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Rule-Based Healthcare-Associated Bloodstream Infection Classification and Surveillance System

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Abstract. Healthcare-associated infections (HAIs) are a major patient safety issue. These adverse events add to the burden of resource use, promote resistance to antibiotics, and contribute to patient deaths and disability. A rule-based HAI classification and surveillance system was developed for automatic integration, analysis, and interpretation of HAIs and related pathogens. Rule-based classification system was design and implement to facilitate healthcare-associated bloodstream infection (HABSI) surveillance. Electronic medical records from a 2200-bed teaching hospital in Taiwan were classified according to predefined criteria of HABSI. The detailed information in each HABSI was presented systematically to support infection control personnel decision. The accuracy of HABSI classification was 0.94, and the square of the sample correlation coefficient was 0.99.

Keywords. Healthcare-associated infection, surveillance, infection control, information systems, Web-based services

Introduction

Healthcare-associated infections (HAIs) are important adverse events associated with health care or developing after admission. Surveillance data showed that HAIs are the most common complications affecting hospitalized patients [1]. Thus, HAIs are a major patient safety issue, also add to the burden of resource use, promote resistance to antibiotics, and contribute to patient deaths and disability [2].

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Hospital-wide surveillance programs are highly labor intensive and tend to divert resources needed to implement control measures and prevention activities. To err is human, particularly for complicated medical care and for medical staff working under high pressure and long hours [3]. The decision guidelines (that is, the case definition) of HAIs were complicated. The quality of HAI surveillance is experience-, time- and/or manpower-dependent. Prospective, hospital-wide on-site surveillance of HAI at the majority of hospitals were conducted by regular visits of infection control nurses to all patient units. Medical records were reviewed to identify patients with HAIs according to definitions of the Centers for Disease Control and Prevention [4]. Data were collected on standardized data collection forms and incorporated into the database by manual entry. The unit-specific incidences of HAI including overall and site-specific infection rates were analyzed monthly and compared to historical data. Feedback was provided to each service to stimulate intervention measures. With the advance of medical information system, data in hospital information system (HIS) and laboratory information system (LIS) are now stored as electronic medical record (EMR).

However, data generated in the medical information system were scattered in numerous databases and data access was hindered by several interfaces. For surveillance and providing quality indicators, comprehensive and consistent surveillance and objective and uniform interpretation based on predefined criteria were fundamental. Previous studies have shown that computer-based decision-support interventions such as automated reminders and alerts to healthcare providers are beneficial and can change clinical practice [5-8]. For HAI surveillance, there were various systems in the previous research. In computer-assisted stage, integrating information in a friendly user interface was helpful [9-11]. Because of the increased use of EMRs, more complex HAI definition could be established in system [12-14]. These previous research conclude that computer-assisted or automated HAI surveillance with EMR was an accurate alternative to surveillance with manually collected data. However, even with an automatic HAI surveillance system, infection control personnel should reconfirm all HAI candidates. Besides relatively complete HAI surveillance rules, a HAI management system was also important. The management system consists of related data integration, display, and a modification user interface.

In order to improve patient safety and quality of care, intimate incorporation from comprehensive surveillance, appropriate data analysis and interpretation to prompt intervention are important. The HAI surveillance system was developed at the 2200-bed teaching hospital in Taiwan. To automatically collect and notify HAI and define organism, the case definition of HAI was implemented in the rule-based clinical decision support system. This research was focused on healthcare-associated BSI (41.6%), one of the most HAI, 2007 [15]. The system adheres to a Service-Oriented Architecture (SOA) and to Health Level Seven (HL7). This up-to-date platform and the rising popularity of EMR not only advance the quality and efficiency of infection control but improve patient safety.

1. Methods

Before further analysis and surveillance, a rule-based HAI classification system was designed and created to consistently and efficiently determine whether infection case is HAI, based on EMR. The HAI event candidates are automatically collected according to the well-defined guidelines monitored every day routinely and every hour if indicated in emerged situation. The architecture of the rule-based HAI and organism classification system is displayed in Figure 1. There are three parts in the system: related data collection, candidate detection, and HAI management. The related data collection subsystem and the HAI management subsystem were described in previous study, which was focus on healthcare-associated urinary tract infection [16].

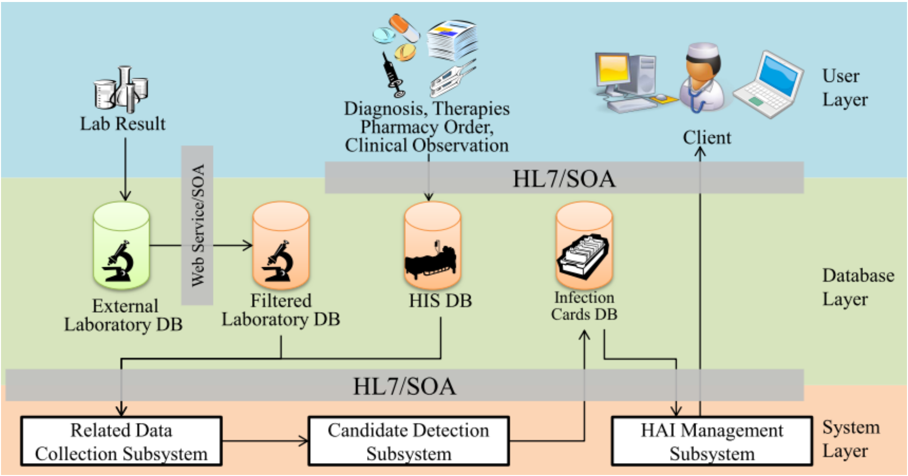

Figure 1. General architecture and integration of medical data in the rule-based HABSI surveillance system.

