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Multimodal surveillance of healthcare associated infections in an intensive care unit of a large teaching hospital

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Key words: Healthcare associated infections, intensive care unit, active surveillance, environmental surveillance, behavioral surveillance, pathogen genotyping
Parole chiave: Infezioni correlate all'assistenza, terapia intensiva, sorveglianza attiva, sorveglianza ambientale, sorveglianza comportamentale, genotipizzazione dei patogeni

Abstract

Background. *Healthcare-associated infections (HAIs), or nosocomial infections, represent a significant burden in terms of mortality, morbidity, length of stay and costs for patients hospitalized in intensive care units (ICUs). Surveillance systems are recommended by national and international institutions to gather data on HAIs in order to develop and evaluate interventions that reduce the risk of HAIs.*
Study Design. *Here we describe the methodology and the results of the surveillance system implemented in the ICU of the Policlinico Umberto I, a large teaching hospital in Rome, from April 2016 to October 2018.*
Methods. *The multimodal infection surveillance system integrates four different approaches: i) active surveillance of inpatients; ii) environmental microbiological surveillance; iii) surveillance of isolated microorganisms; and iv) behavioral surveillance of healthcare personnel. Data were collected on catheter-related bloodstream infections, ventilation-associated pneumonia, catheter-associated urinary tract infections and primary bloodstream infections that developed in patients after 48 h in the ICU. For environmental surveillance 14 points were selected for sampling (i.e. bed edges, medication carts, PC keyboards, sink faucets). The system of active surveillance of HAIs also included surveillance of microorganisms, consisting of the molecular genotyping of bacterial isolates by pulsed-field gel electrophoresis (PFGE). From 1 November 2016, monitoring of compliance with guidelines for hand hygiene (HH) and proper glove or gown use by healthcare personnel was included in the surveillance system. After the first six months (baseline phase), a multimodal intervention to improve adherence to guidelines by healthcare personnel was conducted with the ICU staff.*
Results. *Overall, 773 patients were included in the active surveillance. The overall incidence rate of device-related HAIs was 14.1 (95% CI: 12.2-16.3) per 1000 patient-days. The monthly device-related HAI incident rate showed a decreasing trend over time, with peaks of incidence becoming progressively*

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lower. The most common bacterial isolates were Klebsiella pneumoniae (20.7%), Acinetobacter baumannii (17.2%), Pseudomonas aeruginosa (13.4%) and Staphylococcus aureus (5.4%). Acinetobacter baumannii and Klebsiella pneumoniae showed the highest proportion of isolates with a multidrug-resistant profile. A total of 819 environmental samples were collected, from which 305 bacterial isolates were retrieved. The most frequent bacterial isolates were Acinetobacter baumannii (27.2%), Staphylococcus aureus (12.1%), Enterococcus faecalis (11.1%), Klebsiella pneumoniae (5.2%) and Pseudomonas aeruginosa (4.7%). All Acinetobacter baumannii, Pseudomonas aeruginosa and Klebsiella pneumoniae environmental isolates were at least multidrug-resistant. Genotyping showed a limited number of major PFGE patterns for both clinical and environmental isolates of Klebsiella pneumoniae and Acinetobacter baumannii. Behavioral compliance rates significantly improved from baseline to post-intervention phase.

Conclusions. *By integrating information gathered from active surveillance, environmental microbiological surveillance, surveillance of bacterial isolates and behavioral surveillance of healthcare personnel, the multimodal infection surveillance system returned a precise and detailed view of the infectious risk and microbial ecology of the ICU.*

Introduction

Healthcare-associated infections (HAIs), also known as nosocomial infections, represent a significant burden for hospitalized patients in terms of mortality, morbidity, length of stay and costs, particularly for patients in intensive care units (ICUs) (1). According to the annual epidemiological report for 2016 of the European Centre for Disease Prevention and Control (2), which analyzed a total of 151,709 patients in 1494 ICUs (mostly mixed population general intensive care unit) from EU member states and the EEA, 8.4% of patients hospitalized in an ICU for more than two days were diagnosed with at least one ICU-acquired infection. Specifically, 6% had pneumonia (where 97% of cases were ventilation-associated pneumonia; VAP), 4% had a bloodstream infection (BSI; 44% of which were a catheter-related BSI; CRBSI) and 2% had a urinary tract infection (99% of which were a catheter-associated urinary tract infection; CAUTI). Moreover, a substantial proportion of these HAIs are due to antibiotic-resistant microorganisms. A recent study (3) pointed out that a third of all deaths associated with antibiotic-resistant bacteria in EU and EEA countries occur in Italy, which has the highest prevalence of antibiotic-resistant bacteria among these nations. It is now recognized that factors such as obsolete water supply systems, poor hygienic conditions in the ward, individual susceptibility of patients, inappropriate and prolonged use of antibiotics and invasive devices, and inadequate respect of guidelines on hand hygiene (HH) and barrier devices by healthcare personnel increase the incidence of HAIs (4-7).

To attempt to limit HAIs, several surveillance systems have been developed, providing effective tools for the control of these infections (8-10). These systems are widely recommended by various national and international institutions to gather data on HAIs, in order to develop and implement interventions that reduce the risk of nosocomial infections (11, 12). Such institutions emphasise the importance of establishing a systematic and continuous patient-based surveillance, using standardized criteria for HAI case definitions, and of integrating different monitoring strategies and professional input (5).

