

Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care

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Summary

Background Intravascular devices are a leading cause of nosocomial infection. Specific prevention strategies and improved guidelines for the use of intravascular devices can decrease the rate of infection; however, the impact of a combination of these strategies on rates of vascular-access infection in intensive-care units (ICUs) is not known. We implemented a multiple-approach prevention programme to decrease the occurrence of vascular-access infection in an 18-bed medical ICU at a tertiary centre.

Methods 3154 critically ill patients, admitted between October, 1995, and November, 1997, were included in a cohort study with longitudinal assessment of an overall catheter-care policy targeted at the reduction of vascular-access infections and based on an educational campaign for vascular-access insertion and on device use and care. Incidence of ICU-acquired infections was measured by means of on-site surveillance.

Findings 613 infections occurred in 353 patients (19.4 infections per 100 admissions). The incidence density of exit-site catheter infection was 9.2 episodes per 1000 patient-days before the intervention, and 3.3 episodes per 1000 patient-days afterwards (relative risk 0.36 [95% CI 0.20–0.63]). Corresponding rates for bloodstream infection were 11.3 and 3.8 episodes per 1000 patient-days, respectively (0.33 [0.20–0.56]) due to decreased rates of both microbiologically documented infections and clinical sepsis. Rates of respiratory and urinary-tract infections remained unchanged, whereas those of skin or mucous-membrane infections decreased from 11.4 to 7.0 episodes per 1000 patient-days (0.62 [0.41–0.93]). Overall, the incidence of nosocomial infections decreased from 52.4 to 34.0 episodes per 1000 patient-days (0.65 [0.54–0.78]).

Interpretation A multiple-approach prevention strategy, targeted at the insertion and maintenance of vascular access, can decrease rates of vascular-access infections and can have a substantial impact on the overall incidence of ICU-acquired infections.

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Introduction

Insertion of intravascular devices is among the main causes of nosocomial infections,¹ which exacerbate morbidity and hospital costs in intensive-care units (ICUs).^{2,3} Various strategies have been used to decrease the risk of vascular-access infections, including prevention efforts targeted at the materials from which catheters are made, and catheter care.^{4–7} So far, only a few studies have used a multiple-strategy approach to decrease infection rates and to explore the possible benefits of the combined measures on rates of vascular-access infections.^{8,9} Hitherto, no large-scale study has assessed the impact of an overall management approach in the adult critical-care setting.

We did a prospective cohort study, and implemented a multimodal, multidisciplinary prevention strategy to decrease rates of vascular-access infections and to assess the impact of the strategy on the incidence of ICU-acquired infections.

Methods

Patients

The University of Geneva Hospital is a 1500-bed primary-care and tertiary-care centre. An average of 1400 patients are admitted each year to the 18-bed medical ICU for a mean length of stay of 4 days. All adult patients admitted to the medical ICU for more than 48 h between October, 1995, and February, 1997 (control period), were prospectively surveyed for nosocomial infections by standard methods.¹⁰ The intervention programme was implemented in March, 1997, and its impact was measured during an 8-month period (April–November, 1997). The study was approved by the institutional review board; no informed consent was requested.

Methods

During the 2-year study period, the surveillance of nosocomial infections was done by two infection-control nurses who visited the medical ICU daily and completed a dedicated surveillance chart for each patient. Surveillance was continued until day 5 after the patient was discharged to detect incubating infections attributable to the ICU stay. Hospital-wide surveillance for nosocomial bloodstream infection has been carried out since 1994 at the University of Geneva Hospital.¹¹ All surveillance records were prospectively reviewed and validated by two infection-control physicians. Nursing workload was assessed with the Project Research in Nursing system.¹²

