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Original Article

Use of personal digital assistants to detect healthcare-associated infections in a neonatal intensive care unit in Egypt

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Abstract

Introduction: Personal digital assistants (PDAs) used in electronic laboratory-based surveillance are a promising alternative to conventional surveillance to detect healthcare-associated infections (HAIs). The aim of the study was to monitor, detect, and analyze HAIs using PDAs in a neonatal intensive care unit (NICU).

Methodology: In this descriptive study, 1,053 neonates admitted to the NICU in the obstetrics and gynecology ward at the Cairo University hospital were included and evaluated for HAIs by collecting data using PDAs programmed by Naval Medical Research Unit 3, Cairo, with the definitions for HAIs provided by the National Healthcare Safety Network of the Centers for Disease Control and Prevention. Case records were reviewed three times a week over 19 months, from March 2012 to September 2013.

Results: Of 124 suspected episodes of infection recorded in PDAs, 89 confirmed episodes of infection were identified. HAI and NICU infection rates were 7.4 and 2.72/1,000 patient-days, respectively. Primary bloodstream infection was detected in 81 episodes and pneumonia in 8 episodes. The majority of infections (62%) were acquired in the ward before NICU admission. *Klebsiella* spp. was isolated most frequently (42%), followed by coagulase-negative *Staphylococci* (31%).

Conclusions: This study is the first to report the use of PDAs in surveillance to detect HAIs in the NICU in our hospital. The majority of infections were acquired at the obstetric care department, indicating the importance of implementing rigorous prevention and control programs and a more detailed surveillance to identify other risk factors for infections.

Key words: personal digital assistant; healthcare-associated infections; surveillance; neonatal intensive care unit.

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Introduction

Healthcare-associated infections (HAIs) represent a major burden and safety issue for patients worldwide, and are a leading cause of morbidity and mortality among hospitalized patients [1-3]. The Centers for Disease Control and Prevention (CDC) defines HAI as a localized or systemic condition resulting from an adverse reaction to the presence of an infectious agent(s) or its toxin(s), with must be no evidence that the infection was present or incubating at the time of admission to the acute care setting [4]. They estimate that 1.7 million people develop HAIs and 75,000 people die of HAI-related complications annually, with an estimated incidence of 4.5 per 100 patients in 2002 [5]. In Europe, the average prevalence of HAIs reported by the European Centre for Disease Prevention and Control (ECDC) is 7.1 per 100 patients [6]. Developing countries reported a substantially higher prevalence (15.5 per 100 patients) [7], and the estimated pooled overall HAI density in adult intensive care units was 47.9 per 1,000 patient-days [7], which is almost four times higher than HAI densities reported from the United States (13.6 per 1,000 patient-days) [5].

Nevertheless, the magnitude of the problem in developing countries remains underreported and underestimated largely because HAI diagnosis is complex and requires ongoing surveillance activities. Surveillance is defined as the ongoing systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health [8-10]. Accurate surveillance is crucial to identify areas for improvement and to measure the impact of infection prevention initiatives and practices. Traditional methodologies for HAI surveillance can be resource intensive, time consuming, and can require expertise and resources for data collection, analysis, and interpretation. Additionally, conventional methods are subject to intentional and unintentional misclassification, are difficult to audit, and are prone to inter-observer variability. Algorithmic analysis of electronic health data is a promising alternative to the traditional conventional surveillance. Algorithms that seek combinations of diagnosis codes, microbiological analysis results, and/or antimicrobial dispensing can identify HAIs with sensitivities and positive predictive values that often match or surpass those of conventional surveillance [4,11].

In Egypt, a surveillance project was developed by the Infection Control Unit at Naval Medical Research Unit-3 (NAMRU-3) in collaboration with the Cairo University hospital's [Promotion of Quality and Safety of Healthcare in Egypt], which focused on active prospective surveillance of HAIs in neonatal intensive care units (NICUs) [12]. All types of HAIs were subject to evaluation, and standardized CDC case definitions (defined as standardized criteria used to determine if a person has specific disease, condition or outcome, and usually incorporate clinical laboratory or other diagnostic criteria) were applied according to those published by the CDC's National Healthcare Safety Network [4]. Personal digital assistants (PDAs) developed by NAMRU-3 for monitoring and detecting HAIs in NICUs were used in the surveillance. This project provided the first documented use of PDAs for HAI surveillance in Egypt [13]. The aim of the study was to describe, monitor, detect, and analyze HAIs in NICU by using PDAs.