From April 2016, a multimodal surveillance system was implemented in the main ICU of the Policlinico Umberto I, a large teaching hospital in Rome. This paper aims to describe the methodology and results of this surveillance system from its introduction until October 2018.

Methods

Setting

The surveillance was conducted in the medical/surgical ICU of the Umberto I Teaching Hospital, Sapienza University of Rome, a 1200-bed public hospital. The ICU is divided into five rooms of two beds each, one large seven-bed room and one room for isolation. The ward staff consists of eight physicians, forty nurses and four healthcare assistants.

Surveillance system

The multimodal infection surveillance system integrates four different approaches: i) active surveillance focused on inpatients; ii) environmental microbiological surveillance; iii) surveillance focused on bacterial isolates; and iv) behavioral surveillance of healthcare personnel. The multidisciplinary team involved in the intervention included public health physicians, anesthesiologists/ resuscitators, microbiologists, infectious disease specialists and nurses, as well as members of the Health Directorate of the hospital.

Active Surveillance Focused on Inpatients

An operative protocol for the active surveillance system was based on the National Healthcare Safety Network (NHSN) protocol of the Center for Disease Control (CDC) (13), with reference to a protocol of the European Center for Disease Prevention and Control (ECDC) (14) – in particular as regards the diagnostic criteria of bloodstream infections. The protocol aimed to provide standard diagnostic criteria for the identification of cases of HAI; to describe the methods for analyzing data resulting from the monitoring of HAIs; and to provide instructions for drafting monthly and annual reports to estimate infection incidence rates.

All patients hospitalized in the ICU for at least two consecutive calendar days were included in the active surveillance until their discharge from the ICU. Blood infections related with central lines (catheter-related bloodstream infections; CRBSIs), pneumonia associated with mechanical ventilation (ventilation-associated pneumonia; VAP), urinary tract infections associated with bladder catheters (catheter-associated urinary tract infections, CAUTIs) or primary bloodstream infections (BSIs) occurred after 48 hours from admission were monitored.

Data were collected systematically using a form with four sections: i) patient demographic data and information on hospitalization (date of hospitalization, date of admission to the ICU, admission diagnosis in ICU, route of access, discharge date, status of the patient at discharge); ii) information on exposure to risk factors: the data collection form included information on the start date and end date and duration of the patient's exposure to urinary catheterization, central venous catheterization and mechanical ventilation. It also specified whether the device was present within the 48 h prior to the onset of infection; iii) data on antibiotic therapy: the form collected information on the drug(s) used, the daily dose, the start date and end date and the total duration of antibiotic therapy for each drug used; iv) data on diagnosed HAIs and microbiological cultures performed: data on the site of infection were collected, including information on the date of onset and microbiological confirmation (date of collection, microorganisms identified and relative resistance or sensitivity to the various antibiotics tested in the antibiogram).

Monthly and annual reports were produced for the Hospital Health Directorate containing the following elements: description of the study population (number of patients admitted, characteristics of patients); description of the main characteristics of the infections (microorganisms responsible for infection and their antibiotic-resistance profile); device-days per 100 patient-days;

device-related HAI rates per 1000 patient-days; VAP, CRBSI and CAUTI rates per 1000 device-days; primary BSI rates per 1000 patient-days; days of use of antibiotics per 100 patient-days (Table 1). These reports were sent to the ICU and were discussed with ICU personnel in monthly meetings.

The resistance profile of bacterial isolates was evaluated according to the criteria of Magiorakos et al. (15). Briefly, a microorganism was considered "multidrug resistant" (MDR) if not susceptible to at least one antibiotic in at least three different classes (for *S. aureus*, non-susceptibility to oxacillin or cefoxitin alone identifies the microorganism as MDR); "extensively drug resistant" (XDR) if not susceptible to at least one antibiotic in all but two or fewer classes tested; "pandrug resistant" (PDR) if not susceptible to all antibiotics tested.

Environmental microbiological surveillance

A microbiological surveillance system was designed and implemented to control the spread and persistence of alert microorganisms in the ICU environment, as a result of surface contamination related to procedures not being followed or not being performed correctly (i.e. HH and sanitization guidelines). After an analysis of the activities carried out in the ICU, 14 points were selected for sampling (i.e. bed edges, medication carts, PC keyboards and mice, sink faucets, blood gas analyzer touchscreen, mechanical ventilation system touchscreen), using as selection criteria the proximity to patients, the frequency of usage by healthcare personnel, the contamination risk and the risk of ineffective sanitization. Environmental monitoring

Table 1 - Formulas used to calculate the risk factors for healthcare associated infections (HAIs) and the incidence of HAIs.

