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Original Paper

Comprehensive Evaluation of Healthcare Associated Infection Surveillance System

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Abstract

Background & objectives: *The electronic surveillance system has been applied in healthcare associated infection surveillance. We conducted an evaluation of the real-time healthcare associated infection surveillance system (RT-HAISS) to understand the early warning effect.*

Methods: *We evaluated our RT-HAISS on a dataset of 29074 patients at the Wuxi traditional Chinese medicine (TCM) hospital in 2020, encompassing sensitivity, specificity, positive predictive value, negative predictive value, Youden index and false alarm rate.*

Results: *466 HAIs were confirmed in this hospital in 2020, The RT-HAISS warned the monitors a total of 1715 cases, with 2040 early warning entries and 1736 false alarm entries. The sensitivity and the specificity were 65.24% and 95.74%, respectively. The Youden index was 0.62. In addition, the positive predictive value was 14.90%, and the negative predictive value was 83.86%, with 85.10% of false alarm rate.*

Conclusion: *The RT-HAISS is an important technical mean for healthcare associated infection surveillance, it's necessary to further explore the improvement of real-time surveillance system.*

Keywords

Healthcare associated infection, surveillance system, effectiveness evaluation

1. Introduction

Healthcare associated infection (HAI) surveillance is one of the critical measures for prevention and control infections. Through continuous, systematic and long-term surveillance, we can master the prevalence and the distribution characteristics of HAIs, the focus of prevention and control, as well as evaluating the effectiveness of prevention and control measures (Antonioli, Bolognesi, Valpiani, Morotti, Bernardini, Bravi, Di Ruscio, Stefanati, & Gabutti, 2020). The case surveillance is the basis for HAI surveillance. In the past, the case surveillance was mainly obtained through the active reporting from clinicians and the retrospective review of medical record form discharged patients by infection prevention and control practitioners (IPCP), which was time-consuming and labor-intensive, and was impossible to surveillance in real-time (Zhang, Du, Johnston, Andres, Suo, Yao, Huo, Liu, & Fu, 2019).

Information technique has been applied in HAI surveillance, along with the structuration and improvement of information system in hospital and the development in hospital management (Scardoni, Balzarini, Signorelli, Cabitza, & Odone, 2020). Possible infectious cases were distinguished and pushed by the real-time surveillance system via setting reasonable screening rules, which can be timely diagnosed by the clinicians, with a higher efficiency and a lower omission. It is deserved growing concern to use the hospital infection system more reasonably and scientifically, so as to improve the quality of HAIs management. Evaluation in the early warning capacity and accuracy of surveillance system accompanied with implementation of adjustment measures is an important way to improve the early warning efficiency of surveillance system.

2. Method

2.1 Data Collection

We collected the data from patients who had been hospitalized for above 48 hours in a traditional Chinese medicine (TCM) hospital in Wuxi from January to December 2020.

2.2 Surveillance Method

Prospective surveillance was carried out with the help of a real-time healthcare associated infection surveillance system (RT-HAISS). There were four specific methods. (1) The suspicious cases were picked out automatically by this system, and then confirmed or excluded by both clinicians and IPCP. (2) The HAIs were distinguished and reported voluntarily by clinicians, approved subsequently by IPCP. (3) The suspicious cases were found out from the target surveillance, such as the target surveillance of intensive care units. (4) The underreported cases were spotted from the quality control of special cases such as death, serious disease patients, which were treated as underreported cases by IPCP.