Methodology

Study setting

This study was conducted at the NICU (28 incubators) of the department of obstetrics and gynecology, Kasr Al-Aini Hospital, Faculty of Medicine, Cairo University.

Subjects

All neonates (n = 1,053) admitted to the NICU and delivered in the obstetric care department in the hospital over a 19-month period, from March 2012 to September 2013, were enrolled, monitored, and analyzed for HAIs based on CDC case definitions [4]. The data from subjects with suspected HAIs, defined as subjects suspected of having infections based on clinical examination by clinicians, were recorded into PDAs by qualified and trained NICU nurses. The research ethics committee of the Department of Public Health and Community Medicine, Faculty of Medicine, Cairo University approved the protocol.

Study tools

The tools used in this study included paper-based case report form and data entry. Data were initially collected using a screening log book, a case report log book, and a denominator sheet [13]. In the screening log book, data on all subjects were recorded from the time of enrollment until discharge and included full name, hospital admission number, ICU admission date, patient entry code, date and type of HAI. The case report log books were divided into the following sections: registration data; clinical data; investigations, which included results of laboratory and culture tests, and imaging studies performed; and PDA data, which included the start and end dates of PDA data entry, the organism isolated, and outcome of entered case. The denominator for NICU form included daily recording of number of patient-days and device days based on the birth weights of the neonates (< 750 gm, 751–1,000 gm, 1,001–1,500 gm, 1,501–2,500 gm, and >2,500 gm).

In the PDA-based direct data entry, HP iPAD PDAs and QM software (Questionnaire Mobile) model 210 was used for verifying suspected cases of HAIs. PDAs were divided into two main sections: (a) the **s**uspected HAI section, which included demographic characteristics, admission data, clinical data, investigations, and outcome sections, and (b) the culture section, which identifies types of organisms causing different types of HAIs.

Study design

A descriptive study was used to detect HAIs as part of an active surveillance in NICUs and included the following types of infections: bloodstream infection (BSI), ventilator-associated pneumonia (VAP), central line-associated BSI (CLABSI), catheter-associated urinary tract infection (CAUTI). Total and NICU infection rates were calculated per 1,000 patient-days.

Surveillance by PDAs

NICU nurses joined pediatricians during their clinical rounds three days per week to identify neonates with suspected signs or symptoms of infections.

Specimens were collected on admission per the standardized NICU protocols and based on standardized general and specific infection parameters. Data for NICU patients with suspected infections were extracted from patient files and case report log books, and were entered into the PDAs. In addition, results of laboratory investigations, microbiologic cultures, and imaging studies were all recorded in the PDAs. The PDAs were programmed to alert the medical team if the patient had an infection and what type of infection it was.

Infections occurring in newborns with an event date on day 1 or day 2 of hospital stay were considered to be present on admission, whereas those occurring on day 3 or later were considered HAIs [14]. Data recorded in the PDAs were electronically transferred from the NICU to NAMRU-3 on a weekly basis for data cleaning and analysis by information technology personnel [13] and were presented on an Excel spreadsheet.