Surveillance methods were pretested and standardised in several pilot phases. Interobserver variability was assessed during three separate periods where the two observers worked simultaneously; inter-rater reliability was high for all infections ($\kappa=0.89$, range 0.78–1.0). Nosocomial infections were defined according to modified criteria of the Centers for Disease Control and Prevention.¹⁰ The infection was regarded as ICU-acquired if it occurred within 48 h of discharge from the medical ICU. Primary bloodstream infections were defined as bacteraemia (or fungaemia) for which there was no documented distal source, and included infections resulting from insertion of an intravenous or arterial line.^{10,11,13} The infection was categorised either as microbiologically documented or as clinical sepsis.¹⁰

Guidelines	Control period*	Intervention period†
Material preparation	Based on physicians' individual preferences.	Material prepared according to detailed list to avoid interruption during insertion (cards available in preparation room).
Positioning of patient	According to nursing habits acquired elsewhere—eg, nursing school, hospital wards.	Recommendations for placing of patients and devices to permit optimum access to insertion site. Presence of nurse to assist physician mandatory.
Line insertion	General institutional recommendations.	Detailed written guidelines.
Skin preparation	Hair-shaving.	Hair-cutting instead of shaving. Skin cleansing with surgical swab.
Skin antiseptics	Povidone iodine 10% or alcohol-based (70%) solution of chlorhexidine gluconate (0.5%).	Alcohol-based (70%) solution of chlorhexidine gluconate (0.5%), with 2-min drying time before insertion.
Barrier precautions	Sterile gloves, small fenestrated sheets, paper mask.	Sterile gown and gloves, large sheets, cap, surgical mask (except for peripheral lines).
Insertion technique	Various techniques; no specific training of ICU physicians.	Specific training of ICU physicians;‡ promotion of subclavian (CVC) and wrist vein (short lines) sites.
Dressing	Several types according to individual non-standardised criteria. Transparent occlusive dressings or preprepared devices for peripheral lines.	Occlusive devices not allowed. Written guidelines for dressing. Replaced every 72 h except for the first dressing after catheter insertion. Dry gauze-based dressing occluded with porous adhesive band obligatory.
Replacement	Every 24 h for all dressings, administration sets, and devices.	Every 72 h for administration sets and devices; every 24 h for lipid emulsion lines. Lines for blood product infusions immediately removed after use.
General handling	Universal precautions.	Opening of hub: on antiseptic-impregnated pads after hand disinfection. General measure: new caps after any opening of hubs.
Device removal	Peripheral line; after 3–5 days. Central line: no specific recommendations.	Peripheral line: after 72 h systematically. Central line: as clinically indicated, no routine replacement. Any access: prompt removal if not absolutely necessary. Clinical sepsis: guidewire exchange if unexplained.
Hand hygiene during insertion and care	Handwashing with surgical soap in sink before and after each patient care, or hand disinfection.	Hand disinfection: strongly emphasised before and after any care. Handwashing: for soiled hands, followed by hand disinfection.

*Institutional written guidelines promulgated by nursing department, and available in each ward of hospital.

†Specific written guidelines for critically ill patients adapted from previous guidelines.^{13,15}

‡Individual teaching based on 30-min slide-show sessions, complemented by individual bedside teaching and detailed explanation of background of each guideline for all staff.

Table 1: Comparison of guidelines used during control and intervention periods

Catheter-related bloodstream infections were those for which the same organism had been isolated from a quantitative culture of the distal catheter segment,¹⁴ and from the blood of a patient with clinical symptoms and no other apparent source of infection. In the absence of catheter culture, defervescence after removal of an implicated catheter from a patient with a bloodstream infection was regarded as indirect evidence of infection.¹³ Exit-site catheter infection was defined as the presence of positive quantitative catheter culture in the presence of signs of infection (erythema, tenderness, induration, or purulence) without other documented infectious foci. Growth of more than 100 colony-forming units from a catheter segment by quantitative culture¹⁴ in the absence of signs of inflammation at the catheter site was regarded as catheter colonisation. Clinical sepsis was defined by one of the following clinical signs or symptoms with no other recognised cause: fever (>38°C), hypotension (systolic blood pressure ≤90 mm Hg), or oliguria (>20 mL/h), plus blood culture not done or no organism detected in blood, no apparent infection at another site, and administration of appropriate antimicrobial therapy for sepsis.¹⁰

