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Effectiveness of a programme to reduce the burden of catheter-related bloodstream infections in a tertiary hospital

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SUMMARY

The objective of this study was to assess the effectiveness of a catheter-related bloodstream infection (CR BSI) reduction programme and healthcare workers' compliance with recommendations. A 3-year surveillance programme of CR BSIs in all hospital settings was implemented. As part of the programme, there was a direct observation of insertion and maintenance of central venous catheters (CVCs) to determine performance. A total of 38 education courses were held over the study period and feedback reports with the results of surveillance and recommendations were delivered to healthcare workers every 6 months. A total of 6722 short-term CVCs were inserted in 4982 patients for 58 763 catheter-days. Improvements of compliance with hand hygiene was verified at the insertion (87·1–100%, $P < 0·001$) and maintenance (51·1–72·1%, $P = 0·029$) of CVCs; and the use of chlorhexidine for skin disinfection was implemented at insertion (35·7–65·4%, $P < 0·001$) and maintenance (33·3–45·9%, $P < 0·197$) of CVCs. There were 266 CR BSI incidents recorded with an annual incidence density of 5·75/1000 catheter-days in the first year, 4·38 in the second year [rate ratio (RR) 0·76, 95% confidence interval (CI) 0·57–1·01] and 3·46 in the third year (RR 0·60, 95% CI 0·44–0·81). The education programme clearly improved compliance with recommendations for CVC handling, and was effective in reducing the burden of CR BSIs.

Key words: Catheter-related bloodstream infection, central venous catheter, prevention, programme evaluation.

INTRODUCTION

Catheter-related bloodstream infection (CR BSI) is one of the four leading causes of healthcare-associated infection in developed countries [1–6]. CR BSI is a severe complication that increases the risk of death in intensive-care units (ICU) by 41% [7], and each episode brings about an additional cost that ranges from about US$6005 to US$ 17 300 in the United States and Europe [8–10].

Recognized guidance documents summarize proven measures to prevent CR BSI [11, 12], but the problem remains as to how to encourage healthcare workers to incorporate such recommendations in their common

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tasks [13–15]. Financial policies, such as the widely extended 'pay for performance', or others that penalize preventable complications by not providing hospitals with additional payment for healthcare-acquired conditions, have shown little to no effect [16, 17]. On the other hand, surveillance and education programmes have both been shown to be effective strategies by identifying the epidemiological factors involved and improving compliance with guidelines [10, 18–20]. Although the ICU has been the primary focus of attention over the past two decades, recently the scope of applicability of these programmes has been extended to the non-ICU population, as a result of observations suggesting that the majority of patients with central lines are treated outside the ICU, and also have a substantial rate of CR BSI [21–23].

The principal obstacles to the development and maintenance of infection control and prevention programmes are the need of an adequate number of trained personnel in the team, and the motivation of employees to attend such courses [24–26]. Hence, it is important to understand the burden of disease and identify points for improvement in each clinical environment in order to establish an optimal programme. To this end, we started a surveillance and education programme for all hospital settings that included the measurement of compliance with standard recommendations for insertion and maintenance of central venous catheters (CVCs) with the aim of assessing the effectiveness of the programme to reduce CR BSIs and increase the compliance of healthcare workers with the recommendations.

METHODS

Study population

The study included patients with a CVC admitted to a tertiary university hospital from February 2009 to December 2011. The hospital comprised 900 beds, 40 of which were for critical care (ICU and recovery room). The programme surveyed CR BSIs of short-term CVCs and compliance with recommended guidelines at the time of insertion and during handling of CVCs. The main intervention was continuous information feedback of surveillance results and a brief listing of recommendations for handling CVCs. The updated information was provided in formal reports to the managers of the involved units, and through six editions of 3000 brochures that were delivered to workers in all hospital settings every 6 months. In addition, the standard recommendations for insertion and maintenance of catheters were added to the content of the education courses routinely held by the Preventive Medicine Unit for all parts of the hospital. During years 2009, 2010 and 2011, we conducted 11, 9 and 10 courses respectively, of 60-min duration, geared to nurses, nursing assistants and orderlies, on a 3-week basis, for 20 attendees a time. For doctors, eight informative meetings to update the recommendations for the procedures were organized during the first 2 months of the programme specifically for those units involved in CVC insertion.

