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Major Article

Current status of personnel and infrastructure resources for infection prevention and control programs in the Republic of Korea: A national survey

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Background: There is significant variability in personnel and infrastructural resources for infection prevention and control (IPC) among health care institutions. The aim of this study is to evaluate the current status of individual hospital-based IPC programs in the Republic of Korea (ROK).

Methods: A multicenter cross-sectional survey of 100 hospitals participating in the national surveillance programs for multidrug-resistant organisms (MDROs) in the ROK was conducted in September 2015. The survey consisted of 140 standardized Web-based questionnaires.

Results: The survey response rate was 41.0%. The responding hospitals are largely organized with multibed rooms, with an insufficient numbers of single rooms. Employment status of infection specialists and hand hygiene resources were better in larger hospitals. The responding hospitals had 1 full-time infection control nurse per 400.3 ± 154.1 beds, with wide variations in training and experience. Facilities have great diversity in their approach to preventing MDROs. There appeared to be no difference in supplies consumption and protocols for IPC among the hospitals, stratified according to size.

Conclusions: A greater availability of specialist personnel, single rooms, and a comprehensive IPC program, with the support of a policy-oriented management, is necessary to achieve effective IPC.

Following the findings of the Study on the Efficacy of Nosocomial Infection Control (SENIC Project), many countries defined the duties of hospitals for infection prevention and control and implemented legislation regulating the periodic accreditation of the quality of medical care.[1-3] In the Republic of Korea (ROK), a full-time infection control nurse (ICN) and an infection control physician (ICP) were appointed in 1991, for the first time, at a national university-affiliated hospital.

Since 2010, it is a legal requirement in the ROK to report infections caused by 6 types of multidrug-resistant organisms (MDROs) to a national sentinel surveillance program: vancomycin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus* (VRE), methicillin-resistant *S aureus* (MRSA), multidrug-resistant *Pseudomonas aeruginosa* (MRPA), multidrug-resistant *Acinetobacter baumannii* (MRAB), and carbapenem-resistant *Enterobacteriaceae* (CRE). Since 2011, many hospitals have obtained Joint Commission International accreditation, considered the gold standard certification in global health care. Since the revision of the Regulation of Medical Service Act in 2012, hospitals with >200 beds have been required to appoint an infection control committee and at least 1 full-time experienced staff member to oversee an infection control program.[4] Over the last 25 years, legislation and accreditation procedures have strongly influenced infection prevention and control

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programs.[5] However, there is scarce information on the details of the current status of infection prevention and control programs in acute care hospitals in the ROK.

The purpose of this study is to examine hospitals participating in the national surveillance programs for MDROs to evaluate personnel, structure resources, and strategies associated with infection prevention and control in the ROK.

METHODS

Study design and participants

A multicenter cross-sectional survey was conducted in the ROK in September 2015. Blueprints for this study were drafted on the basis of the SENIC Project design, originally developed by the Centers for Disease Control and Prevention in the United States in the 1970s.[6] Basic information of the 100 hospitals participating in the national surveillance programs for MDROs was obtained from the Korean Association of Infection Control Nurses. To protect the confidentiality of hospitals, researchers compiled a list of the 100 hospitals and directly e-mailed the directors of each infection control unit, inviting them to respond to the Web-based survey. To increase survey response rates, repeat contact by weekly e-mail was made over 4 weeks. Only 1 person in each institution participated in the survey. The study protocol was approved by the institutional review boards prior to starting the study, and the requirement for informed consent was waived (AN15359-001).

Questionnaire

A modified survey form was developed on the basis of the questionnaire used in the SENIC Project.[7] The survey consisted of 140 standardized Web-based questionnaires. There were 3 sections: (1) infrastructure, equipment facilities, and accreditation for infection control programs; (2) human resources, including staff numbers, infection control training, employment status and work experience of ICNs, ICPs, and other support personnel; and (3) detailed practices of infection control activities for MDROs, such as antibiotic stewardship, collection, and analysis of data on the incidence of infections, staff training on infection prevention and control policies and procedures, daily isolation and cohort practices, conference organization and development of policies, employee health, product evaluation, emergency preparedness, and reporting of notifiable diseases.