A multiple-approach intervention strategy targeted at the reduction of vascular-access infections was implemented in March, 1997. An educational campaign consisting of 30-min slide-shows and practical demonstrations was developed for all medical ICU staff (21 fellows or residents, 82 nurses, and 15 nursing assistants), and was completed by individual in-service training. The programme included detailed information on clinical pathways for vascular-access insertion, and device maintenance and use, on the basis of previously identified risk factors.¹³ The guidelines covered the following: preparation of the material to avoid any interruption during insertion; skin preparation (hair-cutting instead of shaving) and disinfection (alcohol-based solution of chlorhexidine gluconate 0.5%, with 2 min drying time); maximum barrier precautions (sterile gloves and gown, cap, mask, and a large sheet) used for all but peripheral lines;⁵ subclavian or wrist vein as standard insertion sites; and dressings (dry gauze covered by a non-occlusive adhesive band).¹⁵ Administration sets, devices, and dressings were replaced every 72 h, except for lines receiving lipid or blood products, and for the first dressing after catheter insertion (24 h). Hand disinfection was strongly emphasised before and after the insertion, replacement, or manipulation of any

vascular device. Central lines were not routinely replaced, but were changed over a guidewire in cases of clinical sepsis without a documented source of infection.^{13,16} Prompt removal of any device not intended for use was strongly recommended. Table 1 details previously employed routine measures and those implemented during the intervention. All vascular lines were inserted by advanced internal-medicine residents or fellows in the medical ICU; there was no change in the physicians' profile between the study periods.

Statistical analysis

The incidence and incidence densities of nosocomial infections were calculated for the two periods (before and after interventions), and were compared by means of a χ^2 test for binomial proportions. Means were compared by *t* tests or Wilcoxon's test for continuous variables, and 95% CI were calculated. EpiInfo 6.0 (CDC, Atlanta, USA) and SPSS 8.0 (SPSS Inc, Chicago, USA) were used for data analysis. All tests were two-tailed.

Results

2104 patients were surveyed during the control period, and 1050 during the intervention period (a total of 13 200 patient-days). The groups were similar with respect to baseline characteristics, underlying disease, and intrinsic susceptibility to infection (table 2). A fifth of the patients required mechanical ventilation (similar proportions in both groups). The duration of ICU stay was similar among patients within the same disease categories. Monthly Project Research in Nursing scores were 188 (SD 66; range 152–210) and 191 (SD 61; range 178–207) during the control and intervention periods, respectively.

468 ICU-acquired infections occurred in 268 patients during the control period, compared with 145 infections in 85 patients during the intervention period. The overall rate of infected patients was 12.7 per 100 admissions in the first period, compared with 8.1 per 100 after programme implementation (relative risk 0.64 [95% CI 0.50–0.81]). After the intervention, the

