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Nationwide Survey of Antimicrobial Stewardship in Korean Hospitals: Insights From the Early Stage of the 2024 National Pilot Implementation

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ABSTRACT

Background: Antimicrobial stewardship programmes (ASPs) are essential for optimising antibiotic use and mitigating antimicrobial resistance. In Korea, antimicrobial consumption exceeds the Organisation for Economic Co-operation and Development average, and ASP activities remain fragmented, particularly in smaller hospitals. In November 2024, the National Health Insurance Service introduced a pilot reimbursement scheme to support ASPs in hospitals with ≥ 300 beds. This study aimed to provide baseline data to evaluate its impact.
Methods: A nationwide web-based survey was conducted between January and February 2025 among 297 hospitals with ≥ 300 beds. The questionnaire was designed to allow comparison with the 2020 national survey and to assess the ASP infrastructure, resources, and practices.
Results: Of 153 responding hospitals, 71 participated in the pilot programme. Participating hospitals were typically large, university-affiliated, and metropolitan-based; non-participants were smaller, non-teaching, and regional. Participating hospitals employed more infectious disease specialists (2.96 vs. 0.63) and paediatric infectious disease specialists (0.66 vs. 0.12) and allocated more full-time equivalent staff to ASP activities. Participants had stronger institutional support, including financial (46.5% vs. 1.2%) and workforce (52.1% vs. 2.4%) support. Guidelines, interventions, monitoring, and information technology-based decision support systems were more common in participating hospitals, which were all registered with the Korea National Antimicrobial Use Analysis System. Non-participating hospitals frequently lacked guidelines (62%) and interventions (48%). Both groups reported workforce shortages and insufficient incentives as major barriers.
Conclusion: The Korean ASP pilot programme strengthened the stewardship infrastructure in participating hospitals, even early on. However, substantial disparities with non-participating hospitals persist, underscoring the need for tailored support for resource-limited institutions.

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Author Contributions

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Keywords: Antimicrobial Stewardship; Drug Resistance; Nationwide Survey; Republic of Korea

INTRODUCTION

Antimicrobial resistance (AMR) remains a major global health threat exacerbated by the inappropriate use of antibiotics across healthcare settings. Therefore, antimicrobial stewardship programmes (ASPs) have become essential strategies for optimising antibiotic use, improving patient outcomes, and reducing the emergence of resistant organisms.[1-3] International guidelines, such as those from the US Centers for Disease Control and Prevention (CDC) and the Infectious Diseases Society of America, have defined core elements for ASPs, including leadership commitment, accountability, pharmacy expertise, monitoring, and education.[4,5]

In the Republic of Korea (ROK), antimicrobial consumption has consistently exceeded the Organisation for Economic Co-operation and Development average,[6,7] underscoring the urgency of ASP implementation. Since the ROK launched its first National Action Plan on AMR in 2016, a series of national strategies have emphasised the need to embed ASPs in hospital practice.[6,8] However, several national surveys have demonstrated that ASP activities remain fragmented and inconsistently applied, particularly in non-tertiary care hospitals such as secondary or primary care institutions where infectious disease (ID) specialists or trained pharmacists are often unavailable.[9,10] These limitations have been attributed to structural factors such as workforce shortages, an absence of financial incentives, and limited institutional support.[11] Specifically, a 2020 nationwide survey found that ASP implementation and awareness were significantly lower in non-teaching and non-tertiary care hospitals, while a 2018 survey reported enduring disparities in ASP resources and engagement.[10,12]

To address these gaps, the ROK introduced the Korean ASP Core Elements in 2022, establishing a framework tailored to the realities of the domestic healthcare system.[13] Strategic efforts have also been made to expand ASP implementation in long-term care hospitals, where ASPs are critically needed but remain insufficiently embedded.[14] In November 2024, the government launched a pilot reimbursement scheme through the National Health Insurance Service to support ASP activities in hospitals with ≥ 300 beds.[6] This initiative represents the first structured financial support for ASPs at the national level and provides a unique opportunity to examine the baseline status of ASP capacity at the onset of government-supported implementation.

Given this significant policy shift, empirical baseline data are essential to assess its effects. It is also important to evaluate how such policies translate into measurable differences in resource allocation, ASP implementation, and institutional engagement.

Therefore, this study aimed to provide a baseline assessment of institutional preparedness during the early phase of the Korean ASP pilot programme. We compared the infrastructure, personnel, and ASP practices of participating and non-participating hospitals and contextualised these findings using data from a similar nationwide survey conducted in 2020. This baseline will serve as a reference point for future evaluations of the impact of the programme and the evolution of ASP implementation in the ROK.

METHODS

Questionnaire design

A research committee was established that consisted primarily of members from the Korean Society of Infectious Diseases, Korean Society for Antimicrobial Therapy, and Korean Society of Pediatric Infectious Diseases who were actively engaged in ASP-related research and hospital-based activities.

The questionnaire was designed to assess both the current status of ASP implementation in Korean hospitals and healthcare providers' awareness of and need for ASPs. It incorporated the Korean Core Elements of ASP and was developed by referencing the 2020 nationwide survey,[10] to enable comparison with past results. Additionally, a literature review of studies on the status and awareness of ASPs was conducted to identify and add items not included in the previous survey. The draft questionnaire underwent multiple rounds of review and discussion by the research committee before it was finalised. The final instrument comprised 61 items.

