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A continuous quality-improvement program reduces nosocomial infection rates in the ICU

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Abstract *Objective:* To assess the impact of a continuous quality-improvement program on nosocomial infection rates. *Design and setting:* Prospective single-center study in the medical-surgical ICU of a tertiary care center. *Patients:* We admitted 1764 patients during the 5-year study period (1995–2000); 55% were mechanically ventilated and 21% died. Mean SAPS II was 37±21 points and mean length of ICU stay was 9.7±16.1 days. *Interventions:* Implementation of an infection control program based on international recommendations. The program was updated regularly according to infection and colonization rates and reports in the literature. *Measurements and results:* Prospective surveillance showed the following rates per 1000 procedure days: ventilator-associated pneumonia (VAP) 8.7, urinary tract infection (UTI) 17.2, central venous catheter (CVC) colonization 6.1, and CVC-related bacteremia and 2.0; arterial catheter colonization did not occur. In the 5 years following implementation of the infection control program there was a significant decline in the rate per patient days of UTI, CVC colonization, and CVC-related bacteremia but not VAP. Between the first and second 2.5-year periods the time to infection increased significantly for UTI and CVC-related colonization. *Conclusions:* A continuous quality-improvement program based on surveillance of nosocomial infections in a nonselected medical-surgical ICU population was associated with sustained decreases in UTI and CVC-related infections.

Keywords Nosocomial infection · Surveillance · Intensive care unit · Continuous quality improvement · Quality indicator

Introduction

Surveillance of nosocomial infection (NI) rates is recommended as a means of assessing the effects of healthcare practices, identifying risk factors for NI, comparing intensive care units (ICU), and monitoring trends in bacterial resistance [1, 2]. The risk of NI is highest in postoperative and in critically ill patients [1]. NIs that should be monitored in critically ill patients include ventilator-associated pneumonia (VAP), urinary tract device-associated infections (UTI), and infections related to central venous catheters (CVCs) and arterial catheters (ACs). NIs are associated with disease severity, the nurse/patient ratio, and the nature of therapeutic interventions [3].

Increasingly, quality of care is being compared across healthcare centers and practices [4]. The number of NIs per 1000 device days has been used to measure quality of care in ICUs. However, wide variability in this measure has been found across ICUs participating in the National Nosocomial Infections Surveillance System (NNISS) in the US. This variability may be ascribable to differences in healthcare practices across ICUs and/or to factors independent of practices [5]. In several studies educational programs designed to improve practices induced short-term reductions in specific NIs such as CVC-related infection [6] and VAP [7].

The aim of the present study was to maximize compliance of physicians and nurses with infection control practices and to assess its long-term impact on the rates of VAP, UTI, and vascular catheter-related infection in critically ill patients.

Materials and methods

The study was performed prospectively over 5 years (July 1995–2000) in the ten-bed medical-surgical ICU of Saint Joseph Hospital, a 450-bed tertiary care center located in Paris. Infection control throughout the hospital is coordinated by an NI Control Committee and an Operative Infection Control Unit. The nurse/patient ratio is one to two, and the nursing assistant/patient ratio is one to ten. Each new nurse receives a 2-month training course, during which specific protocols regarding NI prevention are discussed. There was no change in the structure or staffing of the unit during the study. During the 5-year study period 1,764 patients were admitted to our ICU.

Infection control practices

Infection control practices were written by the ICU staff together with the Infection Control Unit and were derived from Centers for Disease Control (CDC) recommendations [8]. Our guidelines for VAP prevention [9] included staff education, monitoring of VAP rates, use of sterile water and devices, including heat and moisture exchangers, and prevention of gastric overdistension by monitoring residual volume measurements and, starting in late 1999, placing the patients in semirecumbent position [10]. Neither closed aspiration systems nor continuous subglottic aspirations were used. Guidelines for preventing UTI [11] included UTC insertion and handling by trained nurses, skin disinfection with 10% povidone iodine solution, insertion using aseptic technique and sterile equipment, drainage with a closed sterile system, aseptic technique for urine sampling, maintenance of unobstructed urine flow, and monitoring of UTI rates. For prevention of vascular catheter colonization [12] the guidelines consisted of staff education and training, daily examination of catheter sites, skin disinfection with 10% povidone iodine solution, use of surgical drapes and of a gown for the operator, use of single or multiple-lumen catheters as clinically required, use of hemodialysis catheters for fluids or parenteral nutrition only when there was no alternative, replacement of catheter site dressings every 48 h or at longer intervals when clinically indicated, and monitoring of trends in vascular catheter colonization and related bacteremia rates. The site of CVC insertion was at the physician's discretion, but tunneling was required for internal jugular and femoral sites from 1996 and 1999, respectively [13]. Universal measures for preventing person-to-person transmission [14] included hand-washing before and after each patient contact, wearing gloves for handling secretions or contaminated objects, and wearing a gown when soiling was anticipated and/or when the patient had multiple-drug resistant bacteria, and geographical isolation of all patients.