2.3 Alarm Strategy

The RT-HAISS is based on routine process data collected in various hospital databases. All inpatient infection-related data is extracted by the RT-HAISS from electronic systems such as the Hospital Information System (HIS), Laboratory Information Management System (LIS), Operation Anesthesia System (OAS), and Electronic Medical Record (EMR). Suspicious infections are screened by multiple indicators based on the microbiological reports, physical signs, antibiotics administration record, serological and molecular test reports, and body temperature records. Different types of HAIs have specific screening strategies. The RT-HAISS daily automatic alerts the IPCP and clinicians about suspicious infections (occurring at least 48h after admission) combined data within 7 days. The IPCP manually review medical records and confirm suspicious cases according to the criteria. Indicators are included as below: (1) Positive microbial cultures of pathologic specimens, including blood cultures, sputum cultures, and urine cultures. (2) Use of antimicrobial drugs at least 48h after admission. (3) Abnormal leukocytes and neutrophils in routine laboratory tests (including blood, urine, feces, cerebrospinal fluid, pleural fluid, abdominal fluid, etc.). (4) Abnormal non-specific infection-related indicators, including procalcitonin and C-reactive protein. (5) Symptoms of infection, including fever at 37.5 ℃ or more for at least 2 days. (6) Physical sign records in the EMR, etc.

2.4 Evaluation Index

The following indexes were used to evaluate the alarm methodology.

(1) Sensitivity= Confirmed HAIs identified by the RT-HAISS / HAIs during the same period ×100%

(2) Specificity= Uninfected cases determined by the RT-HAISS /Uninfected cases during the same period ×100%.

(3) Positive predictive value = Confirmed HAIs identified by the RT-HAISS /Early warning cases during the same period ×100%.

(4) Negative predictive value = Uninfected cases determined by the RT-HAISS / Cases not warned during the same period ×100%.

(5) Youden index = Sensitivity + Specificity - 1

(6) False alarm rate = False alarm results by the RT-HAISS / Alarm results during the same period × 100%.

2.5 Case Definition

The HAIs definition is in accordance with the Nosocomial Infection Diagnostic Criteria (2001) published by the National Health Commission of the People's Republic of China (NHC). HAIs are infections acquired more than 48 h after admission, and not present or incubated at admission. In this study, HAIs also include the following situations: first, infections present on admission if related to a prior hospitalization in the same hospital. Second, a new infection episode occurring at a different body site (excluding migratory sepsis lesions) or a different type of organism was considered as a new episode (excluding contamination and mixed infection).

2.6 Statistical Analysis

Data analysis was carried out by using Excel 2013.

3. Results

3.1 Generality

A total of 29074 patients were enrolled in 2020, among which there were 466 HAI cases with at least one episode, and the incidence rate was 1.60%.

In 466 cases, 304 cases were correctly identified by the RT-HAISS, 160 cases were derived from clinicians, and 2 cases were spotted from quality control of special cases. The RT-HAISS warned the monitors a total of 1715 cases, with 2040 early warning entries and 1736 false alarm entries.

The sensitivity and the specificity were 65.24% and 95.74%, respectively. The Youden index was 0.62. In addition, the positive predictive value was 14.90%, and the negative predictive value was 83.86%, with 85.10% of false alarm rate.

3.2 Effectiveness of Ward

Table 1 presented the sensitivity, specificity, Youden index, positive predictive value, negative predictive value, and false alarm rates for each ward in this hospital. The results indicated that excellent sensitivity was exhibited in the surgical ward, followed by medicine ward. The excellent positive predictive value was exhibited in the ward of orthopedics and traumatology, followed by medicine ward. The great specificity was exhibited in each ward, which was above 94%, and the highest specificity and negative predictive value were exhibited in the ward of gynecology and pediatrics. The results indicated that excellent Youden index was exhibited in surgical ward, while the highest false alarm rate was exhibited in the ward of gynecology and pediatrics.

Table 1. Evaluation in the ward

Specialty of ward	HAIs	Alarm results	Correct alarms	Uninfected cases	Non-Alarm cases	Sensitivity (%)	Specificity (%)	Youden index	Negative predictive value (%)	False alarms	False alarm rate (%)
Orthopedics	129	311	65	6044	5842	50.39	96.66	0.48	95.10	246	79.10
Gynecology and Pediatrics	6	30	3	1321	1306	50.00	98.86	0.59	83.29	27	90.00
Medicine	246	1206	173	9994	9435	70.33	94.41	0.67	77.30	1033	85.66
Surgery	85	493	63	6735	6484	74.12	96.27	0.69	85.42	430	87.22
Total	466	2040	304	24094	23067	65.24	95.74	0.62	83.86	1736	85.10

3.3 Effectiveness of Infection Sites

Table 2 presented the sensitivity, specificity, Youden index, positive predictive value, negative predictive value, and false alarm rates for all infection sites. The results indicated that bloodstream infection event (BSI) exhibited the highest sensitivity, followed by urinary tract infection (UTI). The RT-HAISS presented lower alarm response for abdomen/ gastrointestinal system infection (AD/ GI), surgical site infection (SSI), bone and joint infection (BJI), and seemed to have no response for oral infection (OI).