The questionnaire was distributed via a web-based survey platform (SurveyMonkey) (**Supplementary Data 1**). Items assessing the awareness of and need for ASPs were measured using a seven-point Likert scale, with higher scores indicating a strong agreement.

Definitions

Hospital types followed the Medical Service Act of Korea[15]: tertiary hospitals (≥ 500 beds) required specialised departments and designation by the Minister of Health and Welfare; general hospitals (≥ 100 beds) had mandatory core departments (i.e., internal medicine, general surgery, paediatrics, obstetrics/gynaecology, diagnostic radiology, laboratory medicine/pathology, anaesthesiology); and hospitals (30–99 beds), in which those with ≥ 100 beds met general hospital criteria.

ID specialists were board-certified physicians who treated adult or paediatric IDs. Board-certified ID pharmacists were those certified in ID pharmacy by the Korean Society of Health-System Pharmacists. In this study, 1.0 full-time equivalent (FTE) was defined as 40 working hours per week, 0.5 FTE as 20 hours per week, and 0.25 FTE as 10 hours per week.

Survey administration

This survey was conducted among hospitals with ≥ 300 beds, in accordance with the eligibility criteria for the national ASP pilot programme initiated in November 2024. Both large- and medium-sized tertiary care hospitals were included, yielding 297 eligible institutions. At each hospital, a single representative, either a physician or pharmacist responsible for ASP activities, was invited to complete the survey. For hospitals without an ASP, the physician in charge of antibiotic management was designated as the respondent.

Two consecutive survey rounds were conducted during the early phase of the ASP pilot programme (15–29 January 2025 and 10–24 February 2025). An official letter requesting participation was distributed to eligible hospitals via the respective provincial public health centres, with support from the commissioning department of the Korea Disease Control and Prevention Agency. During the survey period, response rates were monitored, and additional reminders were sent to institutions in regions with lower participation rates, to encourage completion.

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Statistical analysis

The 2024 survey results were compared between hospitals participating in the ASP and those not participating. Additional analyses were conducted by comparing responses from hospitals with ≥ 300 beds in the 2020 survey with those from 2024 (**Supplementary Tables 1** and **2**).

Data were exported to Microsoft Excel (Microsoft Corp., Redmond, WA, USA) using SurveyMonkey. IBM SPSS Statistics for Windows (version 26.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis. Continuous variables are presented as mean ± standard deviation and median (interquartile range), and categorical variables are expressed as frequency (n) and percentage (%). Continuous variables were compared using the independent samples *t*-test and Mann-Whitney *U* test, whereas categorical variables were compared using the χ^2 test. A *P* value of < 0.05 was considered statistically significant.

Ethics statement

The study protocol was approved by the Institutional Review Board (IRB) of Hanyang University Seoul Hospital (IRB No. 2025-01-021; approval date: 14-02-2025), and the requirement for written informed consent was waived.

RESULTS

Characteristics of the study hospitals

Among the 297 hospitals with ≥ 300 beds identified, 153 hospitals responded to the survey, yielding a response rate of 51.5%. Of these, 71 hospitals (46.4%) participated in the national ASP pilot programme and 82 (53.6%) did not. The primary reasons for non-participation in the ASP pilot programme were personnel shortages, including insufficient ASP staff (79.5%), physician shortages (60.2%), and pharmacist shortages (57.8%). Additionally, a lack of budget (27.7%) was identified as a barrier (**Supplementary Table 3**).

Table 1 shows the marked differences in characteristics between ASP participating and non-participating hospitals. Most participating hospitals were medium-to-large-sized institutions with 600–899 beds (54.9%), university-affiliated (76.1%), and located mainly in the Seoul Metropolitan Area (Seoul 29.6%, Gyeonggi 32.4%). In contrast, most non-participating hospitals were smaller, with 300–599 beds (90.3%); non-teaching hospitals (62.2%); and mainly located outside the capital area, particularly in Gyeongsang Province (40.2%). Gangwon Province and Jeju Island had only three institutions each, with limited ASP participation.

The composition of respondents also varied. ID specialists accounted for a higher proportion of participating hospitals (59.2%), while non-ID physicians (42.7%) and pharmacists (40.2%) predominated in non-participating hospitals.

Resource for the ASP

As shown in **Table 2**, ASP-participating hospitals employed significantly more ID specialists (2.96 ± 1.7 vs. 0.63 ± 2.8; *P* < 0.001) and paediatric ID specialists (0.66 ± 0.12 vs. 0.12 ± 0.40; *P* < 0.001) than non-participating hospitals, with these numbers being approximately twofold higher than those reported in 2020 (**Supplementary Table 1**). The proportion of institutions with ASP-engaged staff differed significantly by ASP participation. Almost all participating hospitals had at least one ID specialist (94.4% vs. 22.0%; *P* < 0.001), with similar differences for paediatric ID specialists (47.9% vs. 7.3%; *P* < 0.001). Participating hospitals were also more

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Table 1. Characteristics of the study hospitals

