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ORIGINAL ARTICLE

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Evaluating effectiveness of infection control efforts in hospitals using information in microbiological laboratory databases

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Abstract

Purpose: To analyze the quality of infection control activities, bacteriological data relevant to infection control was evaluated through the microbiological data warehouse networking hospitals in two medical regions.

Methods: Data regarding bacterial test results of 19 hospitals were extracted from two microbiological laboratory information data bases. The rate of MRSA among total *S. aureus* was used as a general indicator of infection control activities. The occupancy rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples was used as an indicator of attention paid for infection control in intensive care wards. The number of blood culture sets per examined patient was utilized as an indicator for life-long vocational education on updated medical practice relevant to infectious diseases.

Results: The rate of MRSA was significantly higher in secondary private hospitals. The occupancy rate of nasal or pharyngeal swabs was significantly higher in tertiary hospitals. The average number of blood culture set per examined patient were 1.55, 1.54 and 1.39 in tertiary, secondary public and secondary private hospitals, respectively; however, there were no statistical differences between groups.

Conclusions: Data bases of microbiological test results shared by hospital laboratories are useful for evaluating regional infection control activities.

KEYWORDS

blood culture, infection control, information network, MRSA, quality

1 | INTRODUCTION

The purpose of this investigation was to evaluate the infection control activities in hospitals using the data base of microbiological test results of each hospital. Infection control is a problem having multiple facets, and it is not easy to compare the efforts in one hospital with those of other hospitals. Several indicators, such as the consumption volume of alcohol gel for hand-washing, the rate of catheter-related bloodstream

infections, and the occurrence rate of multi-drug-resistant bacteria isolates among all bacteriological samples, could be used to represent some of the qualities of infection control activities. In Japan, the percentage of MRSA among the total number of *Staphylococcus aureus* strains approached 70% in the 1990s[1] and stayed at the same level for more than 10 years. This percentage began to decrease steadily from the beginning of this century, after vigorous infection control efforts were put into practice.[2] We organized an information network connecting 36 hospitals and bacteriological laboratories sharing the same software to accumulate and analyze microbial test results.[3,4] This network revealed high rates of MRSA among the total number of *S. aureus* strains in some hospitals. The spread of multidrug-resistant bacteria in one hospital may cause further spread to other hospitals in the same medical area through treatment of the same patients. Thus, infection control is an issue shared by hospitals within each medical region. To determine the quality of infection control activities, the rates of MRSA and other bacteriological data relevant to infection control were investigated according to hospital type.

2 | METHODS

2.1 | Study design

This study is a retrospective observational study using two independent microbiology data bases for networking hospitals in Akita and Aomori prefectures, Japan.

2.2 | Ethics statement

This study was approved by the ethics committee of Hirosaki University Graduate School of Medicine (Approval number 2014-129).

2.3 | Data source

The data were extracted from two regional microbiological laboratory information data bases: Akita-Regional Network for Infection Monitoring/Control System (ReNICS) shared by 16 hospitals in Akita, and Microbiological Information Network Aomori (MINA) shared by 20 hospitals. The microbiological test results obtained in each hospital were uploaded via information network and stored in web servers placed and managed at the administration facilities, namely Infection Control Division of Akita University Hospital for ReNICS and Infection Control Center of Hirosaki University Hospital for MINA. Aomori and Akita are adjacent prefectures in the northern area of the main island of Japan. The information processing systems for both of the data bases were supplied by KD-ICONS (Tokyo, Japan). Data regarding the changes in rates of MRSA among *S. aureus* strains isolated from inpatients from 2010 to 2014 were obtained from Japan Nosocomial Infection Surveillance (JANIS) and ReNICS. JANIS is a national surveillance program organized by the Ministry of Health, Labour and Welfare (MHLW) of Japan designed to provide information on the incidence and prevalence of nosocomial infections and antimicrobial-resistant bacteria in Japanese hospitals. More than 1000 hospitals with more than 200 beds across Japan are members of JANIS. JANIS member hospitals are required to submit surveillance data on a regular basis. The national data on the incidence of nosocomial infections and the prevalence of drug-resistant bacteria in Japan are publicly available on JANIS website. JANIS member hospitals can get the information on the incidence and prevalence of nosocomial infections or drug resistance restricted to their own institution. ReNICS and MINA are sharing almost the same functions as JANIS but covers only Akita prefecture and Aomori prefecture, respectively.