The guidelines or their modifications were explained and given to all the staff during a yearly unit meeting and to the new nurses and residents by the head nurse. They were continuously available in a specific written form located in the unit.

An assessment of the compliance to hand washing guidelines among 12 nurses and 8 physicians or residents was made by the Infection Control Unit twice during the first year of study. A global score was built from the quality of washing, rinsing, soap or antiseptic utilization, drying, and duration. The mean score was 88±5% initially and 93±4% 6 months later, and considered a good level. Forty-four samples were taken from the hands before and after washing, with a colonization reduction of 85±4% between the two samples. No hand was colonized with pathogenic strains, and the maximum observed after washing was 15 colonies per milliliter. The assessment of the quality of hand washing and invasive devices management was then made each time a patient was colonized with methicillin-resistant *Staphylococcus aureus* (MRSA), as part of a program on microbial resistance containment, among the nurses and physicians in charge of the colonized patient. This represented 136 audits assessing 26 items. Six percent of the items were considered insufficiently respected, and the results allowed the continuous reinforcement of the observance of procedures of hand washing and surfaces cleaning and implementing formation sessions about cross-transmission.

Our policy for containing antibiotic resistance included collection of microbiological specimens from suspected infection sites if at all possible and starting broad-spectrum antibiotic therapy early, then changing to narrow-spectrum therapy as soon as the organism was identified and its antimicrobial susceptibility profile established. Selective digestive decontamination was used in 15 patients (0.8%) as an adjunctive technique to control outbreaks of multiple drug resistant bacteria [15].

Microbiological specimens

All the patients referred to our ICU were included in the NI surveillance program. Microbiological specimens were collected when the attending physician suspected infection based on systemic signs (unexplained fever, chills, hypotension) and/or local signs [purulent tracheal aspirates in mechanically ventilated (MV) patients, purulent urinary drainage, or pus or pain at a vascular catheter insertion site]. They consisted of urine for UTI [11], a protected specimen brush and bronchoalveolar lavage fluid for VAP [16, 17], and the catheter tip for vascular catheter colonization [12, 18]. Urine specimens were not obtained routinely prior to UTC insertion. All CVCs and ACs were cultured at removal, regardless of whether infection was suspected. ICU-acquired infection was defined as infection documented after at least 48 h in the ICU.

Infection criteria

Microbiological specimens were collected as recommended by the CDC [19] and consensus conferences on VAP [17]. For CVCs and ACs we assessed colonization by quantitatively culturing CVC/AC tips [18]. CVC and AC infection was considered when bacteremia due to a micro-organism simultaneously colonizing the catheter (at least two positive blood cultures in the case of *Staphylococcus* spp. other than *S. aureus*) was present. Thresholds above which cultures were considered positive were 10^5 cfu/ml urine for UTI, 10^3 cfu/ml in protected specimen brushes or 10^4 cfu/ml in bronchoalveolar lavage fluid for VAP, and 10^3 cfu/ml for CVC or AC colonization.

Table 1 Patient characteristics (*n*=1,764). *ICU* Intensive care unit, *SAPS II* Simplified Acute Physiology Score II

Mechanical ventilation	976 (55%)
Mechanical ventilation >48 h	682 (39%)
Urinary tract catheter	960 (55%)
Central venous catheter (one or more)	765 (43%)
Central venous catheter used for dialysis	203
Arterial catheter (one or more)	261 (15%)
Age (years)	61±18
Length of ICU stay (days)	9.7±16.1
SAPS II score	37±21
Omega score per ICU stay	138±256
In-ICU mortality	21%

Utilization of invasive procedures

Invasive procedures were utilized according to CDC recommendations [9, 11, 12]. UTC, CVC, AC, and endotracheal tubes were not replaced routinely. UTCs were removed or replaced when bacterial UTI persisted despite appropriate therapy, or when a yeast infection was documented. CVCs were removed when infection was suspected. CVCs inserted before ICU admission were routinely removed or replaced within 48 h after ICU admission. Suspected VAP did not lead to endotracheal tube removal or replacement. Procedure days prior to ICU admission were not considered in this study. Table 1 shows the number of patients who required MV, UTC, CVC, or AC, and Table 2 reports the overall utilization rates for UTC, MV, CVC, and AC and the length of procedure use per patient. The overall rates of VAP, UTI, CVC colonization, and CVC related bacteremia were 8.7, 17.2, 6.1, and 2.0 per 1,000 procedure days, respectively.

