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Original Article

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Development of a Roadmap for the Antimicrobial Usage Monitoring System for Medical Institutions in Korea: a Delphi Study

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ABSTRACT

Background: It is necessary to develop a roadmap for antimicrobial usage monitoring in order to perform monitoring of antimicrobial use at the national level properly. Therefore, this study aimed to develop a roadmap for establishing surveillance and monitoring of antimicrobial use in medical institutions at the national level.
Materials and Methods: A modified Delphi study was conducted, including 3 rounds of an online survey and a virtual meeting with 16 expert panels. The survey items were developed based on a literature review of the surveillance systems for antimicrobial use in 12 countries and interviews with experts. The questionnaire was designed to include both the surveillance and benchmarking systems.
Results: Regarding the scope of target institutions to be included in the surveillance system, medical institutions for sentinel surveillance had the highest proportion of agreement among the panels (75.0%, 9/12). For the benchmarking system, "tertiary- and secondary-care hospitals" were accepted as the scope of target institutions at the current moment. Furthermore, the National Health Insurance claims and prescription data of individual hospitals were considered appropriate data sources for the surveillance system. As for the measures to promote the participation of hospitals in the benchmarking system, "compensation through the establishment of antimicrobial management fees" and "set the participation in the program as a quality evaluation or accreditation index for hospital evaluation" were accepted.

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Conflict of Interest

HBK is editorial board of Infect Chemother; however, he did not involve in the peer reviewer selection, evaluation, and decision process of this article. Otherwise, no potential conflicts of interest relevant to this article was reported.

Author Contributions

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Conclusion: This study provides a roadmap for establishing an antimicrobial use monitoring and benchmarking system for medical institutions at a national level in Korea.

Keywords: Antimicrobial use; Monitoring; Benchmarking; Antimicrobial stewardship; Korea

INTRODUCTION

Antimicrobial resistance (AMR) is a major threat to public health globally. According to a review of AMR reports from the United Kingdom (UK), without effective policies to stop the spread of AMR, the current annual 700,000 deaths caused by infection with antimicrobial-resistant pathogens will increase to 10 million every year by 2050 [1]. However, the development of new antimicrobial drugs took a long time and showed lower success rates in the last decade compared with that of the previous era. The number of new antimicrobial drugs approved by the United States (US) Food and Drug Administration was ≥40% decline compared with that of the 1980s [2]. The lack of effective antibiotics that can treat infections caused by antimicrobial-resistant bacteria leads to higher mortality, longer hospital stay, and higher medical costs [3, 4].

One of the major strategies for combating the problems caused by AMR is the antimicrobial stewardship program (ASP). It is well known that ASP has an effect in reducing the incidence of infections and colonization due to antimicrobial-resistant pathogens as well as reducing *Clostridioides difficile* infections in hospitalized patients and adverse effects of antimicrobial use [5]. To carry out ASP effectively, tracking the current status of antimicrobial use in individual medical institutions and finding out the areas to be improved is recommended [5]. Monitoring allows the pattern of antimicrobial use and resistant bacteria to be analyzed, and changes can be detected early. Intervention can be performed and evaluated if there is a problem [6]. For this purpose, some developed countries, such as the US, UK, and Australia, are operating surveillance systems to analyze and report antimicrobial use [7-9].

Like other developed countries, the Korea National Antimicrobial Use Analysis System (KONAS), a national antimicrobial monitoring and benchmarking system, was developed in Korea and launched in 2021 [10]. KONAS provides not only in-depth analysis results of antimicrobial use within each hospital, but also the antimicrobial use of other hospitals for benchmarking [10]. Besides the development of a monitoring tool, it is necessary to develop a roadmap for antimicrobial usage monitoring to properly monitor antimicrobial use at the national level. This study aimed to develop a roadmap for establishing surveillance and monitoring of antimicrobial use in medical institutions at the national level.

MATERIALS AND METHODS

1. Overview and Assembly of panel

A modified Delphi study, including 3 rounds of an online survey and a virtual meeting with expert panels, was performed from July to October 2021. The expert panel consisted of 4 infectious disease physicians from the academic community, 5 experts who led the surveillance system for infectious diseases in Korea, 4 medical personnel who participated in ASP in hospitals, and 3 experts on policy on AMR who represent the government. All expert panel members consented to participate in the study and were aware that their answers would be used for research.