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Inpatient bed capacity				< 0.001***
300–599	86 (56.2)	12 (16.9)	74 (90.3)	
600–899	46 (30.1)	39 (54.9)	7 (8.5)	
900–1,199	15 (9.8)	14 (19.7)	1 (1.2)	
≥ 1,200	6 (3.9)	6 (8.5)	0 (0.0)	
Hospital type, by educational system				< 0.001***
University-affiliated hospital	63 (41.2)	54 (76.1)	9 (11.0)	
Other teaching hospital	37 (24.2)	15 (21.1)	22 (26.8)	
Non-teaching hospital	53 (34.6)	2 (2.8)	51 (62.2)	
Hospital type				< 0.001***
Tertiary hospital	39 (25.5)	38 (53.5)	1 (1.2)	
General hospital	76 (49.7)	33 (46.5)	43 (52.4)	
Hospital	8 (5.2)	0 (0.0)	8 (9.8)	
Long-term care hospital	29 (18.0)	0 (0.0)	29 (35.4)	
Other	1 (0.7)	0 (0.0)	1 (1.2)	
Region of medical institution				< 0.001***
Seoul	25 (16.3)	21 (29.6)	4 (4.9)	
Gangwon-do	3 (2.0)	2 (2.8)	1 (1.2)	
Gyeonggi-do	39 (25.5)	23 (32.4)	16 (19.5)	
Gyeongsang-do	48 (31.4)	15 (21.1)	33 (40.2)	
Jeolla-do	24 (15.7)	5 (7.0)	6 (7.3)	
Chungcheong-do	11 (7.2)	5 (7.0)	3 (3.7)	
Jeju-do	3 (2.0)	0 (0.0)	3 (3.7)	
Specialty of the respondent (%)				< 0.001***
ID specialist	55 (35.9)	42 (59.2)	13 (15.9)	
Paediatric ID specialist	2 (1.3)	2 (2.8)	0 (0.0)	
Medical doctor (except ID specialist)	39 (25.5)	4 (5.6)	35 (42.7)	
Board-certified ID pharmacist	8 (5.2)	7 (9.9)	1 (1.2)	
Pharmacist (except ID subspecialty)	49 (32.0)	16 (22.5)	33 (40.2)	

Values are presented as number (%).
ASP = antimicrobial stewardship programme, ID = infectious disease.
***$P < 0.001$.

likely to involve non-ID physicians (60.6% vs. 19.5%), board-certified ID pharmacists (18.3% vs. 2.4%), and non-ID pharmacists (91.5% vs. 20.7%) ($P < 0.01$ for all comparisons). Mean FTEs for ASP staff were markedly higher in participating hospitals, including ID specialists (1.14 vs. 0.11), board-certified ID pharmacists (0.23 vs. 0.02), and non-ID pharmacists (1.49 vs. 0.09) ($P < 0.01$ for all comparisons) (**Table 2**). Among ASP-participating hospitals, workforce allocation further differed by hospital size, with large hospitals (≥ 900 beds) employing substantially more core ASP personnel than small- to medium-sized hospitals (**Supplementary Table 4**). In terms of functional roles, pharmacists, as essential staff members in the ASP pilot programme, were mainly involved in monitoring antibiotic consumption and resistance rates (56%) and assisting with ASP interventions (55%) (**Supplementary Table 5**).

Hospital support for ASP was significantly greater in participating hospitals. Financial support (hospital-funded support, not supported by pilot programme) (46.5% vs. 1.2%), workforce support (52.1% vs. 2.4%), and staff incentives (39.4% vs. 1.2%) were more common (all $P < 0.001$). In contrast, the absence of support was far more frequent in non-participating hospitals (89.0% vs. 25.4%; $P < 0.001$). Awareness-raising activities were more frequently implemented in participating hospitals (83.1% vs. 27.7%; $P < 0.001$), particularly ASP guidance and promotion (59.2% vs. 7.3%; $P < 0.001$) and communication of antibiotic appropriateness assessments (46.5% vs. 18.3%; $P < 0.001$). Conversely, a lack of relevant activities was significantly more common in non-participating hospitals (74.4% vs. 16.9%; $P < 0.001$).

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Table 2. Resources for antimicrobial stewardship program