Surveillance of CR BSIs

A research nurse, solely hired for this programme, searched for patients with CVCs in the hospital wards on a daily basis. Patients with a short-term CVC were included in the surveillance and monitored until catheter removal, the patient's death or the diagnosis of BSI related to the catheter. A short-term catheter was defined as indwelling for a maximum of 90 days, and included Swan Ganz, Epicutaneous, Sheldon, Drum-Cartridge and Standard catheters. The following data were collected: patients' characteristics (age, sex, main diagnosis), intrinsic risk factors (obesity, malignancy, diabetes, neutropenia, burns, immunosuppression), extrinsic risk factors (urinary catheter, peripheral line, nasogastric tube, arterial catheters, major surgery, chemotherapy, invasive procedures) for CR BSI, catheter characteristics (insertion date, hospital setting, type of catheter, insertion site, number of lumens), and the diagnosis of CR BSI. We adopted the U.S. Centers for Disease Control and Prevention's (CDC) criteria published in 2002 [11], defining CR BSI as the presence of one or more positive blood cultures and a positive catheter tip culture, from which the same organism (species and antibiogram) was isolated, and not related to another site of infection. Since July 2010, the CDC's National Healthcare Safety Network surveillance definition of healthcare-associated infection and criteria for specific types of infections in the acute-care setting was adopted, that considered a central line-associated BSI to be a primary BSI in a patient that had a central line within a 48-h period and was not a BSI related to another infected site [27]. Catheters suspected to be infected were routinely removed and cultured, using a quantitative method [28]. The

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incidence densities of CR BSI for each semester and year were calculated.

Compliance with recommendations

In order to survey practice of insertion of CVCs, observation periods of 30–60 days were organized for each hospital setting (ICU, recovery room, paediatric ICU, interventionist radiology). For every catheter insertion procedure under observation, compliance with safety measures was checked by a nurse who recorded insertion time, hand hygiene, use of alcoholic solution of chlorhexidine for skin disinfection (instead of povidone iodine), use of barrier methods (mask, sterile gown, sterile gloves, cap), sterile dressings, bandage application, and use of aseptic technique. To verify the maintenance of CVCs, observation periods of 2 h across the 53 wards of the hospital were conducted to record compliance with recommendations by healthcare staff, specifically completion of the hand hygiene regimen and disinfection of ports with alcoholic solution of chlorhexidine before handling.

Statistical analysis

Categorical variables were expressed as percentages and means with standard deviation or medians with interquartile ranges for quantitative variables. The homogeneity of features of the patients and the catheters over the study period were tested using χ^2 test for categorical variables, and Kruskal–Wallis test for continuous variables. Changes in compliance with recommendations for the time periods were tested by χ^2 for trends. The incidence density was expressed as CR BSI episodes/1000 days of CVC usage and annual and semester incidence rates were compared as a rate ratio (RR) with 95% confidence intervals (CIs) using Poisson regression. Statistical significance was defined as $P < 0{\cdot}05$. Statistical packages used were: SPSS v. 19.1 (SPSS Inc., USA). Epidat v. 3.1 (Xunta de Galicia, Spain and Pan American Health Organization/World Health Organization, USA).

RESULTS

Over the 3-year study period, 6722 short-term CVCs were inserted in 4982 patients, giving an aggregate of 59 335 catheter-days. The main groups of patients were those who underwent surgery and/or with severe disease, requiring critical care. Regarding patients' intrinsic factors (Table 1) a small but significant increase was noted during the study in the percentage of patients with malignancy, but although diabetes was the second most common intrinsic factor this remained relatively unchanged over time. Of the extrinsic risk factors, with the exception of those receiving chemotherapy, increases were evident in the number of patients with urinary or arterial catheters, and other indwelling devices. The survey also showed an increase over time in the use of other types of CVCs but most used were Standard, there was also a marginal increase in the use of catheters with two lumens but most had $\geqslant 3$ lumens; slightly more were inserted in the ICU than in the operating theatre in the third study year (Table 2).

Table 3 shows that compliance of staff with recommendations for insertion and maintenance of CVCs increased significantly in certain areas over the study period, notably hand hygiene, skin disinfection with chlorhexidine rather than povidone iodine, use of gowns, and application of bandages during insertion, and hand hygiene during maintenance of the device. The rate of use of sterile gloves for insertion remained high throughout the study.

There were 266 CR BSI incidents recorded in 4982 patients giving an overall study rate of 5·3%. Table 4 shows the incidence density rates by semester and year and at the end of the programme, there was a 40% reduction in the incidence of CR BSIs compared to the first year, which in absolute numbers was 44 fewer infections per year. The reduction was maintained throughout the study, but was particularly marked in the first semester of each year.