1.1. Candidate detection subsystem

After the related data were collected into the HABSI surveillance system, these data were used in a candidate detection subsystem. The guidelines of HABSI surveillance were established by infection control specialists and computer engineers based on literature [4] and local epidemiology. The guidelines of classifying HABSI cases are described in Figure 2, and there are four major types of HABSI. The algorithm for avoiding duplicate set the priority of classification based on the order of HABSI types.

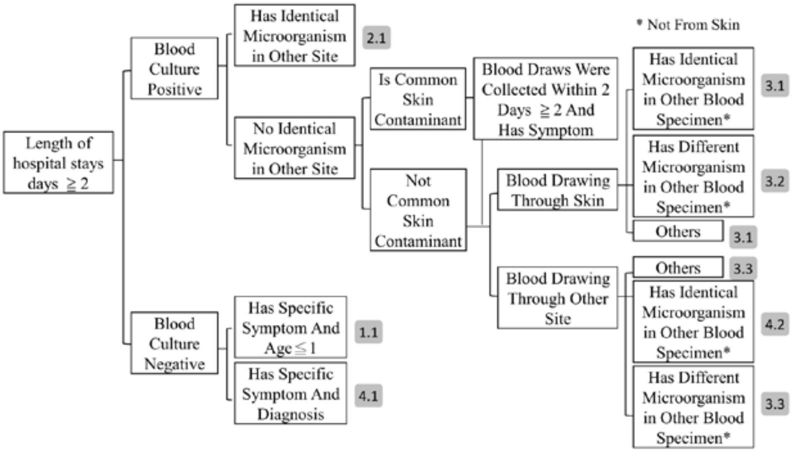

Figure 2. The guidelines of classifying HABSI cases.

1.2. Evaluation of rule-based HAI classification system performance

To evaluate the Rule-based HAI Classification System, the HABSI data between Sep. 1 2010 and Sep. 15 2010 were used. By comparing these data with already existed events which were manually collected by infection control nurses without the system in daily work, the results were divided into 2 parts: the data which were consistent between manually collected events and automatically collected events, and the data which were missed due to different definition of rules. The similarity of distribution of HABSI events with the system and without the system was also considered as an important factor to prove the reliability of HAI classification system.

2. Results

The HABSI classification results are shown in Table 1. There were 80 manually collected events and 107 HABSI automatically detected events between Sep. 1 2010 and Sep. 15 2010. The accuracy of HABSI classification was 93.75% based on manually collected events, which were the reference standard in our experiment. These events were distributed in 22 departments. The correlation of HABSI events count with and without the classification system in different department is calculated. The square of the sample correlation coefficient was 0.992. These results indicate that the tendency and distribution of HABSI events collected by classification system was similar to those by ICN, further proved the reliability of HABSI classification system.

Table 1. Performance of rule-based HABSI classification system.

	Without the System	With the System	Accuracy of BSI detection
Match	75	75	75/80 = 93.75%
Different Definition of Rules	5	32	
Total	80	107	

3. Discussion

The web-based HABSI classification system detected and monitored about 93.75% based on clinical data and the decision guidelines established by infection control personnel and computer engineers. In the correlation analysis, the regression captured 99.2% of the variation in the number of HABSI events in different departments with and without the system.

Besides automatically collecting HAI candidates, this system provides stable and identical HAI event reports, which stand the quality control index of each department. Quality control auditors analyze the number of infection cases and the microorganism reports, reform training and education of health care workers, to improve the patient safety [17]. The challenge of infection control and surveillance is to discover unexpected infection pattern [18]. Using the automatic surveillance system let specialists have more time to deal with special event of infection, return feedback to our system to improve the decision guidelines and find the new patterns of HAI events [19]. From these results, this system provided most candidates of HAI events, and reduced the workload of infection control personnel.

Although our results suggested that the rule-based HABSI surveillance system performs well, it did have several limitations. In the rule-based classification system, first, body temperature was the only symptom information in our EHR, so the system may miss some cases for lack of other symptom information. Otherwise the special events of HAI might not fit any guideline that we established. Then, the computerized HAI decision guideline might not exact represent the manual decision guideline, so there were different definitions of guideline error in HABSI classification system.

In conclusion, this system provides convenient service of HABSI detection. The data connections optimally represent the full conceptual content of the data, allowing automated integration and data-driven decision-making. As of December 20, 2012, the system was still used for HAI surveillance, and became an indispensable tool for infection control personnel daily work. Designing this system could, therefore, improve patient safety as well as the quality of medical care in a hospital.

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