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Human resources				
ID specialist	1.56 ± 1.81	2.96 ± 1.7	0.63 ± 2.80	< 0.001***
Paediatric ID specialist	0.37 ± 0.67	0.66 ± 0.12	0.12 ± 0.40	< 0.001***
Institutions with ≥ 1 staff member engaged in ASP				
ID specialist	85 (55.6)	67 (94.4)	18 (22.0)	< 0.001***
Paediatric ID specialist	40 (26.1)	34 (47.9)	6 (7.3)	< 0.001***
Physician (non-ID specialist)	59 (38.6)	43 (60.6)	16 (19.5)	< 0.001***
Board-certified ID pharmacist	15 (9.88)	13 (18.3)	2 (2.4)	0.003**
Pharmacist (non-ID certified)	82 (53.6)	65 (91.5)	17 (20.7)	< 0.001***
Nurse	28 (18.3)	26 (36.6)	2 (2.4)	< 0.001***
IT staff	10 (6.5)	7 (9.9)	3 (3.7)	0.223
Administrative staff	14 (9.2)	10 (14.1)	4 (4.9)	0.091
FTE of staff involved in ASP activities				
ID specialist	0.6 ± 0.7	1.14 ± 0.67	0.11 ± 0.26	< 0.001***
Paediatric ID specialist	0.1 ± 0.2	0.17 ± 0.31	0.30 ± 0.13	< 0.001***
Physician (non-ID specialist)	0.3 ± 0.5	0.37 ± 0.48	0.20 ± 0.58	< 0.001***
Board-certified ID pharmacist	0.1 ± 0.4	0.23 ± 0.57	0.02 ± 0.11	< 0.001***
Pharmacist (non-ID certified)	0.7 ± 0.8	1.49 ± 0.73	0.09 ± 0.29	< 0.01**
Nurse	0.3 ± 0.6	0.41 ± 0.62	0.18 ± 0.59	0.010*
IT staff	0.1 ± 0.2	0.09 ± 0.32	0.01 ± 0.11	0.048*
Administrative staff	0.1 ± 0.3	0.12 ± 0.36	0.01 ± 0.11	0.019*
Others	0.03 ± 0.19	0.04 ± 0.24	0.21 ± 0.13	< 0.001***
Hospital support for ASP[a]				
Financial support[b]	34 (22.2)	33 (46.5)	1 (1.2)	< 0.001***
Workforce support	39 (25.5)	37 (52.1)	2 (2.4)	< 0.001***
Incentive for staff involved in ASP	29 (19.0)	28 (39.4)	1 (1.2)	< 0.001***
Incorporation of ASP into clinical performance rating	10 (5.4)	8 (11.3)	2 (2.4)	0.045*
No support	91 (59.5)	18 (25.4)	73 (89.0)	< 0.001***
Others	22 (14.5)	14 (19.7)	8 (9.9)	0.106
Activities to raise ASP awareness[a]	82 (53.6)	59 (83.1)	23 (27.7)	< 0.001***
Campaign to raise awareness of antibiotic resistance	4 (2.6)	2 (2.8)	6 (7.3)	0.212
Guidance and promotion for the ASP	48 (34.1)	42 (59.2)	6 (7.3)	< 0.001***
Awarding department or staffs for excellence in ASP	2 (1.3)	0 (0.0)	2 (2.8)	0.214
Communicating the outcomes of antibiotic appropriateness assessments	48 (31.4)	33 (46.5)	15 (18.3)	< 0.001***
No relevant activities	73 (47.7)	12 (16.9)	61 (74.4)	< 0.001***
Others	22 (14.4)	14 (19.7)	8 (9.8)	0.106

Values are presented as mean ± standard deviation or number (%).
ASP = antimicrobial stewardship programme, ID = infectious disease, IT = information technology, FTE = full-time equivalent.
[a]Multiple responses were allowed.
[b]Hospital-funded financial support (not supported by pilot programme).
*P < 0.05, **P < 0.01, ***P < 0.001.

Institutional strategies and practices for antimicrobial stewardship

Table 3 shows that ASP activities are generally more common in hospitals participating in ASPs. In particular, surgical prophylaxis guidelines (73.2% vs. 34.1%; P < 0.001) and disease-specific antibiotic guidelines covering > 5 diseases (45.1% vs. 8.5%; P < 0.001) were significantly more frequent in participating hospitals. In contrast, 62.0% of the non-participating hospitals reported having no guidelines. These guidelines were mainly disseminated through hospital groupware (52.1% vs. 28.1%; P = 0.002) or integration into the prescribing system (42.3% vs. 17.1%; P < 0.001).

ASP interventions were more widely implemented in the participating hospitals. All participating hospitals operated antimicrobial approval programmes (100% vs. 55.4%), and over half performed interventions, such as recommending culture-guided therapy (59.2%

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Table 3. Antimicrobial stewardship programme initiatives