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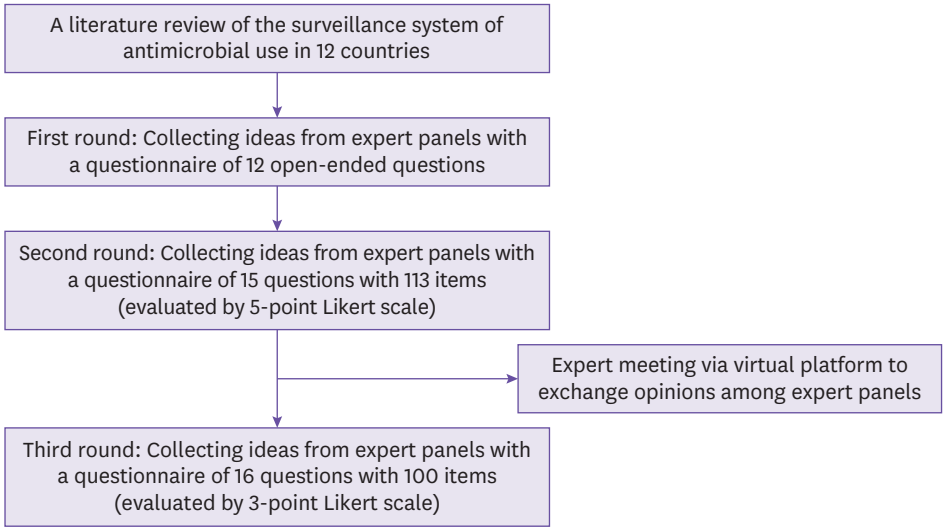

Figure 1. Flow diagram showing the study process.

2. Ethics statement

The study protocol was approved by the institutional review board (IRB) of Hanyang University Seoul Hospital (IRB number:2021-06-042). The requirement for written informed consent from the participants was waived.

3. Development of survey items and the process of Delphi method

The study process was summarized in **Figure 1**. The questionnaire for each survey was sent to the expert panel members via e-mail, and the responses were collected for 2 weeks. A reminder was sent on the 7th day of each survey to encourage participation. The survey items were developed based on a literature review of the surveillance system of antimicrobial use in 12 countries (**Supplementary Table 1**) and interviews with experts on ASP in hospitals. According to the literature review, most countries have established surveillance systems to understand the status of antimicrobial use in nationwide medical institutions. In addition, some developed countries have operated benchmarking systems for understanding antimicrobial use in individual institutions along with the surveillance system. Given that the KONAS benchmarking system has already been established in Korea, the questionnaire was designed to include both the surveillance and benchmarking systems.

The first round of the survey was conducted to collect ideas from expert panels. A questionnaire consisting of open-ended questions and a summary of the literature review was sent to expert panels via e-mail. The questionnaire for the second survey was developed based on the responses of the expert panels of the first survey. The opinions of expert panels on each item were evaluated using a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree), and 4 and 5 were considered as "agree." In addition, expert panels could leave their opinions on each question. A virtual meeting was held between the second and third surveys, and all panel members were invited to participate. The agenda of the meeting was to exchange opinions on the items of the questionnaire used in the second survey. A report with the results of the second survey was sent to all participants before the meeting. The questionnaire used in the second survey was refined by considering the discussion in the virtual meeting and was used for the third round of the survey. In the third round, the opinion of expert panels on each item was evaluated using a 3-point Likert scale (1 = disagree, 2 = neutral, and 3 = agree), and 3 was considered as "agree."

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4. Validation of items

To analyze the responses provided in the second and third surveys and to select items that reached agreement among expert panels, content validity ratios (CVRs) were calculated. We used the formula CVR = (n_e -N/2)/ (N/2), where n_e represents the number of panel experts rating an item as "agree," and N represents the total number of panelists. The minimum CVR was determined by the number of experts participating in each round (0.62 for 10 participants, 0.59 for 11 participants, and 0.56 for 12 participants) [11].

RESULTS

The response rates for the first and second rounds were 68.8% (11/16) and 75.0% (12/16), respectively. Nine expert panels (56.3%) participated in virtual meetings. In the discussion of the virtual meeting, expert panels found that the "scope of target institutions to be included in the monitoring system" and "data source" influenced other items. Therefore, in the third round of the survey, these 2 items were investigated first and the rest items were investigated after finishing the collection of the responses to the first 2 items. Twelve expert panels (75.0%) submitted their opinions to the survey for the first 2 items, while 11 expert panels (62.5%) responded to the survey for the remaining items. One panel did not complete the survey and answered partially; therefore, we applied different CVR standards for each item.