Assessment of HAI risk factors	
Percentage of days of use of device per patient-day	$\frac{\text{Device} - \text{Days}}{\text{Patient} - \text{Days}} \times 100$
Percentage of days of use of antibiotic classes per patient-day	$\frac{\text{Antibiotic Class} - \text{Days}}{\text{Patient} - \text{Days}} \times 100$
Assessment of HAI incidence	
Device-related HAI (drHAI) rate	$\frac{\text{Number of drHAIs}}{\text{Patient} - \text{Days}} \times 1000$
Ventilation-associated pneumonia (VAP) rate	$\frac{\text{Number of VAPs}}{\text{Ventilation} - \text{Days}} \times 1000$
Catheter-associated urinary tract infections (CAUTI) rate	$\frac{\text{Number of CAUTIs}}{\text{Urinary Catheterization} - \text{Days}} \times 1000$
Catheter-related bloodstream infection (CRBSI) rate	$\frac{\text{Number of CRBSIs}}{\text{Central Venous Catheterization} - \text{Days}} \times 1000$
Primary bloodstream infection (BSI) rate	$\frac{\text{Number of primary BSIs}}{\text{Patient} - \text{Days}} \times 1000$

was carried out during the usual activities of the unit twice a month using sterile swabs, after the sanitization interventions, in compliance with ISO 18593: 2004 (16). All samples were analyzed according to standardized culture methods for the determination of alert microorganisms. Monthly reports were produced for the Hospital Health Directorate containing the following elements: description of the main characteristics of the microorganisms; their antibiotic-resistance profile; the exact localization of the sampling site. These reports were also sent to the ICU and were discussed with the ICU personnel in monthly meetings.

Surveillance focused on bacterial isolates

The system of active surveillance of HAIs also included microorganism surveillance, where molecular typing of clinical and environmental bacterial isolates was performed by pulsed-field gel electrophoresis (PFGE). The preparation of chromosomal DNA, restriction digestion and PFGE were performed as previously described (17-20). Interpretation of chromosomal DNA restriction patterns was based on the criteria of Tenover et al. (21). Briefly, strains showing more than three fragment variations were assumed to represent major PFGE patterns, while one to three fragment differences were considered to represent PFGE pattern subtypes.

Behavioral surveillance of healthcare personnel

In October 2016, three nurses and two physicians were trained to perform direct observations of compliance with HH and proper glove or gown use during their daily care activities in the ICU. The training focused on the purposes of observation and the principles of HH and glove use. From 1st November 2016 to 30th April 2018, the five observers gathered data using an anonymous observation form developed according to the 2009 WHO Hand Hygiene Technical Reference Manual (22). The tool investigated four possible types of interaction between healthcare personnel and patients (i.e. touching a patient, device manipulation, touching patient surroundings, and invasive procedure or body fluid exposure), all of which had HH indications both before and afterwards. Moreover, the observers recorded glove use during each interaction and, for invasive procedure or body fluid exposure, also gown use. As a result, a total of thirteen recommendations were investigated; eight concerned HH indications, four concerned glove use and one concerned gown use. Compliance with HH was calculated as the proportion of the number of performed actions to the number of opportunities. Glove use was deemed appropriate during device manipulation and invasive procedure or body fluid exposure, while for touching patient surroundings and touching a patient, glove non-use was considered appropriate. Gown use during an invasive procedure was evaluated as appropriate. After the first six months (baseline phase), a multimodal intervention to improve the adherence of healthcare personnel to the guidelines was conducted with the ICU staff. It was based on education and training of all healthcare personnel coupled with performance feedback, as described elsewhere (23). For the following 12 months (post-intervention phase), the five observers continued to collect data to monitor healthcare personnel behaviour and assess the impact over time of the intervention. Observations were grouped into trimesters for the analysis (two at baseline, four during post-intervention phase).

Statistical analysis

Counts and proportions of device-related HAI, primitive BSI, clinical and environmental bacterial strains and their resistance profiles and PFGE patterns, antibiotics and observation for HH compliance and gloves and gowns use were calculated. Rates for device-related HAI and primary BSI, as well as proportions of devices and antibiotics use per 100 patient-days, were calculated as reported in table 1.

Results

Active surveillance focused on inpatients

Overall, 773 patients hospitalized in the ICU were included in the active surveillance regime. The mean age was 58.3±18.7 years and 66.4% of the patients were male. A total of 388 patients (50.2%) accessed the ICU through the Emergency Department, 258 (33.4%) were transferred from other wards of the same hospital, 73 (9.4%) from other hospitals and 47 (6.1%) were admitted directly to the ICU from the community. Fifty-two percent of the ICU patients were hospitalized for medical reasons, 29% following a traumatic event and 18% following surgery. The median length of stay at the ICU was 10 days (interquartile range 5-22).

Overall, 379 HAIs occurred during the study period, of which 166 were primary BSIs (43.8%) and 213 were device-related (56.2%). Regarding the latter, there were 73 VAPs (19.3%), 85 CAUTIs (22.4%) and 55 CRBSIs (14.5%). Concerning the exposure to risk factors, the proportion of device-days to patient-days was 66% for invasive ventilation, 99.9% for urinary catheterization and 95.2% for central venous catheterization.