Disease category at ICU admission	Number of patients		Mean (SD) age (years)		Mean (SD) length of stay (days)		Number mechanically ventilated		Number of ICU deaths	
	Control period	Intervention period	Control period	Intervention period	Control period	Intervention period	Control period	Intervention period	Control period	Intervention period
Cardiovascular										
Unstable angina	554 (26%)	296 (28%)	66 (12)	66 (12)	2.6 (2.7)	2.7 (1.3)	5 (0.9%)	3 (0.9%)	2 (0.4%)	1 (0.3%)
Myocardial infarction	406 (19%)	218 (21%)	63 (13)	67 (13)*	3.8 (3.6)	3.6 (2.5)	54 (13%)	15 (7.0%)*	31 (7.6%)	9 (4.1%)
Cardiac monitoring†	222 (11%)	116 (11%)	68 (14)	67 (13)	2.1 (1.7)	2.3 (1.6)	7 (3.2%)	1 (0.8%)	4 (1.8%)	0
Cardiac arrest	48 (2.3%)	32 (3.0%)	66 (14)	65 (15)	6.0 (5.6)	6.0 (4.8)	43 (90%)	30 (94%)	15 (31%)	19 (59%)*
Hypertensive crisis	76 (3.6%)	25 (2.3%)	57 (21)	58 (17)	6.1 (14.0)	2.8 (1.2)	9 (12%)	3 (12%)	7 (9.2%)	3 (12%)
Acute heart failure	55 (2.6%)	41 (3.9%)	70 (10)	73 (8)	5.4 (5.3)	5.2 (4.4)	26 (47%)	16 (39%)	2 (3.6%)	2 (4.9%)
Respiratory										
Acute insufficiency	122 (5.8%)	74 (7.1%)	63 (14)	67 (13)	9.0 (8.2)	8.2 (8.5)	59 (48%)	28 (38%)	19 (16%)	10 (14%)
Asthma	54 (2.6%)	19 (1.8%)	45 (18)	36 (14)	3.9 (3.3)	3.5 (2.0)	12 (22%)	4 (21%)	0	0
COPD	54 (2.6%)	15 (1.4%)	66 (13)	66 (10)	7.6 (6.0)	6.1 (2.9)	9 (17%)	2 (13%)	3 (5.6%)	0
ARDS	20 (1.0%)	9 (0.9%)	42 (17)	49 (14)	13.6 (12.0)	13.8 (9.7)	2 (100%)	9 (100%)	13 (65%)	5 (56%)
Neurological										
Intoxication	106 (5.0%)	55 (5.2%)	38 (16)	42 (20)	3.5 (7.1)	2.6 (1.4)	35 (33%)	17 (31%)	2 (1.9%)	0
Miscellaneous‡	105 (5.0%)	42 (4.0%)	58 (17)	56 (19)	5.8 (8.2)	5.0 (3.6)	68 (65%)	25 (60%)	16 (15%)	6 (14%)
Infections	98 (4.7%)	32 (3.0%)	54 (18)	57 (16)	5.3 (4.4)	8.3 (8.6)	59 (60%)	20 (63%)	33 (34%)	11 (34%)
Other disorders§	184 (8.7%)	76 (7.2%)	56 (18)	57 (17)	4.0 (6.4)	3.8 (3.4)	33(18%)	24 (32%)*	12 (6.5%)	7 (9.2%)
Total	2104	1050	62 (16)	63 (16)*	4.1 (5.8)	3.9 (4.2)	439 (21%)	194 (19%)	159 (7.6%)	71 (6.8%)

COPD=chronic obstructive pulmonary disease; ARDS=acute respiratory distress syndrome.

*p<0.05 for differences between groups; †Includes patients admitted for elective electric cardioversion of atrial flutter or fibrillation; ‡Includes cerebrovascular disease, degenerative diseases, and epilepsy; §Includes patients admitted for severe metabolic disturbances (diabetes, electrolytes), induction of haemodialysis treatment, and miscellaneous conditions.

Table 2: Baseline characteristics

incidence density of exit-site catheter infections decreased by 64% and that of bloodstream infections decreased by 67% (table 3). The decrease in the incidence density of bloodstream infections was due to decreased rates of both microbiologically documented infections and clinical sepsis. The incidence density of nosocomial respiratory and urinary-tract infections did not change significantly; that of skin or mucous-membrane infections decreased by 38%. Overall, the incidence density of nosocomial infections decreased by 35% after intervention (table 3).

325 infections were microbiologically documented. The distribution of pathogens was similar in both study periods; the most common isolates in descending order were *Pseudomonas aeruginosa*, *Haemophilus influenzae*, *Escherichia coli*, enterococci, and *Candida* spp. There were 17 episodes of primary bacteraemia due to coagulase-negative staphylococci during the control period, compared with only two during the intervention. Other pathogens causing primary bacteraemia were gram-negative rods (*Enterobacter aerogenes*, *Serratia marcescens*, *E coli*), enterococci, and *Candida* spp. The most common pathogens causing exit-site catheter infections were coagulase-negative staphylococci (55%), *Staphylococcus aureus* (14%), *P aeruginosa* (12%), *Corynebacterium* spp (12%), enterococci, and gram-negative rods.

