in both hospitals before the implementation of the intervention, with seasonal variation. The immediate effect of the unincentivized hospital episodes tended to slightly increase before and after the intervention compared with the incentivized hospital episodes. After the intervention, the incentivized hospital showed a decreasing trend in DOT/PDs, but an increasing trend in DOT/PDs was observed in incentivized hospitals.

Interrupted time-series analysis using segmented regression revealed a marginally significant reduction in the level change of antibiotic use between incentivized and unincentivized hospitals (odds ratio [OR], 0.922; 95% confidence interval [CI] 0.859–1.000). Regarding DOTs per person-days, a significant reduction in the trend change was observed between incentivized and unincentivized hospitals (coefficient $\beta 7$, −0.003; 95% CI, −0.006–−0.001; Table 2).

Table 3 shows the results of the subgroup analysis stratified into six classes of antibiotics. The difference in level change in the use of third-generation cephalosporins (OR, 0.894; 95% CI, 0.817–0.977) and carbapenem (OR, 0.790; 95% CI, 0.630–0.992) was significantly reduced between incentivized and unincentivized hospitals. The difference in the level change of glycopeptide use slightly decreased, although not significant (OR,0.886; 95% CI, 0.620–1.265).

Table 4 shows the results of the secondary outcome, DOTs/PD, to stratify the six classes of antibiotics. The difference in slope change on DOT/PDs of glycopeptides was −0.005 DOT/PDs (P = 0.042), and that of carbapenem was −0.003 (P = 0.048) between incentivized and unincentivized hospitals.

Discussion

In this study, we evaluated the impact of implementing an intervention as an incentive for infection prevention and control of antibiotic use. Hospitals that were eligible for incentives were mainly located in urban areas, and many hospitals had relatively good levels of nursing staff. The comparison hospitals were widely distributed in rural areas, had fewer than 271 beds, and many hospitals had poor nursing grades. Our results showed the immediate effect of antibiotic use, which decreased by approximately 8% post-implementation compared to the comparison hospital. In particular, carbapenems, antibiotics against MDR pathogens, were reduced by 11% after implementation of the intervention. Also, the trend change of DOTs per PDs tended to decrease by post-implementation compared to unincentivized hospital, especially glycopeptide and carbapenem were reduced significantly.

These measures were usually implemented within a framework of individual responsibility, strong administrative support, and access to up-to-date national and local surveillance data. [21,22] In the United States, Pay-for-performance (PFP) initiatives employ financial incentives to encourage or discourage healthcare providers and facilities from improving infection prevention and control measures. Past research has demonstrated the efficacy of PFP programs in reducing healthcare-acquired infections, including central line-associated bloodstream infections, urinary tract infections, and pneumonia. [23,24] In Sweden, P4P led to a higher frequency of physicians choosing narrow-spectrum antibiotics over broad-spectrum antibiotics for treating respiratory tract infections in children. [25] Meanwhile, in China, PFP for antibiotic stewardship (ASP) that utilized financial penalties and feedback effectively reduced antibiotic prescriptions. [26] In Korea, the compensation provided for infection prevention management is not based on outcome incentives like PFP programs in the United States, Sweden, and China. Instead, compensation is given based on meeting specific conditions related to the part of the structure, such as the IPC team or ward audit/rounds and adherence monitoring activity. Furthermore, this compensation was not a short-term reward but an additional

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Table 3
Result of interrupted time series analysis of antibiotic use by type of antibiotics.

Variables	Use of antibiotics											
	Incentivized hospital				Unincentivized hospital				Incentivized/Unincentivized Post- Level Change Difference β6		Incentivized/Unincentivized Trend Change Difference β7	
	Pre (N)	%	Post (N)	%	Pre (N)	%	Post (N)	%	OR	95% CI	OR	95% CI
Third-generation cephalosporins	21130	(21.6)	22127	(21.8)	8416	(22.1)	7595	(22.8)	0.894	0.817 - 0.977	1.002	0.997 - 1.007
Fourth-generation cephalosporins	911	(0.9)	1246	(1.2)	124	(0.3)	153	(0.5)	0.942	0.565 - 1.572	1.001	0.974 - 1.028
Fluoroquinolones	11552	(11.8)	12268	(12.1)	6062	(15.9)	5302	(15.9)	0.996	0.897 - 1.105	0.990	0.985 - 0.996
Betalactamase inhibitor	5005	(5.1)	6945	(6.8)	1033	(2.7)	1543	(4.6)	1.118	0.929 - 1.347	1.002	0.993 - 1.012
Glycopeptide	2228	(2.3)	2442	(2.4)	417	(1.1)	328	(1.0)	0.886	0.620 - 1.265	0.987	0.969 - 1.006
Carbapenem	2828	(2.9)	3244	(3.2)	858	(2.3)	1000	(3.0)	0.790	0.630 - 0.992	1.002	0.990 - 1.014

*adjusted all covariates

incentive provided alongside the daily hospitalization fee for each hospitalized patient, encouraging the establishment of infection prevention-related structures.

In 2012, Japan introduced a health policy that incentivized hospitals to for creating Infection Prevention and Control (IPC) teams. One study assessed whether the introduction of financial incentives to create ASP teams is associated with changes in antibiotic use patterns. They found decreasing trends in total antibiotic use, although there were no meaningful changes in total antibiotic use between the incentivized and unincentivized hospitals for the ASP team. [27] While this study focused on patients admitted to all acute hospitals, our study excluded episodes of hospitalization at the tertiary hospital and hospitals with 100 beds or less. In addition, variations in the types of antibiotics identified may have resulted in different outcomes and changes.