The monthly device-related HAI incident rate showed a decreasing trend over time, with peaks of incidence becoming progressively lower, ranging from 26.9 device-related HAIs per 1000 days in October 2016 to 4.9

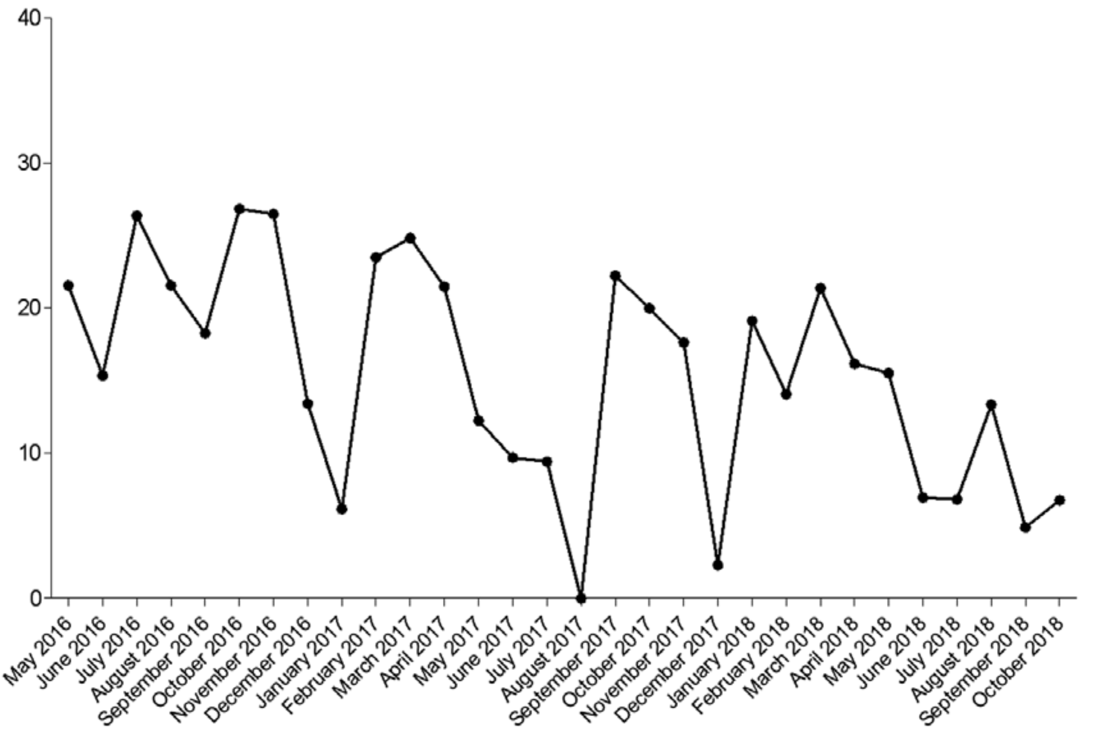

Figure 1 - Device-related healthcare-associated infection (HAI) rates per 1000 patient-days in the Intensive Care Unit of Umberto I Teaching Hospital of Sapienza University of Rome.

in September 2018 (Figure 1). Overall, in the period of interest the incidence rate of device-related HAIs was 16.1 (95% CI: 14.0-18.4) per 1000 patient-days. In more detail, the monthly incidence rate of VAPs showed a slight decrease after a peak of 21.1 per 1000 ventilation-days reached in March 2017 (Figure 2A). The overall VAP incidence rate was 8.3 (95% CI: 6.5-10.5) per 1000 ventilation-days. The CRBSI rate did not showed a recognizable monthly trend, with incident peaks alternating with months without CRBSI (Figure 2B). The overall CRBSI incidence rate was 4.3 (95% CI: 3.3-5.6) per 1000 central venous catheterization-days. CAUTIs showed a reduction in the last seven months of surveillance (Figure 2C). The overall CAUTI incidence rate was 6.7 (95%CI: 5.4-8.3) per 1000 urinary catheterization-days. Primary BSIs showed a more stable trend over time with few peaks (Figure 2D). The overall primary BSI incidence rate was 12.5 (95% CI: 10.9-14.2) per 1000 patient-days (Figure 2D).