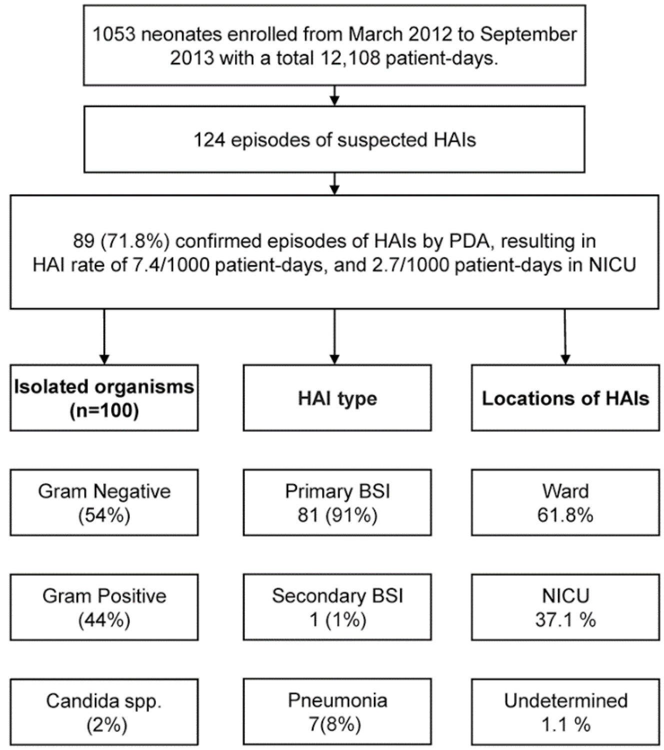
Statistics

Data analysis was done using SPSS version 15 (IBM, Armonk, USA). Simple frequency tables and cross-tabulations were generated to describe qualitative data. Measures of central tendency (mean and median) and measures of dispersion (standard deviation [SD] and range) were used to describe quantitative data.

Results

A total of 1,053 neonates were enrolled from March 2012 to September 2013, with a total of 12,108 patient-days. During this 19-month period, 124 episodes of suspected HAIs were recorded in PDAs. The mean age of suspected HAI cases at the time of hospital admission was 1.88 (range, 0–175 days), at the time of ICU admission was 3.03 (range, 0–183 days), and at the time of discharge was 27.85 (range, 1–204 days). The mean duration ± SD of ICU stay for suspected cases was 23.9 ± 18.2 days, and the median was 21.5 days (range, 1–77). Two-thirds of the suspected cases (67.7%) were males and 82.3% were low birth weight (LBW) (≤ 2,500 gm): 23.4% were 1,501–2,500 gm, 43.5% were 1,001–1,500 gm, and 15.3% were <1,000 gm (Table 1). Of the 124 suspected cases of HAI, the admission diagnosis was preterm (PT) and respiratory distress syndrome (RDS) in 32 (25.8%) subjects, followed by PT RDS white lung in 21 (16.9%), then RDS in 14 (11.3%) cases. Of the 124 suspected BSI cases, 37 (29.8%) subjects were discharged, 34 (27.4%) died, and in 53 subjects (42.7%), the outcome was undetermined since they were still in the NICU (Table 1).

Figure 1. Study Flow Diagram.



HAI: healthcare-associated infection; PDA: personal digital assistant; NICU: neonatal intensive care unit; BSI: bloodstream infection.

A study flow diagram (Figure 1) shows the total number of studied cases (1,053), with 12,108 patient-days, 124 suspected episodes of infections, 89 (71.8%) confirmed episodes of HAIs, HAI rates (total and NICU), isolated organisms, HAI types, and locations of infections.

Of those, 66.3% were males and 84.3% were LBW (≤ 2500 gm): 22.5% were 1,501–2,500 gm, 43.8% were 1,001–1,500 gm, and 18% were< 1,000 gm (Table 1). Of the 89 confirmed BSI episodes, 56 (62.9%) were mechanically ventilated neonates, 6 (6.7%) had central vascular catheters, and 3 (3.4%) had urinary catheters (Table 1). The mean age of confirmed cases at the time of hospital admission was 1 day (range, 0–50 days), at the time of ICU admission was 2.1 days (range, 0–78 days), and the mean age at the time of infection was 9.5 days (range 0–78 days). The mean duration of NICU stay for those discharged at the time of the surveillance was 24.1 days (range, 1–72 days), and the mean age at the time of discharge 25.9 days (range, 1–72 days).

Table 1. Characteristics of suspected and confirmed cases of healthcare-associated infections (HAIs).