1. Scope of target institutions and data source

Table 1 presents the results for the scope of the target institutions and data sources. As for the scope of target institutions to be included in the surveillance system, even though medical institutions for sentinel surveillance had the highest proportion of agreement among panels (75.0%, 9/12), no item reached an agreement. For the benchmarking system, "tertiary- and secondary-care hospitals" were accepted as the scope of target institutions at the current moment; "primary- and long-term care hospitals" was accepted as the scope of target institution after 5 - 10 years. The National Health Insurance (NHI) claims and prescription data of individual hospitals were considered appropriate data sources for the surveillance system.

2. Details of the surveillance system and benchmarking system

Table 2 shows the details of the surveillance system used to understand the status of antimicrobial use in nationwide medical institutions. Expert panels could not reach an agreement on the range of antibiotics that can be included at the current moment; however, they agreed that "some classes of antifungal agents" should be included. In addition, they agreed that "all antibacterial agents" should be monitored after 5 - 10 years. Both methods used by the international organizations (WHO AWaRe classification) and the discussion of the public-private expert council were accepted as appropriate methods for selecting key antimicrobials.

Table 3 shows the details of the benchmarking system used to understand antimicrobial use in individual institutions. Expert panels could not reach an agreement on the range of antimicrobials that can be included at the current moment; however, they agreed that "all antibacterial agents" should be monitored after 5 - 10 years. As for the method for external benchmarking, "comparative analysis of antimicrobial use among hospitals with the same type" and "analysis of antimicrobial use at the hospital level using standardized indicators (*e.g.*, standardized antimicrobial administration ratio) were accepted. In addition, "comparative analysis of antimicrobial use by time," "comparative analysis of antimicrobial use by clinical departments," and "analysis of antimicrobial use at the hospital level using

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Table 1. Scope of target institutions and data source to be used for the antimicrobial usage monitoring system

Items	Agree (%)	Disagree (%)	Neutral (%)	CVR
Q1. Scope of target institutions to be included in the surveillance system for understanding the status of antimicrobial use of the nationwide medical institutions				
All medical institutions	8 (66.7)	4 (33.3)	0 (0.0)	0.333
Certain types of medical institutions of the medical delivery system	8 (66.7)	2 (16.7)	2 (16.7)	0.333
Medical institutions for the sentinel surveillance	9 (75.0)	3 (25.0)	0 (0.0)	0.5
Q2. Scope of target institutions to be included in the benchmarking system for the understanding of antimicrobial use in individual institutions (at the current moment)				
Tertiary-care hospitals[a]	12 (100.0)	0 (0.0)	0 (0.0)	1
Secondary-care hospitals[a]	11 (91.7)	1 (8.3)	0 (0.0)	0.833
Primary-care hospitals and long-term care hospitals	3 (25.0)	7 (58.3)	2 (16.7)	-0.5
Clinics	2 (16.7)	8 (66.7)	2 (16.7)	-0.667
Q3. Scope of target institutions to be included in the benchmarking system for the understanding of antimicrobial use in individual institutions (after 5 - 10 years)				
Tertiary-care hospitals[a]	12 (100.0)	0 (0.0)	0 (0.0)	1
Secondary-care hospitals[a]	12 (100.0)	0 (0.0)	0 (0.0)	1
Primary-care hospitals and long-term care hospitals[a]	11 (91.7)	0 (0.0)	1 (8.3)	0.833
Clinics	8 (66.7)	3 (25.0)	1 (8.3)	0.333
Q4. The data source for the surveillance system for understanding the status of antimicrobial use of the nationwide medical institutions				
National Health Insurance claims data[a]	11 (91.7)	0 (0.0)	1 (8.3)	0.833
Prescription data of individual hospitals[a]	10 (83.3)	1 (8.3)	1 (8.3)	0.667
Pharmaceutical wholesaler data	2 (16.7)	6 (50.0)	4 (33.3)	-0.667
Q5. Institutions that can apply the benchmarking system for the understanding of antimicrobial use in individual institutions using National Health Insurance claims data				
Tertiary-care hospitals[a]	10 (83.3)	2 (16.7)	0 (0.0)	0.667
Secondary-care hospitals[a]	10 (83.3)	2 (16.7)	0 (0.0)	0.667
Primary-care hospitals and long-term care hospitals	9 (75.0)	3 (25.0)	0 (0.0)	0.5
Clinics	9 (75.0)	3 (25.0)	0 (0.0)	0.5
Q6. Institutions that can apply the benchmarking system for the understanding of antimicrobial use in individual institutions using prescription data of individual hospitals				
Tertiary-care hospitals[a]	12 (100.0)	0 (0.0)	0 (0.0)	1
Secondary-care hospitals[a]	12 (100.0)	0 (0.0)	0 (0.0)	1
Primary-care hospitals and long-term care hospitals	9 (75.0)	3 (25.0)	0 (0.0)	0.5
Clinics	9 (75.0)	3 (25.0)	0 (0.0)	0.5