Statistical analysis

Data were analyzed using descriptive statistics. Nominal variables were presented as the number of subjects (percentage) and analyzed using a χ^2 test. Continuous variables were expressed as mean ± SD or median (interquartile range [IQR]) and analyzed using the Mann-Whitney *U* test or Student *t* test, as appropriate. Analysis of variance and χ^2 tests were used to identify differences between the infection prevention and control programs according to hospital size, determined by the total number of beds. All tests were 2-tailed, and a *P* value <.05 was considered statistically significant. Analyses were performed with SPSS Statistics version 20.0 (IBM, Armonk, NY) and SAS 9.2 (SAS Institute, Cary, NC).

RESULTS

The survey response rate was 41.0%, with 41 hospitals divided into categories according to bed size: 200-499 beds (n = 7), 500-699 beds (n = 9), 700-899 beds (n = 17), and ≥900 beds (n = 8). Most of the hospitals were located in the metropolitan area (n = 29, 70.7%). All hospitals were teaching institutions. Univariate analysis found no significant difference in the number of beds ($P > .999$) and the ratio of the number of beds to infection control personnel ($P = .943$) between respondents and nonrespondents.

Infrastructure

The median year in which participating hospitals were founded was 1983 (IQR, 1971-1997). The number of hospital beds ranged from 319-2,471, with a median number of beds of 768 (IQR, 581-871). The median number of intensive care unit (ICU) beds was 44 (IQR, 30-57), and the median proportion of ICU beds to total beds was 5.8% (IQR, 5.1-6.5). The median number of single rooms and cohort rooms for patient isolation was 5 (IQR, 2-8) and 5 (IQR, 3-8), respectively. The median ratio of beds to sink was 2.2 (IQR, 1.5-2.7). The median distance between beds in the ICUs was 1.5 m (IQR, 1.3-1.8).

Personnel

The average number of personnel members specializing in infection prevention and control in each hospital was 3.1 ± 1.7 (median, 3; IQR, 2-4; range, 1-10). Of these, 2.2 ± 1.5 (median, 2; IQR, 1-3; range, 1-9) were employed in a full-time position. The rest were employed on a temporary basis. The average number of full-time ICNs was 2.1 ± 1.4 (median, 2; IQR, 1-3; range, 0-8), with 1 full-time ICN per 400.3 ± 154.1 beds. On average, the ICNs had 63.5 months of experience in infection prevention and control (IQR, 28-87; range, 15-141). Of the responding hospitals, 85.4% and 80.5% employed a specialist in infectious disease and clinical microbiology, respectively. The median year in which infection control units were established was 2002 (IQR, 1996-2005; range, 1991-2008).

Infection control activities

All hospitals established written guidelines on the control of MDROs and setup a committee for infection prevention and control. All facilities have held periodic conferences on infection prevention and control. Frequency was evaluated as follows: <3 times per year (n = 12, 29.3%), 3 times per year (n = 23, 56.1%), and >3 times per year (n = 6, 14.6%). Of the responding hospitals, 97.6% monitored resistance trends of major MDROs and adapted clinical practice accordingly. Routine surveillance culture for MDROs was performed in 51.2% of facilities for the following microorganisms: MRSA (n = 10, 24.4%), VRE (n = 10, 24.4%), MRAB (n = 7, 17.1%), MRPA (n = 5, 12.2%), and CRE (n = 8, 19.5%), on the ICUs. Hospital-wide surveillance cultures were performed for MRSA (n = 4, 9.8%), VRE (n = 5, 12.2%), MRAB (n = 4, 9.8%), MRPA (n = 3, 7.3%), and CRE (n = 3, 7.3%). Contact precautions for carriers of MDROs were implemented in 95.1% of ICUs and 65.9% of hospitals. Single-room isolation was implemented in 14 hospitals (34.1%) for patients on ICUs and in only 8 facilities (19.5%) for those on general wards, respectively. On ICUs, single-room isolation was required for MRSA (n = 4, 9.8%), VRE (n = 25, 61.0%), MRAB (n = 8, 19.5%), MRPA (n = 4, 9.8%), and CRE (n = 22, 53.7%). Single-room isolation within the hospital generally was required for MRSA (n = 2, 4.9%), VRE (n = 25, 61.0%), MRAB (n = 2, 4.9%), MRPA (n = 1, 2.4%), and CRE (n = 19, 46.3%).