2.4 | Exclusions

Because of a paucity of data, 17 of the 36 hospitals participating in ReNICS or MINA were excluded. More specifically, hospitals with the 95% confidence interval for MRSA prevalence exceeding 10% of the average value were excluded. Data from outpatients were excluded.

2.5 | Grouping of the hospitals

The 19 enrolled hospitals were placed into three groups by type, as follows: five tertiary hospitals, 10 public secondary hospitals, and four private secondary hospitals. Tertiary hospitals are major hospitals with full complement of services including various branches of surgery, obstetrics, general medicine, gynecology, pediatrics, psychiatry, and intensive care units for seriously ill patients and newborns requiring intensive and special care. Specialty hospitals dedicated to specific subspecialty care (eg, Cardio-vascular center, Neurosurgical center) were not included in the tertiary hospitals in this investigation. Tertiary care hospitals accept patients from secondary hospitals and smaller hospitals for major operations, consultations to specialists and intensive cares. Secondary hospitals are local base hospitals accepting patients requiring hospital treatment.

2.6 | Data extraction

Data were collected from ReNICS and MINA from January 2014 to December 2014. The rate of MRSA among all *S. aureus* cultured, the rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples, and the number of blood culture sets per examined patients were utilized as the indicators for general infection control performance, extent of MRSA carriage screening, and the quality of clinical treatment of infectious diseases, respectively. For seven hospitals which have been the member of ReNICS ever since its foundation in 2010, the data from January 2010 to December 2010 were compared with those from 2014. The total amount of hand-wash gel purchased by the hospital was surveyed using a questionnaire. The questionnaire was collected from 18 of the 19 enrolled hospitals. The amount of hand-wash gel purchased per patient was estimated using published data (eg, the total amount of hand-wash gel purchased by the hospital, number of beds, bed occupancy rate, and average number of hospitalization days).

2.7 | Statistical analysis

The statistical significance of differences was determined by the one-way ANOVA Tukey-Kramer post hoc test for multiple comparisons.

Correlation between two variables was investigated by calculating the Pearson product-moment correlation coefficient. Differences having $P<.05$ after analysis of variance were defined as statistically significant. All statistical analyses were performed using Statcel 3rd Add-in forms on Excel (OMS publication, Saitama Japan) and SPSS software version 23.0 (IBM, Chicago, IL, USA). The data are expressed as mean±standard error of the mean (SEM) in the text unless otherwise stated.

3 | RESULTS

3.1 | The rate of MRSA among the total number of *Staphylococcus aureus* strains and the rate of MRSA-positive patients against the total number of patients tested for bacteriological cultures

Data from 2010 were available from seven ReNICS participating hospitals. According to the national surveillance JANIS and ReNICS data, the rate of MRSA among the total number of *S. aureus* strains decreased during the period from 2010 to 2014, as did the percentage of MRSA-positive patients against the total number of patients tested for bacteriological cultures (Figure 1). Analysis of the data in 2014 showed that the rate was significantly higher in secondary private hospitals (72.1%±2.9%) than in tertiary (43.4%±4.7%) or secondary public (44.5%±4.6%) hospitals (Table 1).

3.2 | The rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples

Nasal or pharyngeal swab cultures are usually performed as a screening for MRSA carriage in intensive care unit, neonatal intensive care unit, and other department caring immune-compromised hosts. We examined the rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples as a possible indicator of the health care provided by hospitals. The rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples was significantly higher in tertiary hospitals (15.0%±3.2%) than those in secondary private hospitals (3.9%±1.1%) and secondary private hospitals (3.3%±1.2%) (Table 1).

3.3 | The number of blood culture sets per examined patient

The number of blood culture sets per examined patient was 1.55±0.1, 1.54±0.04, and 1.39±0.08 in tertiary, secondary public, and secondary private hospitals, respectively. There were no statistical differences between groups. There was an inverse correlation between the number of blood culture sets per examined patient and the percentage of MRSA among the total number of *S. aureus* strains (correlation coefficient=−0.60, $P=.006$, Figure 2).