Data collection and validation, feedback, and protocol updating

Data on the population of ICU patients were recorded in a database built using FileMakerPro software. For each patient admitted to the ICU a file was created and used to record demographic data, diagnostic and therapeutic codes, dates of invasive device insertion and removal, and documentation of ICU-acquired infections. Disease severity was measured by computing the Simplified Acute Physiology Score II (SAPS II) [20] within 24 h after admission. Treatment intensity throughout the ICU stay was measured using the Omega system [3, 21], an instrument derived from the Therapeutic Intervention Scoring System [22]. The nurses collected the specimens and documented the dates of insertion and removal of devices. The physicians collected all other data, including those establishing the diagnosis of NI. Descriptive statistics of NI rates were communicated to the ICU staff every 6 months. Infection control procedures were modified as required by NI rates,

individual review of each serious nosocomial event, and new data in the literature (i.e., reduced colonization of internal jugular and femoral CVCs by tunneling [13]). Table 1 presents the patients' mean SAPS II score, Omega score, and length of stay in the ICU.

Data analysis

Quantitative data are reported as means ±SD and qualitative data as percentages. For each procedure we computed the *utilization rate* [23] as the number of procedure days divided by the total number of patient days in the unit, the *procedure-associated infection rate* as the number of relevant NIs per 1000 procedure days, and the *incidence rate* as the number of patients with the relevant NI divided by the number of patients exposed to the procedure. Changes in incidence rates over the 5-year study period were tested using the χ^2 test for trend. Mean SAPS II and Omega scores and mean length of ICU stay were compared by analysis of variance among 1-year periods. Finally, the time to the first nosocomial event was compared between the patients of two consecutive periods of equal duration (2.5-years) using a Cox model with or without adjustment for the SAPS II score. Values of *p* smaller than 0.05 were considered statistically significant.

Results

Incidence rates decreased significantly for UTI, CVC-related bacteremia, and CVC colonization but not for VAP (Table 3). No cases of AC colonization were documented during the study period, and consequently no data on this are shown. The decline over time in UTI and CVC-related infection rates was observed despite the absence of significant changes in disease severity (SAPS II score), mean length of ICU stay, and treatment intensity (Omega score: Fig. 1) and regardless of invasive device utilization rates (Fig. 2). Increases in the time to the first NI were found from the first to the second 2.5-year period for UTI (*p* =0.005) and CVC colonization (*p* =0.02) but not VAP. The Cox model comparing the two consecutive 2.5-year periods showed decreases in the rates of UTI and CVC colonization (Table 4). These decreases remained significant after controlling for admission SAPS II.

Table 2 Invasive procedure utilization rates over the 5-year study period (*utilization rate* procedure days divided by patient days, *CVC* central venous catheter, *AC* arterial catheter)

	Procedure utilization rate in all patients (%)	Mean duration of procedure use per patient (days)
Mechanical ventilation	0.74	13.0±18.8
Urinary tract catheter	0.73	13.1±17.9
Central venous catheter	0.61	13.8±18.3[a]
Arterial catheter	0.05	3.5±3.2[b]

[a] Per CVC: 6.2±4.4 days
[b] Per AC: 3.1±2.3 days

Table 3 Incidence of nosocomial infections (*NI*) over the 5-year study period. Nosocomial incidence rates per 1000 procedure days were not used for evaluating time trends because the risks of nosocomial infection on different days are not independent of one another in a given patient (see text). *VAP* Ventilator-associated pneumonia, *MV* mechanical ventilation, *UTI* urinary tract infection, *UTC* urinary tract catheter, *CVC* central venous catheter, *CVC-C* CVC colonization, *CVC-B* CVC-related bacteremia

