# Evaluation of manual and electronic healthcare-associated infections surveillance: a multi-center study with 21 tertiary general hospitals in China

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**Background:** Healthcare-associated infections (HAIs) are still a major health threats worldwide. Traditional surveillance methods involving manual surveillance by infection control practitioners (ICPs) for data collection processes are laborious, inefficient, and generate data of variable quality. In this study, we sought to evaluate the impact of surveillance and interaction platform system (SIPS) for HAIs surveillance compared to manual survey in tertiary general hospitals.

**Methods:** A large multi-center study including 21 tertiary general hospitals and 63 wards were performed to evaluate the impact of electronic SIPS for HAIs.

**Results:** We collected 4,098 consecutive patients and found that the hospitals installed with SIPS significantly increased work efficiency of ICPs achieving satisfactory diagnostic performance of HAIs with

 

0.73 for sensitivity, 0.81 for specificity and 0.81 area under the curve (AUC). However, there were significant heterogeneity own to regions, time of SIPS installation, departments and sample size.
**Conclusions:** SIPS significantly improved ICPs efficiency and HAIs monitoring effectiveness, but there were shortcomings such as untimely maintenance and high cost.

**Keywords:** Healthcare-associated infections (HAIs); surveillance and interaction platform system (SIPS)

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## Introduction

Despite effort of control, healthcare-associated infections (HAIs) are still major health threats worldwide (1-6). Surveillance and feedback of HAIs rates to clinicians and other stakeholders is a cornerstone of infection prevention programs and also is recognized as one of core components comprise manageable and widely applicable ways to prevent HAIs and improve patients' safety (3). Traditional surveillance methods involving manual surveillance by infection control practitioners (ICPs) for data collection processes are laborious, inefficient, and generate data of variable quality. It has been reported that up to 36–45% of infection prevention staff time is dedicated to undertaking surveillance (7-9). Developments in information technology have propelled a movement toward the use of standardized electronic surveillance system (ESS) in assisting ICPs in improving the efficacy of HAIs detecting (10,11) and 23–56% of facilities in USA have ESS (12). ESS was clearly encouraged to adopt in items of tertiary hospital certification (THC) to assist ICP in HAIs surveillance. HAI automatic surveillance and interaction platform (SIPS) is one of the most popular ESS and widespread chosen (13). Despite widespread availability, there is still absence of understanding barriers to implementing SIPS. In this study, we sought to evaluate the impact of SIPS for HAIs surveillance compared to manual survey in tertiary general hospitals.

## Methods

We conducted a multi-center study in China with 21 tertiary general hospitals (13 academic and 8 non-academic centers). All recruited hospitals have adopted SIPS to monitor HAIs. Detailed flow diagram of SIPS was demonstrated in *Figure 1*. The SIPS would collect suspected cases for ICPs, then ICPs and clinicians online interacted and confirmed HAIs finally (*Figure 1*). This study included three stages and was approved by Institutional Review Board (No. 2019-SR-083) and each hospital received permission to participate in this study and sign a cooperation agreement. HAIs complied with CDC/NHSN surveillance definition of HAIs and criteria for specific types of infections in the acute care setting. In the first stage, a cross-sectional study was performed to investigate all the characters of hospitals and SIPS (beds, settings, year of ESS installment, HAI warning strategy and ESS problems). In the second stage. We selected indicators [incidence rate of HAIs, rate of miss-report HAIs, incidence rate of MRSA, CRE, CRAB and CRPA, incidence rate of central line-associated bloodstream infections (CLABSI), incidence rate of ventilator associated pneumonia (VAP) and incidence rate of catheter associated urine tract infections (CA-UTI)], which released by National Health Commission in 2015 (14). A retrospective before-after study of SIPS strategy was conducted to compare these indicators changes after SIPS installed (indicators after ESS one whole year *vs.* indicators before ESS one whole year). In the last stage, we performed a prospective study in 63 wards from 21 hospitals [20 neurosurgical wards, 19 general intensive care units (ICUs), 15 hematology wards, 6 neurology wards, 2 surgical ICUs and 1 vascular surgery ward]. All consecutive cases were judged manually by senior physician/ICP and the patient's attending physician to determine whether they belonged to HAIs (gold standard) while the SIPS were applied to monitor the same cases in parallel. The incidence rate was calculated as the number of patients with HAIs divided by total number of beds and expressed per 100 beds with 95% confidence interval (CI). We calculated sensitivity and specificity for SIPS testing of HAIs. Summary receiver operating characteristic (SROC) curves were used to summarize the diagnostic accuracy of the results (15), and the area under the curve (AUC) was