	Suspected cases (n = 124)	Confirmed cases (n = 89)
Gender		
• Male	84 (67.7%)	59 (66.3%)
• Female	40 (32.3%)	30 (33.7%)
Age (days) at the time of hospital admission: mean ± SD (range)	1.9 ± 16.4 (range 0-175)	0.63 ± 5.33 0-50 days
Age (days) at the time of NICU admission: mean ± SD (range)	3.03 ± 18.28 (0–183)	2.1 ± 9.7 (0–78)
Median (range) duration of ICU stay (days)	27.85 (1–204 days)	24.1 (1–72 days)
Birth weight		
• < 750 gm	5 (4.0%)	3 (3.4%)
• 751–1,000 gm	14 (11.3%)	13 (14.6%)
• 1,001–1,500 gm	54 (43.5%)	39 (43.8%)
• 1,501–2,500 gm	29 (23.4%)	20 (22.5%)
• > 2,500 gm	22 (17.7%)	14 (15.7%)
Risk factors		
• Central venous lines	10 (8.1%)	6 (6.7%)
• Mechanical ventilation	83 (66.9%)	56 (62.9%)
• Urinary catheters	5 (4%)	3 (3.4%)
Device utilization rates*		
• Central venous lines	2.89	2.89
• Mechanical ventilation	1.3	1.3
• Urinary catheters	25.47	25.47
Outcome		
• Discharge	37 (29.8%)	28 (31.5%)
• Death	34 (27.4%)	22 (24.7%)
• Missing	53 (42.7%)	39 (43.8%)

*(No. of device days/no. of patient-days) × 100.

Table 2. Characteristics of confirmed cases of healthcare-associated infections (HAIs).

	Total number (%) (n = 89)
HAI type	
• Primary BSI	81 (91)
• Secondary BSI	1 (1)
• Pneumonia	7 (8)
Infection place	
• Ward	55 (61.8)
• ICU	33 (37.1)
• Missing	1(1.1)
HAI rate	7.4/1,000 patient days
NICU infection rate	2.72/1,000 patient days
Investigations	
• Blood culture (primary BSI)	81(91)
• Blood culture (pneumonia associated)	8 (9)
• Imaging studies (pneumonia X-ray 1)	3 (3.4)
• Imaging studies (pneumonia X-ray 2)	6 (6.7)
• LRT abscess	2 (2.2)
• Leucocytosis	9 (10.1)
• Shift to the left	7 (7.9)

BSI: bloodstream infection; ICU: intensive care unit; LRT: lower respiratory tract.

HAIs were acquired in the NICU in 37.1% of the episodes and before admission to the NICU (*i.e.*, in the ward) in 61.8%; in 1.1%, the source was undetermined. Primary BSI was identified in 81 episodes (91%). Pneumonia cases were confirmed in 8 episodes (9%), which were acquired before admission to the NICU (*i.e.*, in the ward). The overall HAI density in this surveillance was 7.4 per 1,000 patients-days and 2.72 per patients-days in the NICU (Table 2).

Hypothermia, apnea, and hypotension were the most frequent presenting features (13.5%, 12.4%, and 7.9%, respectively) associated with confirmed healthcare-associated BSIs. Abnormal breathing and rhonchi were the presenting features in 11.2% of cases with pneumonia, followed by respiratory distress (10.1%) and increased respiratory secretions (9%) (Table 3).

Table 4 shows the microorganisms detected in different locations of infections (ward and NICU) and the associated mortality. A total of 100 organisms were isolated, and 89 episodes of confirmed HAIs were identified. Sixty percent of organisms isolated were acquired before admission to the NICU (*i.e.*, in the ward), and 40% were acquired in the NICU. Of the isolated organisms, 44% were Gram positive, while 54% were Gram negative. *Candida* spp. were isolated from (2%) of the infected neonates. *Klebsiella* spp. were the most frequently isolated organism and accounted for 42 (42%) of the identified isolates, followed by coagulase-negative *Staphylococci* (CoNS) (31; 31%), *S. aureus* (9; 9%), *Pseudomonas* spp. (7;

Table 3. Presenting features associated with confirmed healthcare-associated infections in the neonatal intensive care unit.