3.4 | Change of the percentage of MRSA among the total number of *Staphylococcus aureus* strains and the number of blood culture sets per examined patient from 2010 to 2014

Data from 2010 were available from seven ReNICS participating hospitals, including one tertiary hospital, five secondary public hospitals, and one secondary private hospital. As a whole, the number of blood culture sets per examined patient was unchanged from 2010 (1.57±0.32) to 2014 (1.54±0.31). The mean percentage of MRSA among the total number of *S. aureus* strains was 53.9% (range 8.9%-80.7%) in 2010 and 42.8% (range 21.7%-76.0%) in 2014. As was shown in Figure 3, the number of blood culture sets per examined patient increased in five of the seven hospitals, and the percentage of MRSA decreased in six of the seven hospitals. It is noteworthy that the percentage of MRSA stayed high in hospital A, a private secondary

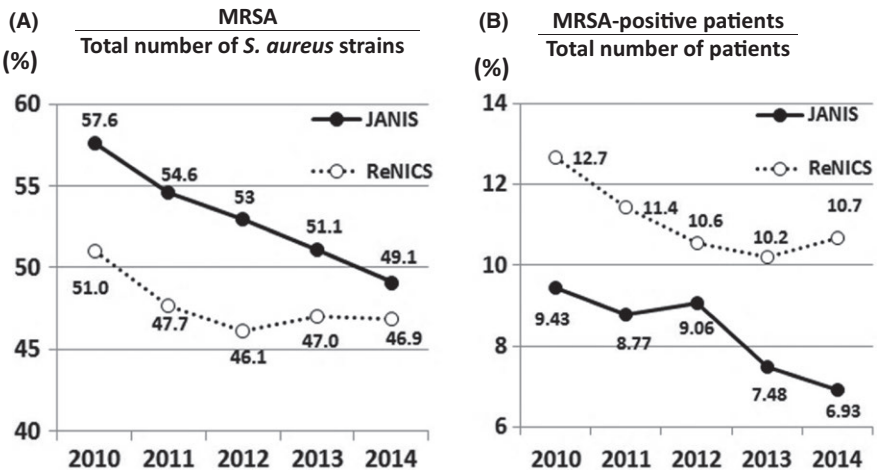

FIGURE 1 Change in the rate of MRSA among the total number of *Staphylococcus* aureus strains and the rate of MRSA-positive patients against the total number of patients tested for bacteriological cultures. The rate of MRSA among the total number of S. aureus strains declined both in nationwide surveillance (831 hospitals, solid line) and Akita-Regional Network for Infection Monitoring/Control System (ReNICS) (seven hospitals, dotted line), from 57.6% and 51.0% in 2010 to 49.1% and 46.9% in 2014, respectively (panel A). The rate of MRSA-positive patients against the total number of patients tested for bacteriological cultures also decreased during the period (panel B)

TABLE 1 Hospital groups and statistical data (2014)

	Tertiary hospitals	Secondary public hospitals	Secondary private hospitals
Rate of MRSA among the total number of *Staphylococcus aureus* strains (%)	43.4±4.7	44.5±4.6	72.1±2.9[a]
Rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples (%)	15.0±3.2	3.9±1.1[b]	3.3±1.2[b]
The number of blood culture sets per examined patient	1.55±0.1	1.54±0.44	1.39±0.08
Amount of hand-wash gel purchased per patient (mL)	326.4±65.2	205.6±32.3	171.0±31.2

[a]$P<.01$ vs Tertiary and Secondary public hospitals.
[b]$P<.01$ vs Tertiary hospitals.

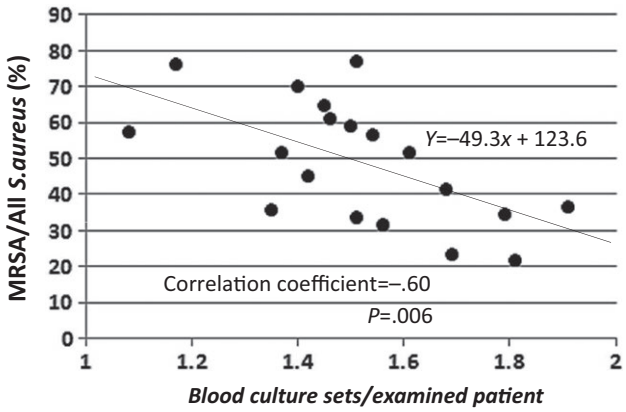

FIGURE 2 Correlation between the number of blood culture sets per examined patient and the percentage of MRSA among the total number of *Staphylococcus aureus* strains. There was an inverse correlation between the number of blood culture sets per examined patient and the percentage of MRSA among the total number of *S. aureus* strains