[a]Items that reached agreement among expert panels.
CVR, content validity ratio; WHO, World Health Organization.

standardized indicators (*e.g.*, standardized antimicrobial administration ratio)" were accepted as methods for internal benchmarking. No item reached an agreement among the time points of feedback for the result of the benchmarking; however, only 1 panel (10.0%, 1/10) agreed that the feedback could be sent after 12 months of the actual antimicrobial prescription.

3. Operation of the antimicrobial usage monitoring system

Table 4 presents the survey results regarding the operation of the antimicrobial usage monitoring system. Expert panels agreed that "the academic community or expert group" or "Korea Disease Control and Prevention Agency (KDCA) or its affiliated antimicrobial resistance management unit" are appropriate participants to operate the system at the current moment, and "KDCA or its affiliated antimicrobial resistance management unit" is the appropriate participant after 5–10 years. As for the measures to promote the participation of hospitals in the benchmarking system, "compensation through the establishment of antimicrobial management fees" and participation in the program as a quality evaluation index or accreditation index for hospital evaluation were accepted.

DISCUSSION

Antimicrobial usage surveillance and monitoring could contribute favorably to initiatives to reduce antimicrobial consumption; thus, it is included as a key component of ASP and emphasized as a key strategy in the National Action Plan on Antimicrobial Resistance in

Table 2. The surveillance system for understanding the status of antimicrobial use of the nationwide medical institutions

Items	Agree (%)	Disagree (%)	Neutral (%)	CVR
Q1. The range of antimicrobial agents that can be included in the surveillance system (at the current moment)				
Some classes of antibacterial agents	7 (63.6)	1 (9.1)	3 (27.3)	0.273
All antibacterial agents	4 (36.4)	5 (45.5)	2 (18.2)	-0.273
Some classes of antifungal agents[a]	9 (81.8)	1 (9.1)	1 (9.1)	0.636
All antifungal agents	1 (9.1)	8 (72.7)	2 (18.2)	-0.818
Antiviral agents	1 (9.1)	8 (72.7)	2 (18.2)	-0.818
Q2. The range of antimicrobial agents that can be included in the surveillance system (after 5 - 10 years)				
Some classes of antibacterial agents	6 (54.6)	3 (27.3)	2 (18.2)	0.091
All antibacterial agents[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
Some classes of antifungal agents	7 (63.6)	1 (9.1)	3 (27.3)	0.273
All antifungal agents	6 (54.6)	4 (36.4)	1 (9.1)	0.091
Antiviral agents	4 (36.4)	3 (27.3)	4 (36.4)	-0.273
Q3. Specific methods of analyzing antimicrobial usage				
By antimicrobial classification (category, WHO AWaRe classification, etc.)[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
By administration route[a]	10 (90.9)	0 (0.0)	1 (9.1)	0.818
By the time (quarterly, monthly, yearly, etc.)[a]	10 (90.9)	0 (0.0)	1 (9.1)	0.818
By hospital characteristics (bed size, hospital type)[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
By region	2 (18.2)	5 (45.5)	4 (36.4)	-0.636
By demographic characteristics (sex, age, etc.)	8 (72.7)	1 (9.1)	2 (18.2)	0.455
By clinical departments	6 (54.6)	3 (27.3)	2 (18.2)	0.091
By wards (intensive care unit, general wards, etc.)	8 (72.7)	2 (18.2)	1 (9.1)	0.455
By infectious disease	8 (72.7)	1 (9.1)	2 (18.2)	0.455
Q4. Method of selecting key antimicrobials				
Adopting methods used by international organizations (WHO AWaRe classification, etc.)[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
According to the discussion of the public-private expert council[a]	9 (81.8)	0 (0.0)	2 (18.2)	0.636
Q5. Indicators to be analyzed in addition to antimicrobial use for a more accurate interpretation				
Characteristics of institutions included in the system (number of beds, number of patients, etc.)[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
The proportion of antimicrobial-resistant pathogens isolated from institutions included in the system[a]	10 (91.9)	0 (0.0)	1 (9.1)	0.818
The number of surgery/procedures performed in institutions included in the system	6 (54.6)	3 (27.3)	2 (18.2)	0.091
Demographic characteristics of patients who visited/admitted to institutions included in the system[a]	9 (81.8)	1 (9.1)	1 (9.1)	0.636
The diagnosis codes of patients who visited/admitted to institutions included in the system	6 (54.6)	2 (18.2)	3 (27.3)	0.091
The proportion of patients with severe diseases among patients who visited/admitted to institutions included in the system	6 (54.6)	2 (18.2)	3 (27.3)	0.091