	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	p^a
VAP/MV patients	17/157	20/182	33/218	22/193	17/205	0.25
VAP/1,000 MV days	7.9	7.7	11.9	9.0	7.7	
UTI/UTC patients	46/175	45/172	50/231	40/173	28/191	0.0006
UTI/1,000 UTC days	21.1	18.1	17.5	17.2	12.9	
CVC-C/CVC patients	16/117	16/154	14/178	10/147	10/153	0.01
CVC-C/1,000 CVC days	9.1	6.4	6.7	4.6	6.3	
CVC-BSI/CVC patients	7/117	6/154	6/178	2/147	0/153	0.001
CVC-BSI/1,000 CVC days	3.5	2.4	2.9	0.9	0.0	

^{a} χ^2 test for tendency

Table 4 Comparisons of infection/colonization rates between 2.5-year periods (Cox model). *VAP* Ventilator-associated pneumonia, *UTI* urinary tract infection, *UTC* urinary tract catheter; *CVC-C* central venous catheter colonization, *HR* hazards ratio, *CI* confidence interval

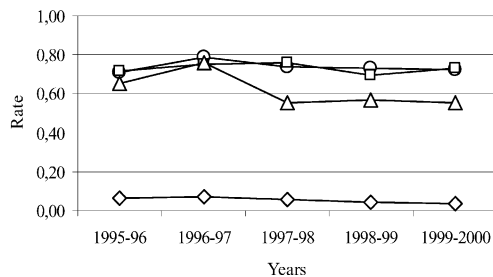|	Period 1		Period 2		Unadjusted			SAPS II adjusted		
	n	%	*n*	%	HR	95% CI	*p*	HR	95% CI	*p*
VAP	47/425	11.1	50/553	9.00	0.99	0.66–1.47	0.95	1	0.67–1.50	1
UTI	89/433	20.6	66/529	12.50	0.63	0.46–0.87	0.005	0.65	0.47–0.91	0.01
CVC-C	42/342	12.3	21/423	5.00	0.53	0.32–0.91	0.02	0.54	0.32–0.92	0.02

Fig. 1 Device utilization rate over 5 years. The rate is obtained by dividing the device days by the patients days in the same period. *Circles* Mechanical ventilation; *squares* urinary tract catheters; *diamonds* central venous catheters; *triangles* arterial catheters. The tendencies observed over time for each procedure are not statistically significant
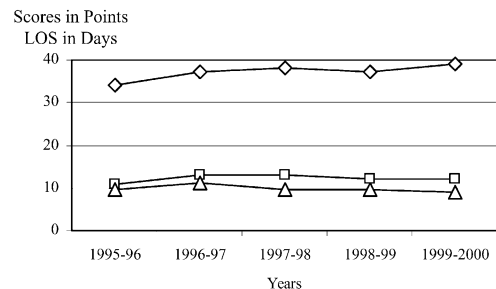

Fig. 2 Trends in clinical scores and length of ICU stay over the 5-year study period. Disease severity at admission (*diamonds* mean SAPS II score), daily treatment intensity (*squares*, mean daily Omega score), and mean length of ICU stay (*triangles*) remained stable over time. *SAPS II* Simplified Acute Physiology Score II. The SAPS II and daily Omega scores are expressed in points, and length of ICU stay in days

Discussion

The NI rate has been proposed for many years as a measure of the quality of care in the ICU [1, 2, 4]. Although recent studies of educational programs have found short-term declines in the rates of CVC infection [6] and VAP [7] in ICU patients, the long-term impact of a continuous quality-improvement program has not been evaluated. In our study, a program including NI rate surveillance, protocol updates in response to the data thus obtained, and assessment of caregiver compliance with infection control measures, reduced UTI and CVC-associated infection rates but not VAP and lengthened

the time to UTI and CVC colonization. These effects increased gradually over the 5-year study period.

Decreasing the rate of ICU infections associated with invasive procedures is a major goal in the ICU. Recent publications by the NNISS [23] report VAP, UTI, and CVC-associated bloodstream infections in medical-surgical ICUs in teaching hospitals at rates of 5.6, 5.1, and 5.2 per 1000 procedure days, respectively. Zack and colleagues [7] have emphasized the need for reducing the rate of VAP as this may be the NI with the greatest attributable morbidity and mortality [24]. Few studies have found beneficial effects of strategies aimed at