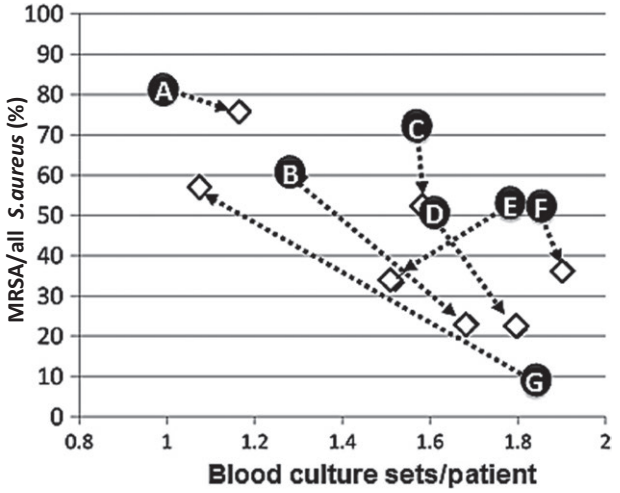

FIGURE 3 Changes in seven hospitals from 2010 to 2014 of the percentage of MRSA among the total number of *Staphylococcus aureus* strains and the number of blood culture sets per examined patient. Hospital A is a secondary private hospital. Hospital F is a tertiary hospital, and the other 5 (B, C, D, E, G) are secondary public hospitals. Circles indicate the values in 2010, and open diamonds indicate the values in 2014

hospital, and that both the MRSA percentage and the number of blood culture sets got worse in hospital G, which lost an efficient infection control doctor during this period.

3.5 | The amount of hand-wash gel purchased per patient

The mean amounts of hand-wash gel purchased per patient, in mL/patient, were 291.5±80.1, 175.3±23.2, and 189.8±31.4 in tertiary hospitals, secondary public hospitals, and secondary private hospitals, respectively. There were no statistical differences between groups. The mean amounts of hand-wash gel purchased per patient differ in each hospital according to the characteristics of the hospital. The amount of hand-wash gel indicates the frequency of hand-wash in the ward, and used as an indicator of infection control activity in each hospital. However, it has not been clear that the amount of hand-wash gel could be a suitable indicator for infection control activities if it was used for making comparison among hospitals with different size and level of medical service. In this study, among the hospitals with different characteristics, there was no statistically significant correlation between the amount of hand-wash gel purchased per patient and the percentage of MRSA among the total number of *S. aureus* strains (Figure 4).

4 | DISCUSSION

Hospital infection control is not only a matter of concern for individual hospitals; rather, it is a responsibility shared by hospitals in the same medical region. A breakdown of hospital infection control activities would lead to the breakdown of infection control for the entire medical region. It would be beneficial for hospitals to share information regarding infection control and to have opportunities to uncover regional problems.

It is not easy to evaluate the quality of hospital infection control, as it is a problem having multiple facets. Surveillance data, such as numbers of urinary tract, surgical site, or catheter-related blood stream infections, may be good references for such evaluations, but trained personnel are required for the surveillance. In Aomori and Akita prefecture, microbiological laboratory information is shared by regional hospitals through data base systems called ReNICS and MINA,

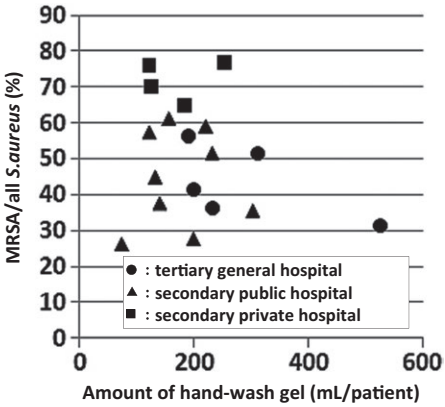

FIGURE 4 Distribution chart of MRSA among the total number of *Staphylococcus aureus* strains and the amount of hand-wash gel purchased per patient in hospitals. Hospitals with a various size and a wide variety of providing health care were included in this figure (●: Tertiary hospitals, ▲: Secondary public hospitals, ■: Secondary private hospitals). There was no correlation, as a whole nor within each hospital group, between the percentage of MRSA among the total number of *S. aureus* strains and the amount of hand-wash gel purchased per patient

respectively. In this study, we tried to evaluate the quality of infection control activities in each hospital through analysis of information in these microbiological data base systems.