Although all 3154 patients in the study had at least one intravenous device inserted, 966 (31%) were exposed to arterial lines, and 1121 (35%) to central venous catheters (CVC), with similar proportions in the control and the intervention periods. The median duration of device use was 8 and 7 days, in the control and intervention periods, respectively. The incidence density of microbiologically documented bloodstream infection decreased from 2.4 to 0.8 episodes per 1000 vascular-access-days (relative risk 0.31 [95% CI 0.09–0.53]) between the two periods; that of exit-site infection dropped from 8.9 to 3.5 episodes per 1000 vascular-access-days (0.39 [0.22–0.69]). Although the overall exposure to CVCs did not differ significantly between the control and the intervention periods (median duration 4 days for each), the incidence density of bloodstream infection decreased substantially from 22.9 to 6.2 episodes per 1000 CVC-days (0.27 [0.13–0.56]) due to a decreased incidence of both microbiologically documented infection (from 6.6 to 2.3 episodes per 1000 CVC-days) and clinical sepsis (from 16.3 to 3.9 episodes per 1000 CVC-days).

By contrast with the changes measured in the medical ICU, the incidence of microbiologically documented, nosocomial bloodstream infection remained stable in the surgical ICU during the entire study period (10.3 episodes per 1000 patient-days between October,

Nosocomial infections	Control period		Intervention period		Relative risk (95% CI)	p
	Number	Incidence density	Number	Incidence density		
Respiratory tract	121	13.5	54	12.7	0.93 (0.68–1.29)	0.75
Bloodstream	101	11.3	16	3.8	0.33 (0.20–0.56)	<0.0001
Microbiologically documented	28	3.1	5	1.2	0.37 (0.14–0.97)	0.04
Clinical sepsis	73	8.2	11	2.6	0.32 (0.17–0.59)	<0.0001
Exit-site catheter	82	9.2	14	3.3	0.36 (0.20–0.63)	<0.0001
Urinary tract	47	5.3	22	5.2	0.98 (0.59–1.63)	1.0
Skin or mucous membranes	102	11.4	30	7.0	0.62 (0.41–0.93)	0.02
Miscellaneous*	15	1.7	9	2.1	1.26 (0.55–2.87)	0.66
Total	468	52.4	145	34.0	0.65 (0.54–0.78)	<0.0001

*Including secondary bloodstream infections occurring during the control period (one *Candida albicans* urinary-tract infection) and the intervention period (one each of *Enterobacter cloacae* skin and urinary-tract infections; one *C albicans* urinary-tract infection).

Table 3: Incidence of nosocomial infections, before and after intervention

1995, and February, 1997, compared with 11.6 between April and November, 1997).

Discussion

Our results demonstrate the impact of a multiple-approach intervention strategy on rates of bloodstream and catheter-related infection, as well as on the overall incidence of ICU-acquired infections. Although infection rates before the intervention (ie, 6.6 episodes of microbiologically documented bloodstream infections per 1000 CVC-days) were within the accepted limits,¹⁷⁻¹⁹ our experience shows that, as postulated,¹ a large proportion of nosocomial infections related to extrinsic factors are still preventable.

Decreasing the rate of bloodstream and catheter-associated infections is a major focus of quality improvement in the critical-care setting, and many interventions have targeted prevention of catheter contamination during insertion or care.^{4-7,13} Raad and colleagues showed the benefits of using maximum sterile barrier precautions during catheter insertion in a selected population of patients with malignancies;³ Maki and colleagues showed the advantage of using 2% chlorhexidine instead of 10% povidone-iodine or 70% alcohol for cutaneous disinfection before insertion of an intravascular device;⁴ and other investigators have emphasised the key role that staff education has in controlling CVC sepsis in critically ill children.^{8,20} We believe that our multidimensional intervention was more successful in decreasing infection rates than any other reported programme from adult ICUs so far. A well-implemented training and education programme, coupled with strategies to reinforce the desired behaviour, are probably the most powerful tools to change physicians' and health-care workers' behaviour and to improve quality of care.²¹ Importantly, our strategy was as successful in decreasing rates of vascular-access infection as the use of newly introduced antibiotic-coated or antiseptic-coated catheters,^{7,22,23} which are potentially associated with acquisition of antibiotic resistance and allergic or toxic reactions.