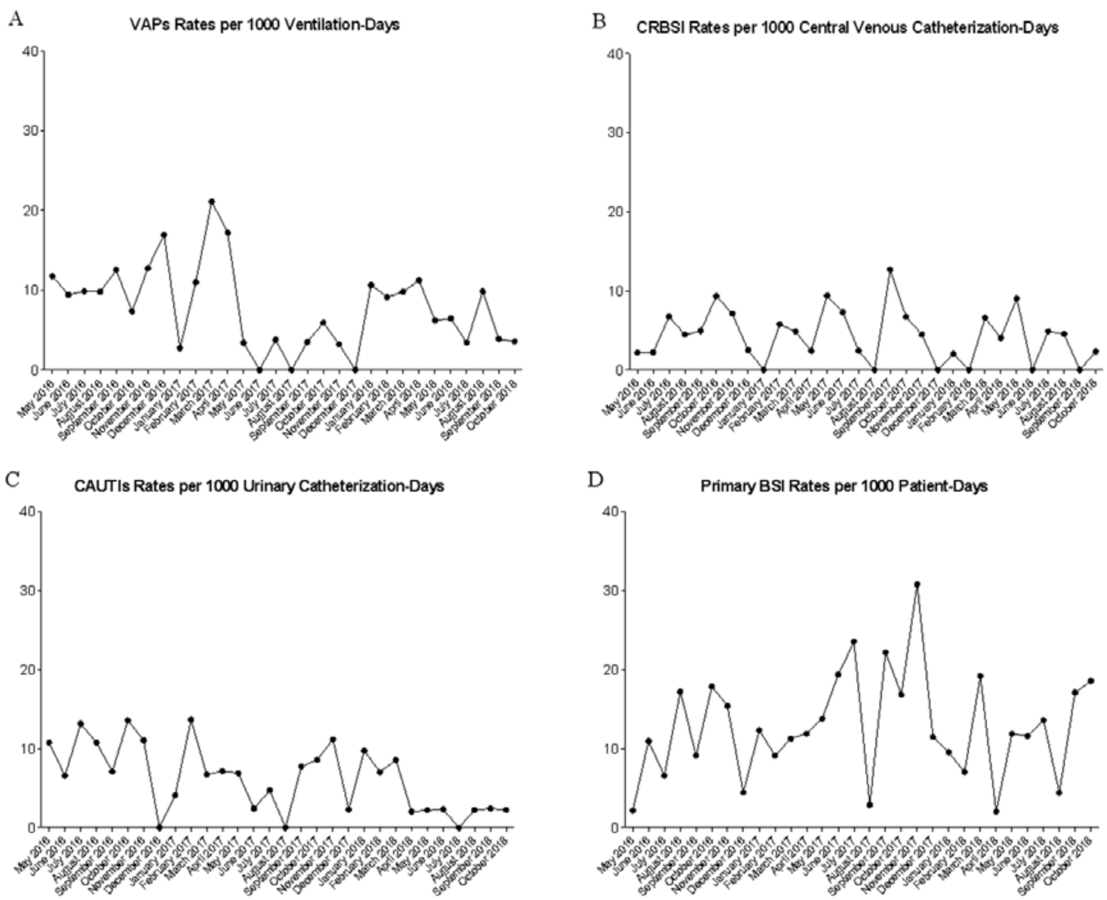

Figure 2 - Specific device-related healthcare-associated infection (HAI) rates and primary bloodstream infection rates in the Intensive Care Unit of Umberto I Teaching Hospital of Sapienza University of Rome: A) Ventilation-associated pneumonia (VAP) rate per 1000 ventilation-days; B) Catheter-related bloodstream infections (CRBSI) rate per 1000 central venous catheterization-days; C) Catheter-associated urinary tract infection (CAUTI) rate per 1000 urinary catheterization-days; D) Primary bloodstream infection rate per 1000 patient-days.

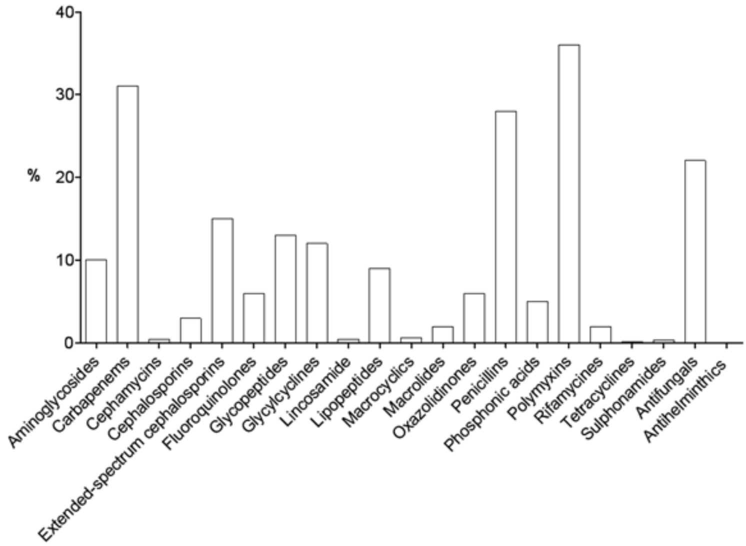

Figure 3 - Days of use of antibiotic classes over 100 patient-days, expressed as a percentage, in the Intensive Care Unit of Umberto I Teaching Hospital of Sapienza University of Rome.