The BSI, SSI and UTI demonstrated the excellent positive predictive value, with values exceeding 92%, while the respiratory infection (RI) exhibited the lowest positive predictive value. More than that, RI exhibited the highest false alarm rate. Nevertheless, the BSI and SSI exhibited the lower false alarm rates, excellently.

Table 2. Evaluation of Infection Sites

Infection sites	Cases	Alarm results	Correct alarms	False alarms	Sensitivity(%)	Positive predictive value(%)	False alarm rate(%)
RI	193	1840	138	1702	71.50	7.50	92.50
BSI	31	28	27	1	87.10	96.43	3.57
AD/ GI	26	18	13	5	50.00	72.22	27.78
UTI	113	97	90	7	79.65	92.78	7.22
SSI	42	22	21	1	50.00	95.45	4.55
Skin and soft tissue	8	7	6	1	75.00	85.71	14.29
BJI	2	2	1	1	50.00	50.00	50.00
OI	2	0	0	0	0.00	-	-
Other	49	26	8	18	16.33	30.77	69.23
Total	466	2040	304	1736	65.24	14.90	85.10

4. Discussion

In a real-time surveillance system, the alarm sensitivity directly affects the quality of HAIs surveillance. Making evaluation and improvement in the surveillance system is essential to boost alarm effectiveness, as well as to reduce workload in manual surveillance and under-reporting of HAIs. In this study, we carried out a comprehensive evaluation of the RT-HAISS, and the results showed a sensitivity value of 66.12%, and a specificity value of 95.74%. In the setting rules of the RT-HAISS, the fever warning value was set as 37.5℃ or more for at least 2 days to reduce the under-reporting results, which was stricter than the limit value set as either 38℃ or more for at least 2 days or 37.5℃ or more for at least 3 days (Zhang, Du, Johnston, Andres, Suo, Yao, Huo, Liu, & Fu, 2019). Therefore, the sensitivity of the RT-HAISS decreased and the specificity increased, subsequently.

The Youden index is a comprehensive index of sensitivity and specificity. In this study, the Youden index was 0.62, which suggested to achieve a certain effectiveness. The higher positive predictive value means the less invalid alarms reserved to be handled manually. In this study, the positive predictive value was 17.57%, and the false alarm rate was 85.10%, which indicated there were plenty of invalid alarms in daily surveillance.

The RT-HAISS achieves suspicious cases confirmation in form of every infection site, integrating information about laboratory results, specimen results and physical signs, which is different from surveillance system just giving out alarms of abnormal results. Meanwhile, The RT-HAISS also has the function of reverse investigation which can exclude noninfectious cases by assigned negative value to relevant medical records. The false alarm rate reported in our study reflected the function of reverse investigation was not well utilized in case exclusion, thus, the efficiency of early warning decreased.

All evaluation indicators were variant in the effectiveness of ward. The excellent sensitivity and the excellent positive predictive value were exhibited in the surgical ward and orthopedic ward, respectively. It was suggested that the alarm indicators should be set reasonably according to distribution characteristics of HAIs in different ward. The BSI exhibited the highest sensitivity and positive predictive value, with the lowest false alarm rate.

There were some deficiencies in this study. The capturing rules of the RT-HAISS reported in this study are different from those in other reports, which confirmed suspicious cases synthesizing multiple indexes concerned with patients, so it was not implemented to assess the sensitivity of each index. Besides, the RT-HAISS incorporated common information related to infection except information such as radiography, pathology, which could be further explored in the improvement of real-time surveillance system.

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