	Total number (%) (n = 89)
Features associated with bloodstream infection (n = 82)	
• Fever	1 (1.1)
• Hypothermia	12 (13.5)
• Apnea	11 (12.4)
• Bradycardia	4 (4.5)
• Hypotension	7 (7.9)
• Chills	0
Features associated with Pneumonia (n = 7)	
• Cough	5 (5.6)
• Sputum change	6 (6.7)
• Increase respiratory secretion	8 (9)
• Abnormal breathing	10 (11.2)
• Wheezing	8 (9)
• Rhonchi	10 (11.2)
• Rhonchi	9 (10.1)
• Tachypnea	3 (3.4)

Table 4. Microorganisms detected in different locations of infections and associated mortality.

Type of microorganisms	No. of organisms and location of infection, n (%)		Total * (100)	Deaths n = 27 (27%)
	Ward	NICU		
Gram negative (54%)				
Klebsiella spp.	24 (40)	18 (45)	42	13 (48)
Pseudomonas spp.	5 (8.3)	2 (5)	7	0 (0)
Escherichia coli	1 (1.7)	1 (2.5)	2	1 (4)
Serratia marcescens	2 (3.3)	0 (0)	2	0
Acinetobacter spp.	1 (1.7)	0 (0)	1	0
Gram positive (44%)				
Coagulase-negative *Staphylococci*	18 (30)	13 (32.5)	31	7 (26)
Staphylococcus aureus	7 (11.7)	2 (5)	9	3 (11)
Streptococcus viridans	1 (1.7)	1 (2.5)	2	1 (4)
Enterococcus spp.	1 (1.7)	1 (2.5)	2	1 (4)
Candida (2%)				
Candida spp.	0	2 (5)	2	1 (4)
Total	60	40	100	27

*Total number of isolated organisms; NICU: neonatal intensive care unit.

7%), *Streptococcus viridans* (2; 2%), *Enterococcus* spp. (2; 2%), *Serratia marscecens* (2; 2%), *Acinetobacter* spp. (1; 1%), and *Escherichia coli* (2; 2%). The mortality rates were highest with *Klebsiella* spp. (48%), followed by CoNS (26%). The lowest mortality rates were associated with *Pseudomonas* spp., *E. coli*, and *Serratia* spp. (Table 4).

The overall HAI density in this surveillance was 7.4 per 1,000 patient-days and 2.72 per 1,000 patient-days in the NICU. HAI incidence was 8.45% (defined as total number of infected cases × 100 / total number of patients, which equaled 8,900 / 1,053).

In this study, laboratory-confirmed BSIs occurred at a rate of 6.7 per 1,000 patient-days and accounted for 91% of all infection episodes. A total of 3 episodes were CLABSI, and the rest (78) were primary BSIs with no other site of infection identified. Of the neonates, 81 had at least one episode of positive culture, 9 had two episodes, and 1 had three episodes. Polymicrobial infection (two organisms in culture) was detected in 9 cases.

Discussion

In the present study, we established the use of PDA for monitoring HAIs in a cohort of 1,053 neonates who were admitted to the NICU over a 19-month period. The total number of patient-days was 12,108. The overall rate of HAIs was 7.4 per 1,000 patient-days, and in the NICU, it was 2.72 per 1,000 patient-days. BSI accounted for 91% of reported HAI episodes, and pneumonia accounted for 9%. The majority (> 80%) of the subjects were LBW neonates, and 63% were mechanically ventilated. Almost two-thirds (62%) of the confirmed HAIs were acquired before admission to the NICU (*i.e.*, in the ward), and more than one-third (37%) were acquired in the NICU.

Gram-negative bacteria were the most frequent causative agent in this study (54%), with *Klebsiella* spp. being the most frequently isolated organisms (42% overall, and 78% of the Gram-negative bacteria), consistent with data recently reported from Egypt [15] and other developing countries ,16,17]. CoNS, which is the most common pathogen implicated in nosocomial neonatal sepsis in developed countries [17], was the second most frequent isolated organism (31%) and the most common Gram-positive microorganism in this study (70%). However, in this study, only a single blood culture was obtained, and therefore contamination cannot be ruled out. The prominence of Gram-negative organisms such as *Klebsiella* spp. and the high frequency of *Staphylococcus aureus* (9%) isolated in the first week of life strongly suggest that lack of appropriate hygiene during labor and delivery, postnatal care, and redundant infection prevention measures are major contributors in the development of overwhelming infections and death in vulnerable newborns. To substantially reduce neonatal mortality in developing countries, low-cost interventions are needed to improve infection-control practices in the peripartum and neonatal period in both the obstetric care department and the ward before transfer to the NICU. Interestingly, group B *Streptococcus* (GBS), which is the leading infectious cause of neonatal morbidity and mortality in the United States and Europe [18], was not isolated in the studied population. Further studies may be needed to improve microbial identification techniques and to better define the burden of GBS maternal colonization and neonatal GBS disease.