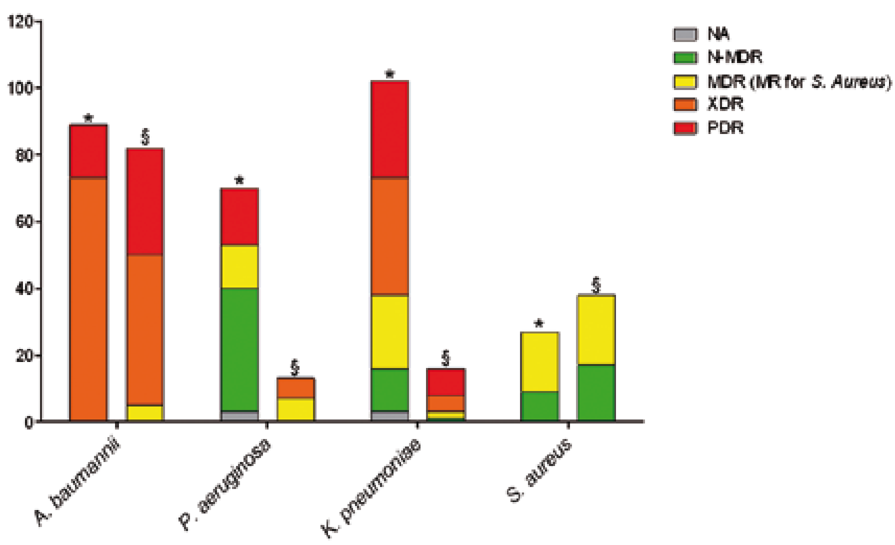

Figure 4 - Resistance profiles of clinical and environmental isolates for *Acinetobacter baumannii, Pseudomonas aeruginosa, Klebsiella pneumoniae* and *Staphylococcus aureus* in the Intensive Care Unit of Umberto I Teaching Hospital of Sapienza University of Rome.
Legend: NA, non-assessable; N-MDR, non-multidrug resistant; MDR, multidrug resistant; MR, methicillin-resistant; XDR, extensively drug resistant; PDR, pandrug resistant. * clinical isolates; § environmental isolates.

The most frequently prescribed classes of antibiotics were polymyxins (36.0% of patient-days), carbapenems (31.0% of patient-days), penicillins (28.0%), antifungals (22.0%), extended-spectrum cephalosporins (15.0%), glycopeptides (13.0%), glycylcyclines (12.0%) and aminoglycosides (10.0%) (Figure 3).

Overall, 477 pathogens were responsible for 380 HAIs that occurred during the study period. The most common bacterial pathogens were *Klebsiella pneumoniae* (20.7%), *Acinetobacter baumannii* (17.2%), *Pseudomonas aeruginosa* (13.4%) and *Staphylococcus aureus* (5.4%) (Figure 4). Concerning the resistance profile, *Acinetobacter baumannii* and *Klebsiella pneumoniae* showed the highest proportion of isolates with a MDR or more severe profile (100% of *Acinetobacter baumannii* and 94.0% of *Klebsiella pneumoniae* isolates), whereas *Pseudomonas aeruginosa* showed a more mixed profile, with 52.9% of the isolates not MDR. More than 50% of *Staphylococcus aureus* isolates were methycillin-resistant (MRSA) (Figure 4). Overall, 230 out of the 477 pathogens responsible for HAIs (48.2%) were at least MDR (specifically, 15.1% MDR, 25.6% XDR and 7.5% PDR).

Environmental microbiological surveillance

During the study period, a total of 60 environmental microbiological monitoring campaigns were performed and 819 samples were collected, which yielded 305 bacterial isolates. *Acinetobacter baumannii* was the most frequently isolated bacterial species (27.2%), followed by *Staphylococcus aureus* (12.1%), *Enterococcus faecalis* (11.1%), *Klebsiella pneumoniae* (5.2%) and *Pseudomonas aeruginosa* (4.7%) (Figure 4). Environmental isolates showed a more resistant profile than clinical isolates, since 213 out of 305 isolates (69.8%) were at least MDR (specifically, 38.3% MDR, 18.4% XDR, and 13.1% PDR). All *Acinetobacter baumannii, Pseudomonas aeruginosa* and *Klebsiella pneumoniae* environmental isolates were at least MDR (Figure 4), whereas 59.4% of *Staphylococcus aureus* isolates were methicillin-resistant and 26.5% of *E. faecalis* isolates where glycopeptide-resistant.

The sampling points in the ward most likely to yield bacterial isolates were bed edges (91 positive samples), medication carts (62 positive samples) and mechanical ventilation system touchscreens (59 positive samples). Fewer positive samples were found on the remaining surfaces sampled: PC keyboard and mouse (43 positive samples); sink faucets (30 positive samples); blood gas analyser touchscreen (20 positive samples).

Surveillance of Bacterial Isolates

A total of 218 clinical and 67 environmental isolates of *Acinetobacter baumannii* and *Klebsiella pneumoniae* from the ICU were typed by macrorestriction analysis of chromosomal DNA and PFGE. Genotyping of the 159 clinical isolates of *Acinetobacter baumannii* showed six major PFGE patterns: PFGE pattern B was found in 107 isolates (67.3%), followed by PFGE pattern A (21 isolates, 13.2%), PFGE pattern C (20 isolates, 12.6%), PFGE pattern E (five isolates, 3.1%), PFGE pattern F (four isolates, 2.5%) and PFGE pattern D (two isolates, 1.2%). For the environmental isolates, three major PFGE patterns were identified: PFGE pattern B (17 isolates, 47.2%), PFGE pattern A (14 isolates, 38.9%) and PFGE pattern C (five isolates, 13.9%). PFGE patterns D, E and F were found in clinical but not in environmental isolates. Genotyping of the 56 clinical isolates of *Klebsiella pneumoniae* revealed 14 major PFGE patterns: PFGE pattern A was retrieved in 37 isolates (66.1%), followed by PFGE pattern B (four isolates, 7.1%), and PFGE patterns

C, D and M (two isolates each). The other ten major patterns were observed in single isolates. For environmental isolates, only two major PFGE patterns were identified: PFGE pattern A, seen in 24 isolates (96%) and PFGE pattern O, observed in a single isolate.