Our study did not demonstrate a consistent reduction in antibiotic use due to infection prevention measures. In Korea, a law was enacted in 2012 mandating the establishment of IPC teams and the compulsory recruitment of infection control professionals without financial incentives. Although we observed an overall decline in antibiotic use during the study period, there was no significant difference in the reduction effects between incentivized and unincentivized hospitals. The incentivized hospitals primarily comprised larger institutions that had been actively engaged in infection prevention and antibiotic monitoring even before the intervention. [11,14] Therefore, the fact that they maintained reduced antibiotic use could be considered a positive outcome. However, it is essential to consider that reducing antibiotic use alone may not be sufficient, and ensuring appropriate and proper antibiotic use is equally critical. [28,29] The lack of a continuous reduction effect in incentivized hospitals may be attributed to various factors. One possibility is that the additional income from infection prevention management fees may not have been entirely utilized to support infection prevention activities, leading to a limited impact. Some experts argue that the compensation level may have been insufficient to have a substantial effect. [12] Nevertheless, our study highlighted a significant decrease in the use of all antibiotics associated to multidrug resistance. This indicates a potential decrease in infection prevention activities related to multidrug-resistant infections and improved antibiotic stewardship practices.

Our study has several limitations. First, it may be difficult to generalize our findings to other countries due to variations in healthcare system models, including differences in access and payment systems. Nevertheless, the recognition of hospital-acquired infections, particularly those caused by multidrug-resistant pathogens, is a critical global healthcare issue, and efforts to enhance healthcare quality in acute care settings are relevant worldwide. Second, our study's reliance on the NHI claims database led to limitations in capturing data on over-the-counter medicines and medications not listed in the database. This may have resulted in an underestimation of the impact of antibiotics. However, patients in Korea cannot access antibiotics without a prescription from physicians. Further research is necessary to explore their antibiotic use and resistance. Third, the lack of detailed clinical information in our database prevented us from investigating clinically important outcomes, such as trends in hospital-acquired infections and bacterial antibiotic sensitivities. Future studies that use additional data sources are required to complement our findings. Fourth, as our study relied on the NHIS database for claims data, the incentive for infection prevention and control was introduced at the hospital level with less than 100 beds, but the number of hospitals receiving incentives was low, and the follow-up period was too short to be included in our study. Further research is required with more accumulated data in the future. Fifth, our research design, hospitals that introduced incentives between September 2017 and December 2019 were excluded. This was done to precisely assess the difference

Table 4
Result of interrupted time series analysis of DOTs/PD by type of antibiotics.

Variables	Days of therapy per person-days								Incentivized/Unincentivized Post-Level Change Difference β6			Incentivized/Unincentivized Trend Change Difference β7		
	Incentivized hospital				Unincentivized hospital				adjusted estimate	95% CI	p-value	adjusted estimate	95% CI	p-value
	Pre		Post		Pre		Post							
	Mean	SD	Mean	SD	Mean	SD	Mean	SD						
Third-generation cephalosporins	0.858	0.765	0.857	0.783	0.781	0.662	0.773	0.595	-0.014	-0.054 - 0.501	0.501	0.000	-0.002 - 0.002	0.906
Fourth-generation cephalosporins	0.370	0.260	0.338	0.269	0.430	0.306	0.528	0.298	-0.009	-0.138 - 0.889	0.889	0.001	-0.006 - 0.008	0.795
Fluoroquinolones	0.834	0.860	0.753	0.736	0.761	0.685	0.761	0.616	-0.011	-0.062 - 0.676	0.676	-0.001	-0.003 - 0.002	0.544
Betalactamase inhibitor	0.379	0.263	0.352	0.266	0.426	0.273	0.476	0.276	0.040	-0.004 - 0.075	0.075	0.001	-0.002 - 0.003	0.551
Glycopeptide	0.287	0.233	0.248	0.219	0.327	0.263	0.320	0.258	0.040	-0.041 - 0.332	0.332	-0.005	-0.009 - 0.000	0.042
Carbapenem	0.387	0.259	0.351	0.266	0.415	0.249	0.444	0.265	0.013	-0.040 - 0.636	0.636	-0.003	-0.005 - 0.000	0.048

*adjusted all covariates

in outcomes before and after the intervention point in interrupted time series. Therefore, for future studies, additional research including all hospitals where incentives were received will be necessary. Finally, we could not take into account various additional measures, such as the initiation of an ASP fee extended to each hospital, the introduction of infection control measures, or the implementation of an antibiotic prescription monitoring system within the our study period.

Conclusion

We observed that incentives for infection prevention and management have had a positive impact on some aspects of antibiotic usage. A partial decrease was observed in antibiotic use, accompanied by a modest reduction in Days of Therapy per person days, particularly in relation to antibiotics aimed at addressing multidrug-resistant pathogens. Further investigation is necessary to establish evidence for extending these incentives.

Ethical approval

We assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Since we used the anonymized data, the need for informed consent was waived by the Institutional Review Board of Yonsei University's Health System (4–2023-0820).

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CRediT authorship contribution statement

Yu shin Park conceived of the presented idea. Yu Shin Park and Soo Young Kim developed the theory and performed the computations. Yu Shin Park and Hyunku Kim verified the analytical methods. Eun-Cheol Park and Suk yong Jang supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

Consent for publication

Not applicable.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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