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Documented guidelines for antimicrobial use[a]				
Disease-specific antibiotic guidelines (≤ 5 diseases)	19 (12.4)	15 (21.1)	4 (5.6)	< 0.001***
Disease-specific antibiotic guidelines (> 5 diseases)	39 (25.5)	32 (45.1)	7 (8.5)	< 0.001***
Surgical prophylaxis guidelines	80 (52.3)	52 (73.2)	28 (34.1)	< 0.001***
Antibiotic guidelines for immunocompromised patients	9 (5.9)	8 (11.3)	1 (1.4)	0.008**
Antibiotic guidelines for emergency patients in the ER	5 (3.3)	4 (5.6)	1 (1.4)	0.126
No guidelines available	54 (35.3)	11 (15.5)	43 (62.0)	< 0.001***
Others	18 (11.8)	7 (10.0)	11 (13.3)	0.496
Implementation of antimicrobial guidelines[a]				
Posting guidelines on the hospital groupware	60 (39.2)	37 (52.1)	23 (28.1)	0.002**
Integrating guidelines into the prescribing system	44 (28.8)	30 (42.3)	14 (17.1)	< 0.001***
Conducting departmental training on the guidelines	21 (13.7)	16 (22.5)	5 (6.1)	0.003**
Monitoring prescription compliance and providing feedback	16 (10.5)	7 (9.9)	9 (11.0)	0.822
Others	3 (2.0)	1 (1.4)	2 (2.4)	0.647
Approval for specific antimicrobial prescription[a]				
Restricted antibiotics	117 (76.0)	71 (100.0)	46 (55.4)	< 0.001***
Restricted antiviral agents	39 (25.3)	32 (45.1)	7 (8.4)	< 0.001***
Restricted antifungal agents	69 (44.8)	51 (71.8)	18 (27.3)	< 0.001***
No restriction	36 (23.4)	0 (0.0)	36 (43.4)	< 0.001***
Prospective audit and feedback[a]				
Intervention for redundant antimicrobial therapy	45 (29.2)	37 (52.1)	8 (9.6)	< 0.001***
Optimising duration of therapy	39 (25.3)	31 (43.7)	8 (9.6)	< 0.001***
Recommendation for IV to PO switch	34 (22.1)	27 (38.0)	7 (8.4)	< 0.001***
Recommendation for culture-guided therapy	57 (37.0)	42 (59.2)	15 (18.1)	< 0.001***
Recommendation for antibiotic de-escalation	46 (29.9)	37 (52.1)	9 (10.8)	< 0.001***
Monitoring and promoting guideline adherence	30 (19.5)	26 (36.6)	4 (4.8)	< 0.001***
Therapeutic drug monitoring	44 (28.6)	40 (56.3)	4 (4.8)	< 0.001***
Management of the restricted antimicrobial program	98 (63.6)	63 (88.7)	35 (42.2)	< 0.001***
None	41 (26.6)	3 (4.2)	38 (45.8)	< 0.001***
Formulary restriction	26 (16.9)	13 (18.3)	13 (15.8)	0.687
clinical decision support system for antibiotic use	45 (29.2)	38 (53.5)	7 (8.4)	< 0.001***
Drug safety alert system for antibiotic use	52 (33.8)	35 (49.3)	17 (20.5)	< 0.001***
Automated IV antibiotic order sets	37 (24.0)	28 (39.4)	9 (10.8)	< 0.001***
Automated drug allergy alert system	72 (46.8)	48 (67.6)	24 (28.9)	< 0.001***
Automated guidance for antibiotic adjustment based on susceptibility results	3 (1.9)	2 (2.8)	1 (1.2)	0.477
Automated surveillance system for ASP team upon detection of critical pathogens	48 (31.2)	30 (42.3)	18 (21.7)	0.007**
Programme that prompts for documentation of antibiotic use	9 (5.8)	4 (10.8)	5 (25.0)	0.253
Intervention for surgical antibiotic prophylaxis[a]	57 (37.0)	37 (52.1)	20 (24.1)	< 0.001***
Antibiotic choice	49 (32.0)	33 (46.5)	16 (19.5)	0.340
Duration of therapy	53 (34.6)	37 (52.1)	16 (19.5)	0.012*
Timing of administration	41 (26.8)	26 (36.6)	15 (18.3)	0.767
Route of administration	14 (9.2)	10 (14.1)	4 (4.9)	0.749
Others	1 (0.7)	1 (1.4)	0 (0.0)	0.464

Values are presented as number (%).
ASP = antimicrobial stewardship programme, ER = emergency room, IV = intravenous, PO = per os.
[a]Multiple responses were allowed.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

vs. 18.1%), promoting antibiotic de-escalation (52.1% vs. 10.8%), and addressing redundant antimicrobial therapy (52.1% vs. 9.6%) ($P < 0.001$ for all comparisons). In contrast, nearly half of the non-participating hospitals reported no related interventions.

In addition, the participating hospitals demonstrated significantly greater adoption of computerised support systems, including drug allergy alerts (67.6% vs. 28.9%), clinical decision support systems (53.5% vs. 8.4%), drug safety alerts (49.3% vs. 20.5%), and

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automated IV antibiotic order sets (39.4% vs. 10.8%) ($P < 0.001$ for all comparisons). Compared with 2020, ASP implementation significantly improved in participating hospitals in 2024. Disease-specific and surgical prophylaxis guidelines increased from 19.4% to 66.2% and from 48.0% to 73.2%, respectively ($P < 0.001$), while hospitals lacking antimicrobial guidelines decreased from 39.8% to 15.5% ($P < 0.001$). Restrictive antibiotic policies became universal (62.2% to 100%), and clinical decision support system use more than doubled from 25.5% to 53.5% ($P < 0.001$) (**Supplementary Table 2**).

Monitoring and reporting practices for antimicrobial stewardship

Table 4 shows that all ASP-participating hospitals were registered with the Korea National Antimicrobial Use Analysis System and more frequently operated monitoring systems for antibiotic use (54.9% vs. 19.5%; $P < 0.001$). Most hospitals conducted antibiotic use analyses