All hospitals had a hand hygiene monitoring program and feedback system, and 37 facilities (90.2%) implemented these on a regular basis throughout the hospital. All hospitals have organized educational sessions for staff to improve hand hygiene measures. The frequency of these sessions was either once per year (n = 34, 82.9%) or at least twice per year (n = 7, 17.1%). Staff education seminars on infection prevention and control were held annually in 22 hospitals (53.7%). Thirty-eight hospitals (92.7%) implemented an antibiotic

Table 1
General characteristics and infrastructure of infection prevention and control in the study hospitals stratified according to size

Variables	200-400 beds	500-699 beds	700-899 beds	≥900 beds	*P* value
General characteristics					
No. of hospitals	7 (17.1)	9 (22.0)	17 (41.5)	8 (19.5)	<.001
University-affiliated hospital	1 (14.3)	4 (44.4)	14 (82.4)	7 (87.5)	<.001
Location in capital area	6 (20.7)	8 (27.6)	10 (34.5)	5 (17.2)	.306
Certification by the JCI	1 (14.3)	0 (0)	3 (17.6)	2 (25.0)	.502
No. of hospital accreditations in a year	2.7 ± 0.5	2.7 ± 0.5	2.3 ± 0.8	2.4 ± 0.5	1.000
Participation in KONIS	3 (42.9)	8 (88.9)	16 (94.1)	7 (87.5)	.020
Facilities and personnel in the ICUs					
No. of beds in the ICUs	24 ± 7.5	38.9 ± 13.0	45.5 ± 11.1	81.9 ± 38.1	<.001
Proportion of ICU beds of the total (%)	6.6 ± 2.4	6.6 ± 2.3	5.6 ± 1.2	6.2 ± 1.5	.469
Distance among beds (m)	1.36 ± 0.30	1.67 ± 0.41	1.48 ± 0.49	1.83 ± 0.28	.104
No. of beds to sinks ratio	5.1 ± 4.5	2.9 ± 1.2	2.0 ± 0.6	1.6 ± 0.3	.004
Equipping a single room	7 (100)	7 (77.8)	16 (94.1)	8 (100)	.242
Nurses to bed ratio	1.5 ± 0.5	1.6 ± 0.2	1.4 ± 0.4	1.4 ± 0.8	.907
Staff characteristics					
No. of staff associated with infection control	1.7 ± 0.5	1.9 ± 0.6	2.4 ± 0.9	5.0 ± 2.5	<.001
No. of beds to specialist infection control personnel ratio	236.8 ± 94.9	352.3 ± 136.0	387.2 ± 161.6	290.7 ± 106.7	.090
Employment of infection control physician	3 (42.9)	9 (100)	15 (88.2)	8 (100)	.004
Employment of clinical microbiologist	3 (42.9)	9 (100.0)	15 (88.2)	6 (75.0)	.026
Experience of infection control nurse (mo)	40.1 ± 22.6	55.7 ± 20.8	82.0 ± 34.9	46.5 ± 28.6	.006

Values are n (%), mean ± SD, or as otherwise indicated.
ICU, intensive care unit; *JCI*, Joint Commission International; *KONIS*, Korean Nosocomial Infections Surveillance System.

stewardship program. Of these, 90.2% ran computerized antibiotic stewardship programs. In 23 hospitals (56.1%), infection control units implemented quality management systems for medical devices, including sterilization products.