reducing VAP rates. The semirecumbent position, however, received strong emphasis at a recent consensus conference on VAP [25] as a useful preventive measure. The beneficial effect of semirecumbent positioning was established in late 1999 [10], 7 months before the end of our study, and only then did we start using this measure routinely in our ICU. This might explain the nonsignificant trend toward a decrease in the VAP rate late in our study period (Table 3). Two measures have a strong impact on CVC-related infections: maximal sterile barrier precautions [26], which were used throughout our study period, and the type of skin disinfection, which was with 10% povidone iodine solution in our patients; we did not use 2% chlorhexidine as advocated by Maki and colleagues [27] because this preparation is not on the market in France. The available preparation, 0.5% chlorhexidine, was tested recently by Humar and colleagues [28] and found similar to 10% povidone iodine. No cases of AC colonization occurred in our study, and although this finding is probably due in large part to the limited duration of AC use (3.1±2.3 days), it also indicates that our skin disinfection technique was effective.

Our UTI rates were higher than recently published NNISS results [23] apparently because of insufficient compliance with prevention measures. This may also reflect the fact that the clinical part of the definition of urine infections includes some subjectivity. In our series every new febrile event, a phenomenon which may be due to noninfectious causes in ICU patients, led to new samples, and our rates may reflect a mixture of infection and colonization. Nevertheless, our rates were based on objective quantitative criteria and decreased over time. Our rates of CVC colonization were high, and of bacteremia were low. All CVC tips were cultured at removal, whether or not infection was suspected, in order to limit the subjectivity of the criteria used for sampling; in contrast, routine cultures are discouraged in the CDC recommendations [12], and our policy may well have increased our overall colonization rates. We chose to assess CVC colonization in addition to CVC-related bloodstream infection because the latter corresponds to rare events which may weaken their statistical power [29]. Eventually the two of these rates decreased in the same proportion. Our definition of VAP required positive quantitative distal specimens [17]. VAP rates in our study were similar to those published by the NNISS [23] and may be considered low [30]. During the three last 6-month periods of the study, these rates (6.2–7.8 per 1000 MV days) were similar to those reported by Zack and colleagues [7] after implementation of an educational program. The relatively low VAP rates in our study, together with the scarcity of new effective prevention measures [27], may explain in part why VAP rates failed to decline significantly over our 5-year study period.

Several components of our program may have contributed to the decline in NI rates recorded during our study period. Surveillance per se has been shown to influence infection rates [31], and this was probably the case for UTI in our study, as the largest decrease occurred after the first 6-month period. Surveillance with communication of the results to the ICU caregivers undoubtedly raises awareness of the magnitude of the problem and need to comply with infection control measures [32]. The development and implementation of protocols was also a major component of our program. Protocols were regularly updated by the ICU caregivers based on surveillance data from the ICU and on new data published in the literature. This may explain why the decline in infection rates was sustained over time. Furthermore, the caregivers played a central role in developing the protocols, a factor known to improve compliance [32]. Compliance with the protocols was checked by the ICU caregivers and Operative Infection Control Unit initially and then each time a patient colonized with MRSA as part of another program designed to reduce cross-transmission in the unit. Our program might have been more effective if we had audited the total of all the procedures we used, but this evaluation was limited by our available resources.

As all admitted patients were included in our study, our findings are probably applicable to other medical-surgical ICUs, although they may have been influenced by case-mix and practices in our particular unit. Importantly, the infection rate decline seen in our study was not related to disease severity or treatment intensity, as the SAPS II and daily Omega scores remained remarkably stable over time. Our results cannot be attributed to less severe disease in our patients than in other series. The MV utilization rate was higher in our patients than in the NNISS series (0.74 vs. 0.55 [23]). The impact of this difference cannot be determined accurately because disease severity score values are not available for the NNISS series. However, disease severity in our population was similar to that in a French multicenter database of medical-surgical ICU patients [33].

Finally, the comparison of the two 2.5-year periods in our study suggests that our program prevented as many as 51 colonizations or infections, an approx. 25% reduction compared to the earlier period. This is consistent with findings by others and represents substantial reductions in morbidity, mortality, and cost [6].

In conclusion, our study demonstrates that surveillance of NI rates and regular updating of written protocols as part of a continuous quality-improvement program produced steady declines in UTI and CVC colonization and infection rates, with increased times to occurrence of these events, in a nonselected population of medical-surgical ICU patients. Whether the absence of reduction in VAP rates was due to the relatively low VAP rates at program initiation or to the lack of new effective preventive measures for VAP remains to be investigated.

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