[a]Items that reached agreement among expert panels.
CVR, content validity ratio.

Korea [12, 13]. The present study's results will greatly help implement a robust surveillance and monitoring system for antimicrobial use at the national level, along with KONAS.

The present study shows that both NHI claims and prescription data from individual hospitals were considered appropriate data sources for the surveillance system. The data source of the national surveillance system should be selected considering data accuracy and ease of collection. In Korea, the NHI system covers almost the entire population, including low-income families with medical aid, and can provide standardized data. Several studies about national antimicrobial use were conducted using NHI claims data [14, 15]. However, even though the NHI claims data are relatively easy to collect, inaccurate results are likely to be drawn because the data only include components associated with reimbursement of claims [16]. On the contrary, prescription data of individual hospitals can reflect the actual prescription status in the hospital; however, it is hard to collect because the electronic health record system in each hospital differs. Collecting data in non-teaching community hospitals seems especially hard due to the lack of infrastructure and workforce [17]. Considering the benefits and shortcomings, the NHI claim data could be preferably used for operating the surveillance system for understanding the status of antimicrobial use of the national medical institution in "medical institutions for the sentinel surveillance". To compensate for the shortcomings of NHI claims data, collecting prescription data of individual hospitals, especially in tertiary and

Table 3. The benchmarking system for the understanding of antimicrobial use in individual institutions