Of the responding hospitals, 34 (82.9%) participated in the Korean Nosocomial Infections Surveillance System, which is the nationwide monitoring system for nosocomial infection in the ICUs, consisting of a standardized protocol and a Web-based prompt response network. Twelve facilities (29.3%) conducted environmental cultures to detect MRSA, VRE, MRAB, MRPA, or CRE on a routine basis. Regular environmental disinfection on the ICUs was performed once a day (n = 14, 34.1%), twice a day (n = 13, 31.7%) or 3 time a day (n = 10, 24.4%).

Infection prevention and control program by hospital size

There was no significant difference in the ratio of number of beds to infection control personnel among the 4 groups (Table 1). More infection specialists and the lower bed numbers per handwash stands were noted in larger hospitals (Table 1). However, supplies consumption and protocols for infection prevention and control seemed to have no difference by the size of the hospitals (Tables 1 and 2). Also, there were no differences among the groups in the rates of active environmental surveillance cultures, average number of cultures performed per hospital bed, and consumption of hand sanitizers and disposable gowns per hospital bed (Table 2).

Changes in infection prevention and control program since 2010

A number of changes have been observed since 2010, after the implementation of a surveillance network for MDROs and the creation of infection control committees under the Infectious Disease Control and Prevention Act. Three facilities (7.3%) have complied with the regulation of infection prevention and control since the introduction of legislation. Five hospitals (12.2%) employed a full-time ICP. Thirteen hospitals (31.7%) introduced the use of disposable tissue towels, and 3 hospitals (7.3%) introduced hand sanitizers and disinfectants. Twenty-three facilities (51.6%) introduced a monitoring and feedback program for hand hygiene in 2010, and 15 hospitals (36.6%) commenced regular education seminars for MDRO infection prevention and control. A significant increase was observed between 2009 and 2014 in the median number of personnel specialized in infection control within each hospital (1.6 ± 1.2 vs 2.4 ± 1.9, $P = .011$). Between 2009 and 2014, monitoring of the prevalence of MRSA (57.4% vs 42.6%, $P = .118$) and VRE (60.0% vs 40.0%, $P = .024$) and active surveillance for carriers of MRSA (66.7% vs 33.3%, $P = .022$) and VRE (64.3% vs 35.7%, $P = .062$) were scaled down. Conversely, monitoring (12.5% vs 87.5%, $P < .001$) and active surveillance programs (11.1% vs 88.9%, $P = .013$) for CRE were strengthened, whereas there were no changes in monitoring or active surveillance programs for carriers of MRPA and MRAB during this time. In terms of isolation practices, using a single room or a cohort program followed similar trends to the MDRO detection policies: isolation of patients with MRSA (75.0% vs 25.0%, $P = .026$) or VRE (60.9% vs 39.1%, $P < .001$) was stopped in some hospitals, whereas isolation of patients with CRE (15.4% vs 84.6%, $P < .001$) was introduced in others.

DISCUSSION

In the ROK, a 2015 outbreak of Middle East respiratory syndrome coronavirus with large clusters of nosocomial infections increased our interest in infection prevention and control programs. This study provides comprehensive information on the current status of facilities and staff personnel for infection prevention and control programs among hospitals in the ROK. These findings may help to identify the optimal strategies to manage infection control and prevention programs effectively in the ROK.

The structure of the hospital facilities and medical equipment or supplies are the critical components for effective infection prevention and control. It is a well-known fact from the outbreak of Middle East respiratory syndrome coronavirus in the ROK that multibed rooms enable the spread of infectious diseases, and this represents part of the chronic problems of the Korean health care system.[8] In this study, the median number of single rooms in each hospital was 5 (range, 0-63). Patients with known or suspected infectious diseases acquired by contact or droplet routes or airborne droplet nuclei should be physically isolated from other patients.[9] The use of single-room isolation with adherence to the requirements of isolation can be a cornerstone in the prevention and control of MDROs in hospitals.[10] However, this practice is a challenge in the ROK where hospitals are largely organized in multibed rooms, with insufficient numbers of single rooms. A health care organization that

Table 2
Activities of infection prevention and control programs in the study hospitals stratified according to size