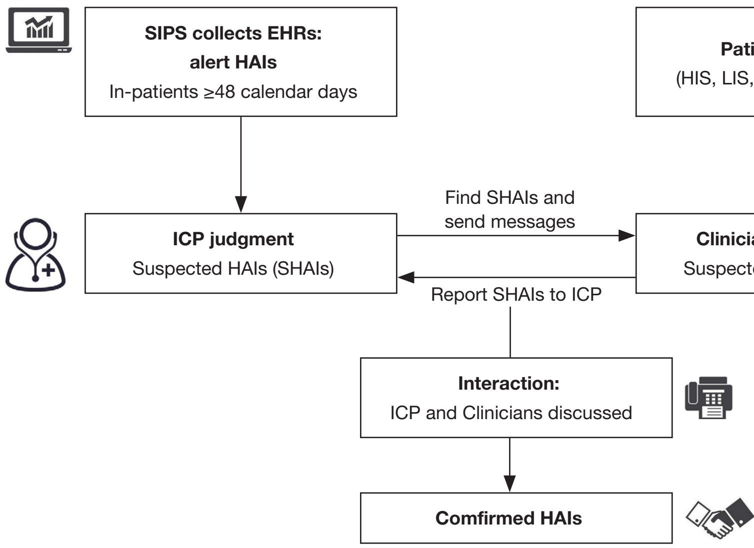


**Figure 1** Flow diagram demonstrating the SIPS. SIPS, surveillance and interaction platform system; HAI, healthcare-associated infection; HASIP, healthcare-associated infection automatic surveillance and interaction platform; EHRs, Electronic health records; AOS, anesthesia operation system; HIS, hospital information system; ICP, infection control practitioner; LIS, laboratory information system; PACS, picture achieving and communication system.

estimated to evaluate the diagnostic performance. AUC values of ≥0.97, 0.93–0.96, and 0.75–0.92 were considered to be excellent, very good and good diagnostic accuracy, respectively. $I^2$ statistic was used as the preferred measure of variance to describe the heterogeneity of total variation in study and the random effects model approach was selected as study heterogeneity because of the variance. Potential sources of heterogeneity were investigated by meta-regression. Stata/SE 15.1 for Windows (College Station, TX, USA) and Review Manager software (Version 5.3, The Nordic Cochrane Centre) were used for data analysis.

## Results

The flowchart of SIPS was shown in *Figure 1*. In all, 21 tertiary general hospitals and 63 wards participated in this study. In the retrospective study, there were 27,030 HAIs among 1,143,457 patients in SIPS group and 16,791 HAIs among 938,117 patients in Without-SIPS group, and SIPS would significantly assist to detect more 1.5-fold new HAIs cases [odd ratio (OR) =1.50, 95% CI, 1.14–1.96]. In the subgroup study, we found SIPS would detect more 1.64-fold incidence of MRSA (OR =1.64, 95% CI, 1.05–2.56), 1.98-fold CRE (OR =1.98, 95% CI, 1.12–3.53), 2.21-fold CRAB (OR =2.21, 95% CI, 1.46–3.37) and 1.39-fold CR-UTI infection (OR =1.39, 95% CI, 1.01–1.90) and decrease 58% miss report rate of HAIs (OR =0.42, 95% CI, 0.30–0.59) (*Table 1*). In the prospective study, we collected 4,098 consecutive patients in 21 hospitals with 63 wards. The pooled sensitivity and specificity of SIPS for HAIs were 0.73 (95% CI, 0.67–0.78) and 0.81 (95% CI, 0.75–0.86), respectively (*Figure 2*) while there was significantly heterogeneity. The SROC curve revealed an AUC of 0.81 (95% CI, 0.77–0.84) (*Figure 3*). To reveal the sources of heterogeneity in this study, we performed a meta-regression analysis with the covariates including "early warning strategy difference (imaging examination, body temperature, serum inflammatory bio-markers, etc.)" "study areas" "beds of hospitals" "install year of SIPS" "wards (ICU or non-ICU)", and "sample size" were assessed. We found that all of them showed significant influence on heterogeneity.

The inter-quartile range (IQR) of time saving identified varied from 50% to 90% (median: 76%), while all selected hospitals have some comments for SIPS, such as slow maintenance and frequent vulnerabilities (52.38%, 11/21 hospitals), unstable maintenance staff (71.43%, 15/21 hospitals), service attitude problem (33.33%, 7/21 hospitals) and high maintenance costs (42.86%, 9/21 hospitals).