Items	Agree (%)	Disagree (%)	Neutral (%)	CVR
Q1. The range of antimicrobial agents that can be included in the benchmarking system (at the current moment)				
Some classes of antibacterial agents	7 (70.0)	1 (10.0)	2 (20.0)	0.4
All antibacterial agents	5 (50.0)	5 (50.0)	0 (0.0)	0
Some classes of antifungal agents	8 (80.0)	0 (0.0)	2 (20.0)	0.6
All antifungal agents	1 (10.0)	8 (80.0)	1 (10.0)	-0.8
Antiviral agents	1 (10.0)	6 (60.0)	3 (30.0)	-0.8
Q2. The range of antimicrobial agents that can be included in the benchmarking system (after 5 - 10 years)				
Some classes of antibacterial agents	6 (60.0)	1 (10.0)	3 (30.0)	0.2
All antibacterial agents[a]	10 (100)	0 (0.0)	0 (0.0)	1
Some classes of antifungal agents	7 (70.0)	1 (10.0)	2 (20.0)	0.4
All antifungal agents	7 (70.0)	2 (20.0)	1 (10.0)	0.4
Antiviral agents	4 (40.0)	3 (30.0)	3 (30.0)	-0.2
Q3. Method for external benchmarking (comparison with external institutions)				
Comparative analysis of antimicrobial use among hospitals with the similar bed size	7 (70.0)	2 (20.0)	1 (10.0)	0.4
Comparative analysis of antimicrobial use among hospitals with the same type[a]	9 (90.0)	1 (10.0)	0 (0.0)	0.8
Comparative analysis of antimicrobial use among hospitals with the same region	2 (20.0)	5 (50.0)	3 (30.0)	-0.6
Comparative analysis of antimicrobial use among hospitals with a similar number of infectious diseases specialists	5 (50.0)	3 (30.0)	2 (20.0)	0
Analysis of antimicrobial use at the hospital level using standardized indicators (*e.g.*, Standardized Antimicrobial Administration Ratio)[a]	10 (100.0)	0 (0.0)	0 (0.0)	1
Q4. Method for internal benchmarking (comparison within an institution)				
Comparative analysis of antimicrobial use by time (quarterly, monthly, yearly, etc.)[a]	9 (90.0)	0 (0.0)	1 (10.0)	0.8
Comparative analysis of antimicrobial use by clinical departments[a]	9 (90.0)	1 (10.0)	0 (0.0)	0.8
Comparative analysis of antimicrobial use by wards (intensive care unit, general wards, etc.)	6 (60.0)	2 (20.0)	2 (20.0)	0.2
Comparative analysis of antimicrobial use by physicians	6 (60.0)	2 (20.0)	2 (20.0)	0.2
Analysis of antimicrobial use at a certain level within the hospital using standardized indicators (*e.g.*, Standardized Antimicrobial Administration Ratio)[a]	9 (90.0)	0 (0.0)	1 (10.0)	0.8
Comparative analysis of antimicrobial use by characteristics of patients	8 (80.0)	0 (0.0)	2 (20.0)	0.6
Comparative analysis of antimicrobial use by infectious diseases	7 (70.0)	1 (10.0)	2 (20.0)	0.4
Q5. The time point of feedback for the result of the benchmarking				
Within 3 months of the actual antimicrobial prescription	7 (70.0)	2 (20.0)	1 (10.0)	0.4
Within 6 months of the actual antimicrobial prescription	7 (70.0)	1 (10.0)	2 (20.0)	0.4
Within 12 months of the actual antimicrobial prescription	5 (50.0)	4 (40.0)	1 (10.0)	0
After 12 months of the actual antimicrobial prescription	1 (10.0)	9 (90.0)	0	-0.8
Q6. Selection of participating hospitals				
Mandating to participate in all institutions belonging to the target type of hospitals	5 (50.0)	3 (30.0)	2 (20.0)	0
Mandating to participate in sentinel institutions belonging to the target type of hospitals	5 (50.0)	2 (20.0)	3 (30.0)	0
Voluntarily participation in institutions belonging to the target type of hospitals	6 (60.0)	2 (20.0)	2 (20.0)	0.2

[a]Items that reached agreement among expert panels.
CVR, content validity ratio.

secondary care hospitals, for operating the benchmarking system to understand antimicrobial use in individual institutions should be considered. From this perspective, it would be desirable to establish a standardized electronic database system that can analyze and monitor the use of antimicrobials using hospital prescription data, such as the National Healthcare Safety Network-Antimicrobial Use module of the Center for Disease and Control and Prevention (CDC), which provides a mechanism for facilities to report and analyze antimicrobial use [7].

According to the results of this study, it would be desirable to implement a benchmarking system in tertiary- and secondary-care hospitals first, then expand to "primary- and long-term care hospitals" after 5 - 10 years. As for measures to promote the participation of hospitals in the benchmarking system, both carrots (financial incentives) and sticks (quality evaluation) seem to be required. Several developed countries have been providing financial incentives and performing accreditation evaluations for antimicrobial usage monitoring and ASP to promote the participation of hospitals [18-22]. The Japanese medical reimbursement system introduced a fee for the implementation of ASP, which compensates physicians for