Table 4. Monitoring and reporting of antibiotic use

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Registered to KONAS	90 (58.4)	71 (100.0)	19 (23.2)	< 0.001***
System for monitoring antibiotic use	55 (35.7)	39 (54.9)	16 (19.5)	< 0.001***
Regular report of antibiotic use analysis results	82 (53.2)	47 (66.2)	25 (30.5)	< 0.001***
Frequency of report				
Annually	8 (5.2)	4 (5.6)	4 (4.8)	1.000
Every 6 mon	35 (22.7)	22 (31.0)	13 (15.9)	0.034*
Every 3 mon	24 (15.6)	16 (22.5)	8 (9.8)	0.044*
Monthly	5 (3.2)	5 (7.0)	0 (0.0)	0.020*
Irregularly	1 (0.7)	1 (1.4)	0 (0.0)	0.464
None	73 (47.4)	24 (33.8)	59 (72.0)	< 0.001***
Report recipients[a]				
Hospital management	64 (41.6)	42 (59.2)	22 (26.8)	< 0.001***
General staff	12 (7.8)	8 (11.3)	4 (4.9)	0.227
Nursing and administrative managers	19 (12.3)	12 (16.9)	7 (8.5)	0.143
Physicians in specific departments	22 (14.3)	17 (23.9)	5 (6.1)	0.003**
Physicians in the antibiotic stewardship committee	64 (41.6)	42 (59.2)	22 (26.8)	< 0.001***
Physicians in the healthcare quality management committee	12 (7.8)	8 (11.3)	4 (4.9)	0.227
Report to others	6 (3.9)	4 (5.6)	2 (2.4)	0.417
Monitoring for the appropriateness of antibiotic use	27 (17.6)	22 (31.0)	5 (6.1)	< 0.001***
Monitoring for the compliance with recommendation by ASP team	42 (27.5)	37 (52.1)	5 (6.1)	< 0.001***
System for monitoring antibiotic side effects	99 (64.7)	61 (85.9)	38 (46.3)	< 0.001***
System for monitoring CDI	79 (51.6)	56 (67.5)	23 (28.0)	< 0.001***
Regular report of antibiotic resistance rates				
Frequency of report				
Annually	16 (10.4)	8 (11.3)	8 (9.6)	0.796
Every 6 mon	33 (21.4)	21 (29.6)	12 (14.5)	0.031*
Every 3 mon	56 (36.4)	35 (49.3)	21 (25.3)	0.004**
Monthly	8 (5.2)	3 (4.2)	5 (6.0)	0.725
Irregularly	6 (3.9)	1 (1.4)	5 (6.0)	0.217
None	35 (22.7)	3 (4.2)	32 (38.6)	< 0.001***
Report recipients[a]				
Hospital management	64 (41.8)	42 (59.2)	22 (26.8)	< 0.001***
General staff	12 (7.8)	8 (11.3)	4 (4.9)	0.227
Nursing and administrative managers	19 (12.4)	12 (16.9)	7 (8.5)	0.143
Physicians in specific departments	21 (13.7)	17 (23.9)	4 (4.9)	0.001**
Physicians in the antibiotic stewardship committee	64 (41.8)	42 (59.2)	22 (26.8)	< 0.001***
Physicians in the healthcare quality management committee	12 (7.8)	8 (11.3)	4 (4.9)	0.066
Report to others	9 (5.9)	4 (5.7)	5 (6.1)	1.000

Values are presented as number (%).
ASP = antimicrobial stewardship programme, KONAS = Korea National Antimicrobial Use Analysis System, CDI = *Clostridioides difficile* infection.
[a]Multiple responses were allowed.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

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every 6 months, with results typically reported to hospital management and ASP committees. Regular reporting of antibiotic resistance rates was also more common in participating hospitals, particularly at 3-month intervals (49.3% vs. 25.3%; $P < 0.001$). Conversely, non-reporting was substantially higher among non-participating hospitals (38.6% vs. 4.2%; $P < 0.001$).

Monitoring activities were more widely implemented in the participating hospitals, including monitoring the appropriateness of antibiotic use (31.0% vs. 6.1%; $P < 0.001$) and compliance with stewardship recommendations (52.1% vs. 6.1%; $P < 0.001$). Systems for monitoring adverse drug reactions (85.9% vs. 46.3%) and *Clostridioides difficile* infections (67.5% vs. 28.0%) were also significantly more common in the participating hospitals ($P < 0.001$ for all comparisons).

Education and awareness

Institutional training on appropriate antibiotic use was far more frequent in participating hospitals (87.3% vs. 13.4%; $P < 0.001$), whereas education for patients and caregivers remained minimal (1.4% vs. 0%). Education for residents (38.0% vs. 7.2%) and medical students (31.0% vs. 3.6%) was also more commonly reported in the participating hospitals ($P < 0.001$ for all comparisons) (**Table 5**).

Table 6 demonstrates that respondents from the participating hospitals demonstrated a markedly higher level of understanding of ASPs (77.5% vs. 17.1%; $P < 0.001$) and more

Table 5. Education for antimicrobial use

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Institutional training on appropriate antibiotic use	73 (47.7)	62 (87.3)	11 (13.4)	< 0.001***
Educational targets[a]				
Hospital management	49 (67.1)	47 (75.8)	2 (18.2)	< 0.001***
Specialists (e.g., professors, attending physicians, fellows)	61 (83.6)	55 (88.7)	6 (54.5)	0.014*
Physicians in training (e.g., residents, interns)	43 (58.9)	37 (59.7)	6 (54.5)	0.752
Non-physician healthcare professionals (e.g., pharmacists, nurses)	58 (79.5)	50 (80.6)	8 (72.7)	0.660
Patients and guardians	1 (0.6)	1 (1.4)	0 (0.0)	0.464
Frequency of education				
Annually	30 (41.1)	25 (40.3)	5 (45.6)	0.752
Every 6 mon	8 (11.0)	8 (12.9)	0 (0.0)	< 0.001***
Every 3 mon	1 (1.4)	1 (1.6)	0 (0.0)	0.464
Monthly	2 (2.7)	2 (3.2)	0 (0.0)	0.214
Irregularly	32 (43.8)	26 (41.9)	6 (54.5)	0.518
Training modalities[a]				
Online course	24 (32.8)	22 (35.5)	2 (18.2)	0.320
Distribution of educational materials	27 (37.0)	23 (37.1)	4 (36.4)	1.000
Face-to-face session: group education	57 (78.1)	52 (83.9)	5 (45.5)	0.011*
On-site departmental training	19 (26.0)	18 (29.0)	1 (9.1)	0.268
Provision of ASP training from ID division for residents and fellows				
Yes	33 (21.6)	27 (38.0)	6 (7.2)	< 0.001***
No	64 (41.6)	42 (59.2)	22 (26.5)	< 0.001***
No ID division	56 (36.4)	2 (2.8)	54 (65.1)	< 0.001***
Integration of ASP education into the medical school curriculum				
Yes	25 (16.2)	22 (31.0)	3 (3.6)	< 0.001***
No	26 (16.9)	19 (26.8)	7 (8.4)	0.004**
Non-teaching hospital	84 (54.5)	15 (21.1)	69 (83.1)	< 0.001***
Unknown	18 (11.7)	15 (21.1)	3 (3.6)	< 0.001***