The rate of MRSA among *S. aureus* strains isolated in Akita University Hospital began to decline after vigorous infection control activities were put into practice by certified infection control nurses and doctors (data not shown). Hence, it would be reasonable to use the rate of MRSA among *S. aureus* strains as one of the indicators of current infection control activities. Data from JANIS and ReNICS both showed decreases of the rate of MRSA among *S. aureus* strains and the rate of MRSA-positive patents against the total number of patients tested for bacteriological cultures. The rate of MRSA was higher in secondary private hospitals than in tertiary hospitals and secondary public hospitals. This may be because of the fact that the private hospitals in this study were relatively small sized compared with those of the other types. It is not easy for small hospitals to employ full-time certified infection control personnel. Moreover, private hospitals are managed more strictly than are public hospitals, which are financially supported by local governments.

The rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples could suggest the presence of intensive care units or departments actively screening MRSA carriage in the hospital.

The importance of standard precautions and basic hand-washing for infection control are widely accepted. It was reported that MRSA and other multidrug-resistant bacteria decreased as the consumption of hand-wash solution increased.[5,6] The amount of hand-wash alcohol gel purchased per patient tended to decrease in tertiary hospitals, secondary public, and private hospitals, in that order. The relationship of the infection rates and consumption of alcohol hand-wash gel among hospitals might be more clearly demonstrated if the volume purchased was solely used for hand-washing; however, this amount likely included the gel discarded for being beyond the expiration date. The amount of hand-wash alcohol gel purchased per patient would not be a good indicator for infection control activities when it was used for the comparison among hospitals with various size and quality; however, it could be used as the indicator of the change in infection control activities over time within each hospital.

In patients with suspected blood stream infection, it is generally accepted that two blood culture sets, each comprising an aerobic and an anaerobic bottle, should be collected from separately prepared sites.[7] The number of culture bottles used for one blood culture test correlated inversely with the MRSA rate measured in this study. It was reported that the practice of performing two sets of blood culture tests increased through education of physicians by the infection control team.[8] Hence, the rate of multiple sets included among all blood culture tests performed may be used as an indicator of the educational activities by infection control teams. The ministry of labor and welfare did not permit the health insurance system to pay for multiple sets of blood cultures until 2014. This payment restriction, at least to some extent, decreased the rate of performing two sets of blood culture tests in private hospitals under strict management. There is a possibility that the accuracy and sensitivity of blood culture tests might not have reached a satisfactory level in our medical regions.

The occupancy rate of nasal or pharyngeal swabs among MRSA-positive bacteriological samples would increase if the hospital has departments checking for MRSA in all patients treated. Nasal screening may be beneficial for the departments of orthopedic surgery, cardiovascular surgery, and intensive care units[9,10]; however, controversy persists.[11] The hospitals with a high percentage of nasal or pharyngeal swabs had departments of cardiovascular surgery, orthopedic surgery, and intensive care units. Hence, a high percentage of nasal or pharyngeal swabs indicated the type of hospital as well as the infection control activities.

The change in the rates of MRSA among all *S. aureus* strains and the number of blood culture sets per examined patient in 2014 were compared with those in 2010 in seven hospitals. Hospital A, a secondary private hospital, continued to have a high rate of MRSA and a low number of blood culture sets. This may due to the absence of certified personnel working exclusively in infection control in that hospital. Hospital G, which had a relatively low rate of MRSA and an acceptable number of blood culture sets in 2010, had notably worse performance in 2014. Hospital G could not fill the vacancy after an efficient certified infection control doctor moved to another hospital in 2011. These observations suggest the importance of employing certified infection control personnel in each hospital.[12] Observing the time course of the indicators utilized in this study would provide clues for recognizing infection control issues in the entire medical region as well as at each hospital. The authors are expecting the hospitals participating to the microbiological information network in the medical areas to improve their infection control activities to provide safe and quality care.

This study has several limitations. Small hospitals without a sufficient amount of data on bacteriological test results were excluded from this study. The infection control activities effective for preventing occupational infections could not be evaluated. The number of hospitals having long-term data is still limited.

5 | CONCLUSION

In conclusion, it was shown that the quality of infection control varies according to the characteristics of the hospitals in our medical regions. Data bases of microbiological test results shared by hospitals in the same medical area were useful tools for evaluation of regional infection control activities.

CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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