## Discussion

Ten years ago, nosocomial infection monitoring was mainly

**Table 1** SIPS significantly detected more HAI retrospective studies in 21 hospitals

| Category | Number of studies | SIPS | | Control (without SIPS) | | OR (95% CI) | $I^2$ (%) |
|---|---|---|---|---|---|---|---|
| | | Number of HAIs in 1 year | Total patients in 1 year | Number of HAIs in 1 year | Total patients in 1 year | | |
| Incidence of HAIs | 21 | 27,030 | 1,143,457 | 16,791 | 938,117 | 1.50 (1.14–1.96) | 99 |
| Incidence of MRSA infection | 19 | 1,489 | 975,061 | 864 | 887,957 | 1.64 (1.05–2.56) | 95 |
| Incidence of CRE infection | 17 | 768 | 929,886 | 378 | 848,072 | 1.64 (1.05–2.56) | 94 |
| Incidence of CRAB infection | 18 | 2,659 | 946,730 | 1,343 | 864,925 | 2.21 (1.46–3.37) | 97 |
| Incidence of CRPA infection | 15 | 761 | 799,662 | 439 | 730,696 | 1.46 (0.94–2.26) | 90 |
| Incidence of Type I SSI | 18 | 460 | 124,650 | 236 | 98,276 | 1.23 (0.86–1.74) | 74 |
| Incidence of VAP | 21 | 634 | 58,807 | 549 | 50,387 | 0.94 (0.79–1.12) | 48 |
| Incidence of CLABSI | 17 | 131 | 88,443 | 104 | 91,547 | 1.13 (0.84–1.51) | 7 |
| Incidence of CRUTI | 20 | 354 | 245,719 | 180 | 196,783 | 1.39 (1.01–1.90) | 56 |
| Miss report of HAIs | 15 | 1,730 | 17,685 | 1,748 | 12,964 | 0.42 (0.30–0.59) | 93 |

SIPS, surveillance and interaction platform system; HAI, healthcare-associated infection; MRSA, *Methicillin-resistant staphylococcus aureus*; CRE, *Carbapenem-resistant Enterobacteriaceae*; CRAB, *Carbapenem-resistant Acinetobacter baumannii*; CRPA, *Carbapenem-resistant Pseudomonas aeruginosa*; SSI, surgical site infection*; VAP, ventilator-associated pneumonia*; CLABSI, central line-associated bloodstream infection; CRUTI, catheter-related urinary tract infection.

manual and inefficient (16). For example, ICPs retrieved the microbial report from the laboratory, and then judged whether the patient has a nosocomial infection according to the results of microbial isolation and identification. However, there was a large underestimation of the risk of HAIs. ESS were wildly utilized to understand the nosocomial infections development (17-22). To date, our study firstly adopted large sample, multi-center studies to overall assess the impact of SIPS in the diagnosis of HAIs. Our study demonstrated that SIPS significantly improve ICPs work efficiency, detecting more HAIs which was consistent with Du *et al.*'s findings which SIPS assisted ICPs to deal with 70 new suspicious HAIs cases in one large volume hospital with 3,500 inpatients each day (13). Moreover, in the subgroup study, we found SIPS would significantly detect more 1.64-fold MRSA, 1.98-fould CRE, 2.21-fould CRAB and 1.39-fold CR-UTI and decrease 58% miss report rate of HAIs.

In the prospective study, we found SIPS maintained high levels of sensitivity (0.73, 95% CI, 0.67–0.78) and specificity (0.81, 95% CI, 0.75–0.86), and yields considerable dividends in ICPs staff time (median 76%, 95% CI, 50–90%). Our data demonstrated that adopting SIPS considerably improved the capacity for HAIs surveillance for ICPs staff. Interestingly, in the meta-regression study, we found that there was significant heterogeneity in sensitivity and specificity which affected by regions, hospital scale (bed number), system installation time, early warning strategy and wards. Meanwhile, SIPS was a purely commercial software that requires a lot of manpower, material and financial resources to update and maintain timely (23,24). In this case, SIPS has shortcomings in collecting data as a regional HAI monitoring platform, resulting in insufficient inter-regional comparability which should be considered carefully.

## Conclusions

This study is the first large-scale multi-center study in tertiary general hospitals in China to comprehensively evaluate the effectiveness of SIPS. We demonstrated that SIPS significantly improved ICPs efficiency and HAIs monitoring effectiveness, but there were shortcomings such as untimely maintenance and high cost. In the choice of monitoring software of HAIs, the hospital needs to fully consider the scale, volume, monitoring purposes, the characteristics of the target population and the defect of the software itself (23,25).

 