Behavioral Surveillance of Healthcare Personnel

Over a 18-month study period, a total of 12,853 observations were collected, with a mean of 2142 observations per trimester; of these, 7908 observations related to HH, 3956 observations concerned glove use and 989 observations referred to gown use. The overall compliance rates improved from 41.9% (first trimester) to 62.1% (third trimester) and this result was sustained in the following trimesters. In particular, compliance with HH guidelines increased from 32.4% (first trimester) to 60.4% (third trimester), while compliance with proper glove or gown use was higher both at baseline (first trimester: 56.8%) and during the post-intervention phase (third trimester: 64.6%).

The results of the behavioral surveillance of healthcare personnel, during which four types of interaction with patients were investigated (i.e. touching a patient, device manipulation, touching patient surroundings and invasive procedure or body fluid exposure) are described in detail elsewhere (23). Briefly, however, we found that each compliance rate significantly improved from baseline to post-intervention phase, and that, throughout the study period, the four HH indications after approaching patients registered higher compliance rates than the four indications before approaching patients.

Finally, the compliance rates of nursing staff were always higher than the compliance rates of physicians, both for HH observations and proper glove or gown use, and both at baseline and during post-intervention phase.

Discussion

Surveillance is defined as "the ongoing, systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know" (24). In the context of a high-risk setting for HAIs, such as ICUs, implementation of a surveillance system plays a pivotal role in the control of such infections and in the evaluation of interventions aimed at reducing the HAI risk (8, 25, 26). Although the mechanisms through which surveillance reduces the HAI risk are still unclear (27), providing feedback to healthcare personnel on the surveillance data may help to modify their behavior in ways that reduce the incidence of HAIs (9). Moreover, a patient-based surveillance, providing risk-adjusted incidence rates (14), allows comparisons between institutions and the collection of data that can identify risk factors and critical areas of intervention (28). Apart from the CRBSI rate, which is higher in our ICU, our results on HAI incidence rates are in line with those of other ICUs in Italy, which have been analyzed as part of the SITIN Project (the Italian program of HAI surveillance in ICUs). According to the 2015 SITIN Report, the considerable variability among Italian ICUs in the incidence of HAIs is likely to be due to differences in patient characteristics and in the case mix index (CMI) of each ICU (29). Probably for similar reasons, Italian ICUs show rather higher incidence rates than reported by American hospitals participating in the National Healthcare Safety Network in the US (30). Overall, we have witnessed a slight decrease over time in the risk- adjusted device-related HAIs rates. Although this decrease was less than expected, it was sustained mainly by a reduction in the incidence of VAPs, which are often associated with a worse outcome for patients (31).

The high prevalence of MDR bacterial strains in both clinical and environmental samples, particularly of *Acinetobacter baumannii* and *Klebsiella pneumoniae* strains, together with the limited spectrum of major PFGE patterns observed in the genomes of these pathogens, is likely to be due to the high selective pressure carried out by the extensive use of antibiotics such as carbapenems, polymyxins and broad spectrum cephalosporins, with a subsequent selection of resistant clones (32-35). The possibility of cross-contamination from environmental surfaces to susceptible patients has been demonstrated by observing a clonal relationship between environmental and clinical bacterial isolates using PFGE (36, 37). Although the role of environmental contamination in the transmission of HAIs is still uncertain, it is now widely recognized that MDR organisms associated with HAIs can survive for weeks on environmental surfaces commonly touched by healthcare personnel or patients (38-43). In our experience, the most contaminated surfaces were the bed edges, the medication carts and the PC keyboards and mice. The occurrence of common PFGE patterns in clinical and environmental strains seems to indicate cross-contamination between the patients and the environment. Moreover, these findings strongly confirm the power of including molecular typing techniques in HAI surveillance systems (44).

Several studies point out that improved cleaning or disinfection of environmental surfaces can reduce transmission of hospital pathogens. Contaminated surfaces can spread microorganisms to susceptible patients directly. Moreover, when healthcare personnel come into contact with such contaminated surfaces, in the absence of appropriate HH, they can contribute to the transmission of pathogens. Indeed, HH is considered the primary measure necessary for reducing HAIs (4, 6). Despite this, and the relative simplicity of HH procedures, a lack of compliance among healthcare personnel remains a relevant issue (45-46). To improve compliance, the WHO has elaborated evidence-based guidelines for the implementation of correct HH, with monitoring of the behavior of healthcare personnel deemed essential (22). In our ICU, we used direct observation of the performance of healthcare personnel, using incognito workers, as recommended by the WHO (4). Though the intervention to improve adherence of healthcare personnel to HH guidelines doubled the rate of compliance, the achievement of only a suboptimal level of compliance is probably the main reason for the persistent, albeit diminishing, trend of HAIs in the ICU after the intervention.

The multimodal surveillance protocol described in this article focused on the epidemiologic triad host - etiological agent - environment and was enriched by information obtained from the analysis of the behavior of healthcare personnel. The methodology described was founded on multidisciplinarity and the integration of the skills and knowledge of different professionals was essential to the project. The surveillance system was supported by appropriate technological-instrumental apparatus and quality laboratory methods that comply with mandatory regulations. This multimodal surveillance protocol seem applicable concretely in a multiplicity of to many other welfare contexts, making the whole model exportable.