Table 4. The operation of the antimicrobial usage monitoring system

Items	Agree (%)	Disagree (%)	Neutral (%)	CVR
Q1. An appropriate subject to operate the system (at the current moment)				
The academic community or expert group[a]	9 (81.8)	1 (9.1)	1 (9.1)	0.636
Korea Disease Control and Prevention Agency or its affiliated antimicrobial resistance management unit[a]	10 (90.9)	0 (0.0)	1 (9.1)	0.818
Health Insurance Review & Assessment Service or its affiliated antimicrobial resistance management unit	3 (27.3)	8 (72.7)	0 (0.0)	-0.455
Other national agencies or its affiliated antimicrobial resistance management unit	2 (18.2)	3 (27.3)	6 (54.6)	-0.636
Q2. An appropriate subject to operate the system (after 5 - 10 years)				
The academic community or expert group	3 (27.3)	5 (45.5)	3 (27.3)	-0.455
Korea Disease Control and Prevention Agency or its affiliated antimicrobial resistance management unit[a]	11 (100)	0 (0.0)	0 (0.0)	1
Health Insurance Review & Assessment Service or its affiliated antimicrobial resistance management unit	2 (18.2)	9 (81.8)	0 (0.0)	-0.636
Other national agencies or its affiliated antimicrobial resistance management unit	4 (36.4)	3 (27.3)	4 (36.4)	-0.273
Q3. Measures to promote participation of hospitals in the benchmarking system for the understanding of antimicrobial use				
Compensation through the establishment of antimicrobial management fees[a]	10 (100.0)	0 (0.0)	0 (0.0)	1
Set the participation in the program as a quality evaluation index or accreditation index for hospital evaluation[a]	9 (90.0)	0 (0.0)	1 (10.0)	0.8
Mandating the participation in the system as a regulation	4 (40.0)	2 (20.0)	4 (40.0)	-0.2
Q4. Linkage between the surveillance system of antimicrobial use and antimicrobial management activities/policies				
Performing periodically analysis of the surveillance results and discuss countermeasures at the public-private expert committee[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
Establishment as an indicator of antimicrobial resistance management measures reflecting the significant results found in the surveillance system[a]	11 (100.0)	0 (0.0)	0 (0.0)	1
Qualitative evaluation and identifying specific problems in antimicrobial use when outlier results are found	6 (54.6)	2 (18.2)	3 (27.3)	0.091
Promote the system and surveillance results to the public	6 (54.6)	1 (9.1)	4 (36.4)	0.091
Q5. Linkage between the antimicrobial usage monitoring system and the surveillance system of antimicrobial resistance				
The same governmental department operates both systems	9 (81.8)	0 (0.0)	2 (18.2)	0.636
Integrating web pages of both systems	10 (90.9)	0 (0.0)	1 (9.1)	0.818
Issuing periodical report about antimicrobial use and resistance	11 (100.0)	0 (0.0)	0 (0.0)	1
Select indicator antimicrobials that correlate with major antimicrobial resistance	9 (81.8)	1 (9.1)	1 (9.1)	0.818

[a]Items that reached agreement among expert panels.
CVR, content validity ratio.

the ASP activities, encourages physicians to participate in ASP, and results in a significant reduction of unnecessary antibiotic prescriptions [20]. Likewise, the financial incentives for reductions in broad-spectrum antibiotic prescriptions in primary care offered by the UK Quality Premium program promoted the participation of clinics in ASP and resulted in an immediate reduction in the total broad-spectrum antibiotic prescribing rate as well as an antimicrobial resistance rate against broad-spectrum antibiotics [19]. In the US, successful implementation of ASP in each hospital was achieved through setting ASP as a requirement of accreditation of hospitals by The Joint Commission and tying antibiotic use metrics of the CDC to reimbursement policy by the Centers for Medicare and Medicaid Services [18, 21, 22].

The "KDCA or its affiliated antimicrobial resistance management unit" was considered the appropriate participant to operate the antimicrobial usage monitoring system in Korea in the future. There are some benefits to operating a nationwide monitoring system by government-affiliated organizations. First, the results of antimicrobial usage monitoring can be directly linked to the national ASP policies. To facilitate this, the monitoring results can be reviewed and discussed by the public-private expert committee and included in governmental policies. Second, recruiting a wide range of institutions for the benchmarking system would be beneficial. Given that Korea has a single-payer health insurance program operated by a government-affiliated organization, medical institutions in Korea are greatly influenced by the national policy [23]. Indeed, the government agency could provide carrots (financial incentives) and sticks (quality evaluation) to each medical institution in order to recruit to the system.

As with other Delphi processes, this study has some limitations. First, the depth of knowledge regarding antimicrobial use monitoring systems might differ among expert panels. To

minimize this, we offered a summary of the literature review of the surveillance systems of antimicrobial use in 12 countries to the panels before the start of the surveys. Although discrepancies in the understanding level may exist, it is necessary to listen to and coordinate the opinions of various stakeholders. Second, definitive guidance for each question of the survey was not offered; therefore, some panels might have misunderstood some questions. Notwithstanding, the results of our study are meaningful in providing direction for developing a national antimicrobial use monitoring and benchmarking system in Korea.

In conclusion, this study provides a roadmap for establishing an antimicrobial monitoring and benchmarking system for medical institutions at the national level in Korea. The system should be well established using this roadmap, and a more effective ASP at the national level should be realized.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1

References for literature review of the surveillance system of antimicrobial use in 12 countries

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