Variables	200-400 beds	500-699 beds	700-899 beds	≥900 beds	*P* value
Cleaning and environmental disinfection measures					
Regular environmental disinfection	6 (85.7)	8 (88.9)	16 (94.1)	7 (87.5)	.261
Frequency in a day	3.4 ± 1.1	4.0 ± 1.1	3.6 ± 0.8	3.8 ± 1.3	.695
Disinfection by nurses	2 (28.6)	3 (33.3)	3 (17.6)	1 (12.5)	.691
Regular surveillance culture	1 (14.3)	2 (22.2)	8 (47.1)	1 (12.5)	.001
Disinfectants					.206
Sodium hypochlorite	2 (28.6)	6 (66.7)	3 (17.6)	4 (50.0)	
Quaternary ammonium compounds	4 (57.1)	3 (33.3)	13 (76.5)	3 (37.5)	
Others	1 (14.3)	0 (0)	1 (5.9)	1 (12.5)	
Materials for infection control program					
Consumption of the no. of disposable gowns in a year to beds ratio	62.0 ± 73.2	317.6 ± 375.3	453.2 ± 526.0	411.9 ± 509.4	.278
Consumption of hand sanitizers in a year (bottles) to beds ratio	1.5 ± 2.6	3.0 ± 2.0	2.4 ± 1.5	2.8 ± 2.5	.524
Regular monitoring of hand hygiene	7 (100.0)	8 (88.9)	15 (88.2)	8 (100.0)	.600
Yearly frequency of regular education seminars for hand hygiene	0.4 ± 0.5	0.6 ± 0.8	0.8 ± 0.8	0.4 ± 0.5	.329
Standard inspection of sterilized products	1 (14.3)	2 (22.2)	3 (17.6)	4 (50.0)	.299
No. of nonblood cultures performed per bed	24.0 ± 15.1	53.1 ± 31.8	58.0 ± 48.4	43.9 ± 35.9	.275
No. of blood cultures performed per bed	48.3 ± 21.6	53.1 ± 23.1	49.1 ± 36.7	51.5 ± 30.5	.980
Prevention and control program for MDROs					
Regular education seminar for prevention and control of MDROs	2 (28.6)	6 (66.7)	11 (64.7)	5 (62.5)	.369
Periodic monitoring of prevalence or incidence					
MRSA	4 (57.1)	4 (44.4)	6 (35.3)	5 (62.5)	.532
VRE	4 (57.1)	5 (55.6)	6 (35.3)	5 (62.5)	.532
MRAB	4 (57.1)	5 (55.6)	6 (35.3)	5 (62.5)	.532
MRPA	4 (57.1)	4 (44.4)	6 (35.3)	5 (62.5)	.569
CRE	4 (57.1)	5 (55.6)	7 (41.2)	5 (62.5)	.739
Active surveillance culture in ICUs					
MRSA	1 (14.3)	2 (22.2)	3 (17.6)	4 (50.0)	.299
VRE	2 (28.6)	2 (22.2)	3 (17.6)	3 (37.5)	.740
MRAB	0 (0)	1 (11.1)	3 (17.6)	3 (37.5)	.258
MRPA	0 (0)	1 (11.1)	2 (11.8)	2 (25.0)	.530
CRE	1 (14.3)	2 (22.2)	2 (11.8)	3 (37.5)	.482
Isolation or cohort in ICUs					
MRSA	2 (28.6)	0 (0)	1 (5.9)	1 (12.5)	.246
VRE	5 (71.4)	7 (77.8)	8 (47.1)	5 (62.5)	.427
MRAB	1 (14.3)	1 (11.1)	4 (23.5)	2 (25.0)	.836
MRPA	1 (14.3)	0 (0)	2 (11.8)	1 (12.5)	.733
CRE	5 (71.4)	8 (88.9)	5 (35.3)	3 (37.5)	.036
Antibiotic stewardship programs					
Antibiotic stewardship programs	6 (100.0)	7 (87.5)	16 (100.0)	7 (100.0)	.242
Computerized antibiotic prescription system	6 (100.0)	7 (87.5)	15 (93.8)	7 (100.0)	.349

Values are n (%), mean ± SD, or as otherwise indicated.
CRE, carbapenem-resistant *Enterobacteriaceae*; *ICU*, intensive care unit; *MDRO*, multidrug-resistant organism; *MRAB*, multidrug-resistant *Acinetobacter baumannii*; *MRPA*, multidrug-resistant *Pseudomonas aeruginosa*; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *VRE*, vancomycin-resistant *Enterococcus*.

is planning to expand its facility may now consider the need for single rooms.