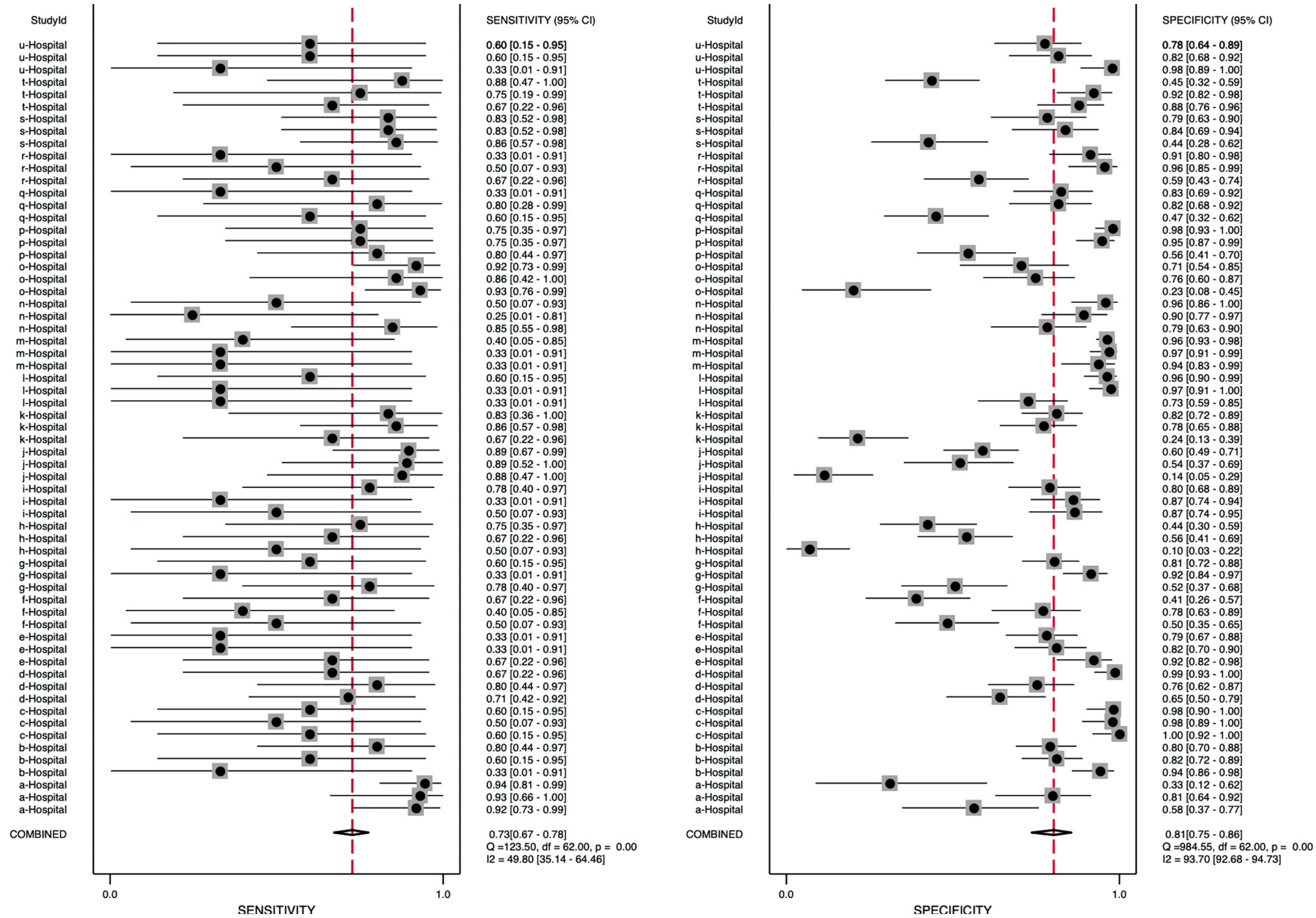


**Figure 2** SIPS *vs.* manual survey for HAIs in a multi-center study with 21 tertiary general hospitals and 63 wards. SIPS, surveillance and interaction platform system; HAI, healthcare-associated infection.

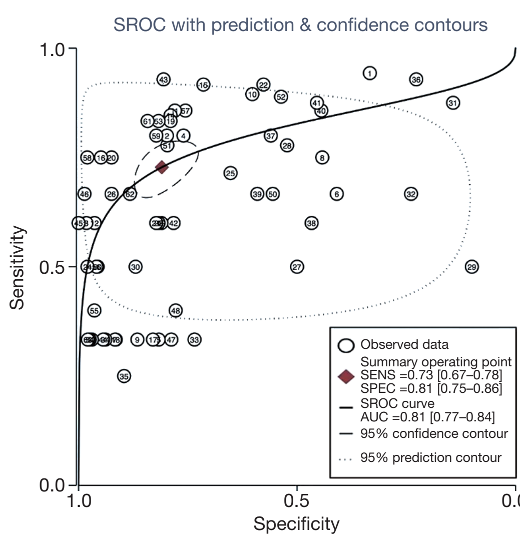


**Figure 3** SROC curve of SIPS *vs.* manual survey for HAIs in a multi-center study with 21 tertiary general hospitals and 63 wards. SIPS, surveillance and interaction platform system; HAI, healthcare-associated infection; SROC, summary receiver operating characteristic.

 

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was approved by Institutional Review Board (No. 2019-SR-083) and each hospital received permission to participate in this study and sign a cooperation agreement. Written informed consent was obtained from all patients.

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