Our findings are applicable to other critical-care settings, since the study population was not restricted to patients who met certain inclusion criteria. Despite the lack of randomisation criteria, comparison of patients' characteristics and nursing workload during the control and intervention periods showed a similar case-mix and medical practice.

Whereas the incidence of respiratory and urinary-tract infections remained unchanged after the implementation of the strategy, we observed a significant decrease in skin and mucous-membrane infections. This effect was probably related to the continuous promotion of bedside hand disinfection before and during vascular-access care, which was possibly associated with increased compliance with hand hygiene during other patient-care and nursing activities. Although a hospital-wide promotion campaign aimed at improving compliance with hand hygiene practices has been in operation at our institution since January, 1995, this policy alone is unlikely to explain the observed effect, in particular for the following reasons: (1) improvement in hand-hygiene compliance was similar in the medical and surgical ICUs between 1994 and 1997 but remained relatively unsatisfactory;^{24,25} (2) no change in the rate of catheter-

associated bloodstream infections was observed in the surgical ICU over the study period despite a similar hand-hygiene promotion campaign in the two units; and (3) the vascular-access-targeted intervention strategy described here had no impact on respiratory, urinary, or other miscellaneous infections. In common with other investigators, we strongly advocate the necessity to improve hand-hygiene compliance. However, we are convinced that although they may have been a contributing factor, improvements in compliance alone could not explain the observed impact of the intervention.

On the basis of the presented data, our strategy may have prevented more than 75 nosocomial infections during the 8 months of intervention, including at least 30 primary bloodstream infections and 25 vascular-access infections. Using conservative estimates of attributable costs associated with these two types of infections,^{2,26} we calculated that the programme was largely beneficial for the patient and the hospital. The prevention of those infections would amount, at least, to the annual salary of three full-time infection-control nurses. We recognise that a refined analysis is necessary to validate these crude estimates.

Our data should be interpreted within the context of the study design. No randomisation was done to exclude systematic bias. The lack of a significant decrease in the incidence of surgical-ICU-acquired primary bloodstream infections over the study period argues against a major bias. However, our findings deserve further study by means of a time-series analysis with temporally sequenced interventions. Compliance with the proposed guidelines was assessed on a few occasions with a standardised form (data not shown), but regular on-site observation would require substantial resources and could be associated with observer bias. Consequently, we were unable to assess which particular recommendation had the greatest impact. This information would strengthen cause and effect conclusions and may identify components of the intervention that were not effective. In addition, uncontrolled factors, such as variations in physicians' skills or individual commitment to prevention, may have contributed to the decreased infection rates. However, such confounders are unlikely to explain the overall impact of the intervention. We are currently investigating whether the intervention strategy has had a sustained effect after the end of the study period; preliminary results suggest that it did.

Contributors

Philippe Eggimann was the field investigator. Marie-Noëlle Constantin and Sylvie Touveneau did on-site surveillance of nosocomial infections, and reviewed and wrote the guidelines for vascular-access insertion, care, and maintenance. All three carried out the educational campaign. Jean-Claude Chevolet and Didier Pittet reviewed the guidelines and helped in the implementation of the multiple-approach prevention strategy. Stephan Harbarth and Didier Pittet validated the infection-surveillance data and were responsible for statistical analysis. Philippe Eggimann, Stephan Harbarth, Jean-Claude Chevolet, and Didier Pittet wrote the paper. All investigators were involved in the study design.

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