In 1999, the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System recommended 1 full-time ICN per 100 hospital beds and 1 full-time ICN for each additional 250 beds.[1,11] Actually, the average number of infection control professionals per 100 beds was 1.2 in U.S. hospitals enrolled in the National Health and Safety Network and 0.8 in Canadian acute care hospitals.[12,13] Although infection prevention and control policies have largely improved the medical environmental on infection prevention and control, changes in the use of specialized personnel for infection prevention and control fell short of recommendations. For example, the ratio of the number of beds to ICNs in the ROK (1 full-time ICN per 400.3 ± 154.1 beds) was lower than in other countries with established infection prevention and control programs.[12-16]

Our study found a wide variation in the training and experience of ICNs. To date, there is no formal certification process to assess the practice of ICNs and ensure a minimum level of competence. The Korean Society for Healthcare-associated Infection Control and Prevention has recently attempted to provide a formal educational process for the updated practice for infection prevention and control. Promoting the training and appointment of specialist personnel to support and expand infection prevention and control programs should be the ongoing focus of effective policy-oriented management. The buildup of a highly qualified workforce should be based on the political support of continuous human resource development.

Of the responding hospitals, 97.6% have monitored the resistance proportion of major MDROs and have shared their results in clinical practice. Routine surveillance culture for targeted MDROs was conducted in 51.2% of hospitals; however, only some hospitals isolated the carriers to single rooms: 34.1% for the patients in the ICUs, and 19.5% for those in the general ward. Screening for carriers of MDROs and isolation of positive carriers appear to have a significant role in the reduction of the pool of colonized patients and in the prevention of cross-transmission.[17,18] However, these studies only identified carriers of MDROs and did not establish isolation of patients with contact precautions.

The increasing prevalence of gram-negative MDROs has recently become a significant threat worldwide, including in the ROK.[19] This study shows that the active surveillance culture introduced in 2014 has targeted gram-negative MDROs rather than gram-positive organisms. It is likely that the emergence of carbapenem-resistant organisms will result in changes in the choice of organisms for active surveillance cultures. However, facilities have great diversity in their approach to preventing gram-negative MDROs. The definitions of multidrug resistance and the criteria of isolation were not even unified, compared with those for gram-positive MDROs.[20] On the

other hand, the centralized management of the increase in MDROs can be temporarily effective, under conditions of finite resources. However, a comprehensive and multifaceted approach simultaneously covering the various MDROs should be designed to minimize opportunity costs.[21]

Over the last 5 years, the newly implemented Infectious Disease Control and Prevention Act and the hospital accreditation have resulted in substantial investment in infection prevention and control by hospitals throughout the ROK. However, the current fee-for-service payment system in the ROK does not offer reasonable incentives for infection prevention and control programs. Reflecting on the current state of the health care system, our study found a shortage of skilled workforce and inferior facilities for handwashing and a shortage of single rooms in relatively scaled-down hospitals. The lack of financial incentives for these activities potentially limits quantitative and qualitative improvement in infection prevention and control programs. A reasonable medical insurance fee should be established based on the multidisciplinary approach for effective execution of ideal infection prevention and control programs.

Our study has several limitations. Although this is the first report, to our knowledge, on the changes introduced since the implementation of a national surveillance network for MDROs, the sample size is small. Furthermore, the possibility of survey selection bias and information bias cannot be excluded.

CONCLUSIONS

This study demonstrates that despite policy changes, personnel resources for effective infection prevention and control programs in the ROK need reinforcement, both in terms of the numbers of specialists and the quality of their training. Investment in development of single rooms and implementation of a comprehensive program are also required, with the support of a sensible policy on medical insurance fees.

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