Values are presented as number (%).
ASP = antibiotic stewardship programme, ID = infectious disease.
[a]Multiple responses were allowed.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

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Table 6. Awareness and needs for antimicrobial stewardship programme

Variables	Total (N = 153)	ASP participating hospitals (n = 71)	ASP non-participating hospitals (n = 82)	*P* value
Understanding of ASP				< 0.001***
Good	69 (45.1)	55 (77.5)	14 (17.1)	
Partial	59 (38.6)	15 (21.1)	44 (53.6)	
Limited	25 (16.3)	1 (1.4)	24 (29.3)	
Awareness of ASP[a]				
Sufficient training on ASP	3.4 ± 1.9	4.0 ± 1.9	3.1 ± 1.9	0.014**
ASP infringe on the autonomy of individual physicians	3.2 ± 1.5	2.8 ± 1.4	3.5 ± 1.5	0.002**
ASP can be source of tension among clinicians	4.0 ± 1.6	3.9 ± 1.5	4.1 ± 1.7	0.356
Considered factors to impede ASP settlements[a]				
Lack of appropriate compensation for ASP implementation	5.8 ± 1.4	6.1 ± 1.2	5.5 ± 1.5	0.007**
Lack of proper evaluation for ASP implementation	5.0 ± 1.5	5.3 ± 1.4	4.7 ± 1.6	0.083
Insufficient personnel for ASP implementation	6.3 ± 1.2	6.5 ± 1.0	6.2 ± 1.5	0.100
Lack of education and promotion for medical staff regarding ASP	5.7 ± 1.1	5.7 ± 1.0	5.7 ± 1.3	0.207
Lack of incentives/disincentives for appropriateness of antibiotic prescribing	4.8 ± 1.6	4.9 ± 1.5	4.8 ± 1.7	0.817
Lack of tools for programme implementation (e.g., guidelines, electronic programs)	5.7 ± 1.3	5.6 ± 1.2	5.8 ± 1.5	0.113
Concerns about clinical outcomes or litigation	5.3 ± 1.5	5.5 ± 1.2	5.1 ± 1.7	0.221
Clinical training environment (e.g., team discipline, instructions from supervisors)	4.8 ± 1.5	5.3 ± 1.2	4.4 ± 1.7	0.001*
Policies to promote ASP[a]				
Support for dedicated personnel to manage ASP activity	6.3 ± 1.0	6.6 ± 0.7	6.2 ± 2.1	0.053
Establishment of educational programmes linked to CME credits	5.7 ± 1.3	5.9 ± 0.9	5.3 ± 2.2	0.930
Implementation of incentive system based on the appropriateness of antibiotic use	4.8 ± 1.6	4.9 ± 1.5	4.7 ± 1.8	0.562
Inclusion of ASP implementation as a quality management item in hospital accreditation	5.2 ± 1.6	5.6 ± 1.3	4.9 ± 1.8	0.012*
Provision of tools and resources for ASP implementation	5.9 ± 1.3	6.0 ± 1.0	5.8 ± 1.6	0.470

Values are presented as number (%) or mean ± standard deviation.
ASP = antimicrobial stewardship programme, CME = continuing medical education.
[a]Each item was measured on a 1–7-point Likert scale; higher scores indicated stronger agreement.
*P < 0.05, **P < 0.01, ***P < 0.001.

frequently reported having received sufficient training (mean: 4.0 vs. 3.1; P = 0.014). In contrast, respondents from non-participating hospitals expressed greater concern that ASPs would infringe on physician autonomy (3.5 vs. 2.8; P = 0.002). The main barriers to ASP implementation included personnel shortages, insufficient compensation, and a lack of education or promotion, with no major differences between the groups. However, the clinical training environment was perceived as a greater challenge in the participating hospitals (5.3 vs. 4.4; P = 0.001). Both groups emphasised the importance of supporting dedicated personnel and providing adequate tools and resources as key strategies to promote ASPs. Additionally, participating hospitals more strongly endorsed ASP implementation as a quality management item in hospital accreditation (5.6 vs. 4.9; P = 0.012).

DISCUSSION

This study is the first nationwide survey conducted immediately after the launch of Korea's pilot reimbursement programme for ASPs. Despite being undertaken just 1 month after implementation, the participating hospitals have already demonstrated notable progress in core ASP elements, including the assignment of dedicated personnel, establishment of ASP committees, and development of institutional guidelines. These findings suggest that the pilot initiated a transition from fragmented, individual-led activities to more structured, system-wide programmes, although the sustainability of these early changes remains to be determined. By documenting these early institutional changes, this study established a baseline against which the future trajectory of ASP implementation in the ROK can be assessed.