In this study, most of the infections were acquired before admission to the NICU in the emergency obstetric care department; therefore, risk factors related to antenatal care such as chorioamnionitis, prolonged rupture of membranes, and antenatal corticosteroids were not reported in the surveillance and may have a role in infection outside the NICU. These risk factors should be included to enhance the surveillance of HAIs. Furthermore, infection control practices should aggressively target health facilities, as preventing transmission would ultimately reduce the number of neonatal infections.

In a recently published study describing HAIs in a tertiary hospital NICU in Egypt [15], 434 neonates were enrolled. The cumulative incidence of HAIs in the NICU was 28%, which is higher than the rate reported in this study. Similar to our results, BSIs accounted for 85% of HAI episodes, and pneumonia for 10%. The most common organism isolated was *Klebsiella* spp. The main risk factors identified on multivariate analysis were gestational age < 38 weeks (relative risk [RR], 1.63), birth weight < 1,500 g (RR, 1.39), mechanical ventilation (RR, 1.74), and surgical procedures (RR, 1.65). The mortality rate attributed to HAIs was 11.75%, and the extra length of hospital stay attributed to HAIs was 8 days [15].

Although we have a well-characterized study population, this study has some limitations, mainly because not all HAI cases were recorded in the PDAs. Inadequate recording was mainly due to staff shortage, overly busy staff, unwillingness, lack of expertise, or lack of motivation. All these factors combined hindered the optimal implementation of such a system. Underreporting in this study resulted in a lower-than-expected HAI rate of 7.4 per 1,000 patient-days, and in the NICU, 2.72 per 1,000 patient-days. Similar issues were reported by Koller *et al*. [19] in the monitoring of nosocomial infections in intensive care units (MONI ICU) surveillance results, a computerized system for automated identification and continuous monitoring of ICU-associated infections for 12 ICUs in Austria.

To overcome these shortcomings, well-trained and highly skilled motivated personnel should be assigned to ensure consistent recording and thorough documentation and to guarantee completeness and accuracy of the data.

Conclusions

This study recorded the first use of PDAs in our hospital to detect HAI episodes while saving personnel resources and generating fewer false-positive and false-negative results. Automated surveillance has an accurate, clearly defined medical knowledge base, unlike conventional manual surveillance methods that are based on positive cultures alone and are prone to generate both under-diagnosis (false-negatives) and over-diagnosis (false-positives) [20-22]. Conventional manual surveillances have limitations and weakness related to time constraints and human factors such as stress and fatigue, which can all negatively influence decision making. Subjectivity is also an important factor contributing to a lower performance of manual surveillance methods; despite the standardization of HAI detection rules, there are interpersonal variations of those rules, and even variations across time in the same person.

The widespread implementation of electronic data systems such as PDAs offers uniform, efficient surveillance within reach in the hospital units, at the actual time of suspicion of infection during the daily clinical rounds. We therefore strongly recommend the use of PDAs or mobile phones set up with simple programs for surveillance by pediatricians in NICU settings to enhance case management and practice for early detection of HAIs.

Authors' contributions

No one other than the named authors had a role in the gathering or preparation of data or in the writing of the manuscript. EF, AMS, JK, and YM designed the study, enrolled subjects, and collected the data. EF, DAS, and MH analyzed and interpreted the data and ensured the quality of the collected data. DAS ensured the quality of data entry and performed the statistical analysis. EF and MH wrote the first draft of the manuscript. All authors read and critically reviewed the manuscript and approved the final manuscript.

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