Conclusions

By integrating the information gathered from the active surveillance regime, environmental microbiological surveillance, surveillance of bacterial isolates and behavioral surveillance of healthcare personnel, our model returned a precise and detailed view of the risk of nosocomial infection and of the microbial ecology in the ICU at the Policlinico Umberto I Teaching Hospital. However, the results obtained in terms of reduction of HAIs suggest that greater efforts should be made in the implementation of targeted interventions, such as the application of bundles for the reduction of the risk infection due to the use of invasive devices, together with ongoing educational interventions for healthcare personnel, in parallel with continuous surveillance.

Declarations

Competing interests. The authors declare that they have no competing interests.

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Riassunto

Sorveglianza Multimodale delle Infezioni Correlate all'Assistenza in una Unità di Terapia Intensiva di un Grande Policlinico

Introduzione. Le infezioni correlate all'assistenza sanitaria (ICA) rappresentano una problematica significativa in termini di mortalità, morbilità, durata del soggiorno e costi per i pazienti ospedalizzati nelle unità di terapia intensiva (UTI). I sistemi di sorveglianza sono raccomandati da istituzioni nazionali e internazionali al fine di raccogliere dati sulle ICA che possano permettere di elaborare e valutare interventi volti alla riduzione del rischio di ICA.

Disegno dello studio. In questo articolo descriviamo la metodologia e i risultati del sistema di sorveglianza implementato nella UTI del Policlinico Umberto I, un grande ospedale universitario di Roma, da aprile 2016 a ottobre 2018.

Metodi. Il sistema multimodale di sorveglianza delle infezioni è consistito nell'integrazione di quattro diversi approcci: i) sorveglianza attiva incentrata sui pazienti ricoverati; ii) sorveglianza microbiologica ambientale; iii) sorveglianza focalizzata sui microrganismi isolati e, iv) sorveglianza comportamentale del personale sanitario. Sono state considerate ICA le batteriemie correlate a catetere (CRBSI), le polmoniti associata a ventilazione (VAP), le infezioni del tratto urinario associate a catetere (CAUTI) e le batteriemie primitive che si sono verificate dopo 48 ore dall'ammissione. Per la sorveglianza ambientale sono stati selezionati 14 punti per il campionamento (bordi del letto, carrelli per farmaci, tastiere per PC, rubinetti dei lavandini). Il sistema di sorveglianza attiva delle ICA ha incluso inoltre una sorveglianza focalizzata sui microrganismi, basata sulla genotipizzazione molecolare degli isolati batterici attraverso l'elettroforesi su gel a campo pulsato (PFGE). Dal 1° novembre 2016 è stato integrato nel sistema di sorveglianza il monitoraggio del rispetto delle linee guida sull'igiene delle mani (HH) e dell'uso corretto di guanti e camici da parte del personale sanitario. Dopo i primi sei mesi, è stato condotto con il personale dell'UTI un intervento multimodale volto a migliorare l'aderenza alle linee guida.

Risultati. Complessivamente, 773 pazienti sono stati inclusi nella sorveglianza attiva. Il tasso di incidenza totale delle ICA correlate a dispositivi è stato di 14,1 (IC 95%: 12,2-16,3) per 1000 giorni di degenza. L'incidenza mensile delle ICA correlate a dispositivi ha mostrato un andamento decrescente nel tempo, con picchi di incidenza progressivamente inferiori a quelli precedenti. Gli isolati batterici più comuni sono stati *Klebsiella pneumoniae* (20,7%), *Acinetobacter baumannii* (17,2%), *Pseudomonas aeruginosa* (13,4%) e *Staphiylococcus aureus* (5,4%). *Acinetobacter baumannii* e *Klebsiella pneumoniae* hanno mostrato la più alta percentuale di isolati con un profilo multiresistente. Sono stati raccolti un totale di 819 campioni ambientali, con il recupero di 305 isolati batterici. Gli isolati batterici più frequenti sono stati *Acinetobacter baumannii* (27,2%), *Staphiylococcus aureus* (12,1%), *Enterococcus faecalis* (11,1%), *Klebsiella pneumoniae* (5,2%) e *Pseudomonas aeruginosa* (4,7%). Tutti gli isolati ambientali di *Acinetobacter baumannii, Pseudomonas aeruginosa e Klebsiella pneumoniae* erano multiresistenti. La genotipizzazione ha mostrato un numero limitato di pattern PGFE per *Klebsiella pneumoniae e Acinetobacter baumannii* sia negli isolati clinici che in quelli ambientali. Il tasso di aderenza alle linee guida sul lavaggio delle mani e l'utilizzo di guanti e camici è migliorato significativamente tra pre- e post-intervento.

Conclusioni. Attraverso l'integrazione delle informazioni raccolte dalla sorveglianza attiva, dalla sorveglianza microbiologica ambientale, dalla sorveglianza focalizzata sugli isolati batterici e dalla sorveglianza comportamentale del personale sanitario, l'applicazione di questo modello restituisce una visione precisa e dettagliata del rischio infettivo e dell'ecologia microbica all'interno dell'UTI.

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