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In this study, marked differences emerged between participating and non-participating hospitals. Institutions joining the pilot programme, predominantly large tertiary or teaching hospitals in metropolitan areas, were able to rapidly consolidate ASP frameworks by building upon existing ID specialists and clinical pharmacists. In contrast, the non-participating hospitals were mostly smaller, non-teaching, regionally located institutions with fewer resources and lower baseline indicators. In some domains, their scores fell below those reported in the 2020 national survey of hospitals with ≥ 300 beds.[12] This likely reflects a selection effect whereby intermediate hospitals with moderate resources and capabilities preferentially joined the pilot programme, leaving the most structurally under-resourced institutions among the non-participants.[5,16] A similar stratification has been documented internationally, where early ASP expansion is concentrated in well-resourced centres, and under-resourced hospitals lag behind.[4,16]

Collectively, our results highlight both the achievements and challenges of the pilot scheme. The most immediate benefit was the establishment of core ASP elements in participating hospitals, confirming that financial and regulatory incentives can drive the rapid adoption of essential ASP components. Importantly, these findings primarily reflect early structural and organisational changes rather than downstream clinical or microbiological outcomes. Simultaneously, the persistence of wide disparities underscores the fact that this survey captures the initial institutional landscape rather than programme outcomes. Future follow-up surveys will be crucial to determine whether these early gaps narrow over time and whether targeted measures can extend the ASP capacity to smaller resource-limited institutions. Furthermore, such longitudinal studies will determine the impact of the Korean ASP pilot program on clinical and microbiological outcomes.

Several implications have emerged from a policy perspective. The documented improvements in participating institutions demonstrate that reimbursement and formalised requirements can rapidly strengthen core elements such as leadership commitment, accountability, and guideline-based practices.[5,13] However, the risk of reinforcing a "rich-get-richer" dynamic remains, whereby large, resource-rich hospitals continue to advance, while smaller institutions fall further behind. International experience supports this concern. In the United States, Australia, and Europe, ASP adoption was initially concentrated in major centres, prompting recommendations for targeted support to smaller hospitals.[16-18] Similarly, the World Health Organization has highlighted the need for tailored capacity-building strategies in hospitals with limited infrastructure, particularly in low- and middle-income countries.[19] Practical approaches may include the provision of standardised toolkits and training modules to guide implementation and the use of information technology platforms or tele-stewardship models that enable remote support from larger centres.[20,21]

Several strategic directions have emerged from these findings. First, smaller, non-teaching, and provincial hospitals require targeted support, including financial incentives, dedicated personnel, education, and access to IT resources such as clinical decision support systems. Second, network-based approaches, such as hub-and-spoke collaborations, regional tele-ASP programmes, or stewardship consultative networks, may extend expertise from tertiary centres to resource-limited hospitals.[22] Third, long-term care hospitals warrant particular attention, as tailored interventions, including education, guideline dissemination, and feedback, have demonstrated effectiveness in improving prescriptions.[14,20,23] Ultimately, to enable these strategies to take root and evolve, consolidation of the pilot reimbursement scheme into a sustained nationwide programme is essential, ensuring long-term stability and providing a structural foundation for equitable ASP expansion.

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This study has several limitations that warrant careful consideration. Most critically, the survey was undertaken at the outset of the pilot programme and should therefore be interpreted as capturing initial organisational responses rather than meaningful programmatic outcomes. This short timeframe raises questions about the sustainability and depth of reported changes, as hospitals may have implemented superficial structural modifications without the corresponding changes in clinical practice. Self-reported data may also overstate the actual implementation, particularly given the recent introduction of financial incentives tied to programme participation. In addition, the response rate was moderate (51.5%), and participating hospitals were more likely to be large, tertiary, and metropolitan institutions, which may limit the generalisability of the findings to smaller or rural hospitals. This potential selection bias should be considered when interpreting the results. Nevertheless, using the same methodology as the 2020 survey enhances comparability, and the nationwide inclusion of both participating and non-participating hospitals strengthens the representativeness of the findings.

When interpreted within these contextual limitations, the findings nonetheless offer important insights into the programme's early impact and the structural challenges ahead. The Korean ASP pilot programme has yielded tangible improvements in the ASP infrastructure among participating hospitals, even within the first month. Concurrently, substantial disparities persist, reflecting longstanding structural inequalities. These baseline findings should inform the refinement of the national ASP policy, sustaining gains in resource-rich institutions, while prioritising tailored support for under-resourced hospitals. By addressing these disparities, the ROK can ensure equitable ASP implementation and strengthen its national capacity to combat AMR.

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SUPPLEMENTARY MATERIALS

Supplementary Data 1
Supplementary Methods

Supplementary Table 1
Characteristics of study hospitals: 2020 vs 2024

Supplementary Table 2
Comparison of antimicrobial stewardship programme implementation and monitoring: 2020 vs 2024

Supplementary Table 3
Reasons for not participating in the ASP (N = 82)

Supplementary Table 4

Resources for antimicrobial stewardship program by number of hospital beds (≥ 900 vs < 900)

Supplementary Table 5

Roles of pharmacists and nurses in antimicrobial stewardship programmes in Korean hospitals

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