Only 8% of CR BSIs occurred in the first 72 h of introduction of a catheter, and <16% within the first 5 days. Coagulase-negative staphylococci (43·4%) were the most frequent bacteria isolated from blood cultures followed by *Pseudomonas aeruginosa* (17·2%), Enterobacteriaceae (16%), *Candida* spp. (9·4%), *Enterococcus* spp. (3·7%), and *Staphylococcus aureus* (3·3%), one of which was methicillin resistant. Other miscellaneous unidentified species accounted for the remainder. About 32% of Enterobacteriaceae produced extended-spectrum β-lactamases.

DISCUSSION

This study describes a 3-year surveillance programme, covering a large cohort of patients with CVCs, with the aim of measuring compliance of healthcare workers with recommended guidelines for the insertion and maintenance of such devices, and the effect of these

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Table 1. *Patient features and risk factors for catheter-related bloodstream infection*

	Year			
	2009	2010	2011	*P* value
No. of patients	1555	1689	1738	
Age, years, median (P25–P75)	59·8 (39–72)	60·9 (42–73)	61·9 (43–73)	0·045
Male gender, % (*n*)	59·9 (931)	62·3 (1053)	60·0 (1042)	0·251
Intrinsic risk factors, % (*n*)				
Obesity	7·1 (110)	5·5 (93)	7·3 (127)	0·072
Malignancy	23·7 (369)	23·1 (391)	32·2 (559)	<0·001
Neutropenia	1·5 (24)	1·4 (23)	1·2 (21)	0·710
Diabetes	18·8 (293)	19·7 (332)	21·4 (372)	0·168
Burns	1·0 (16)	1·3 (22)	1·1 (19)	0·742
Immunosuppression	3·8 (59)	5·9 (100)	5·6 (98)	0·013
Extrinsic risk factors, % (*n*)				
Urinary catheter	72·9 (1133)	79·4 (1342)	80·6 (1401)	<0·001
Peripheral line	64·7 (1007)	79·7 (1346)	90·6 (1575)	<0·001
Nasogastric tube	50·5 (786)	56·3 (951)	50·6 (880)	<0·001
Arterial catheter	52·0 (808)	65·8 (1111)	70·9 (1232)	<0·001
Mechanical ventilation	19·9 (309)	26·9 (455)	28·4 (493)	<0·001
Chemotherapy	6·4 (99)	4·0 (68)	5·1 (89)	0·011
Surgery	48·9 (760)	54·3 (918)	55·4 (963)	<0·001

CVC, Central venous catheter.

measures on BSIs. To our knowledge, this is the first study to evaluate the impact of an education programme on the total burden of disease of CR BSIs in a tertiary-care hospital.

Overall the results show that there was a general improvement in the performance of both insertion and maintenance of CVCs by staff. Compliance rates for some of the key infection preventive measures such as hand hygiene increased by >40% compared to starting values. Previous to the study, povidone iodine was routinely used for skin disinfection, but throughout the study the use of alcoholic chlorhexidine became widespread among the workers and expanded into all units involved in CVC insertion. For several of the observed points, such as the use of sterile gloves, wearing of a cap, etc., the changes in compliance were not significant owing to the already high initial levels of compliance. At the end of the study we attained comparable, and at times superior, levels of compliance than those described in other similar interventional studies [15, 29] for most of the recommendations. Despite this, adherence to some elements of full barrier precautions still has potential for improvement, suggesting that efforts in education should continue.

The outcomes strengthen the evidence that surveillance programmes with educational interventions significantly reduce the rate of CR BSIs. We achieved a sustained reduction of CR BSIs, reaching 40%, when comparing the results of the third year with the starting point. This corresponds in absolute numbers to 60 infection-free patients with CVCs every year in our hospital. Both the percentage reduction in BSI in these patients and the overall infection incidence density at the end of the study are comparable to studies conducted in ICUs and other settings [3–5, 19]. However, there is evidence from other studies that with similar interventions, the rate of CR BSI can possibly be further improved to values of $\leqslant 1$ CR BSI/1000 catheter-days [18, 19]. The reduction in infection was more evident in the first semesters in both years 2010 and 2011, and less marked for the second semesters. A possible explanation for this may be the seasonal change of personnel, since more temporary staff are employed during the summer months, and end of year, to provide cover for vacations. As a result temporary staff may receive less training [30] and reduced exposure to hand hygiene campaigns [31], and should therefore be considered for educational courses.

The delivery of surveillance data through periodic brochures was a practical, effective and informative method that supplemented the internal reporting. It was well received by staff and of positive value according to course attendees as it increased accessibility to information and positive feedback.

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Table 2. *Features of central venous catheters (CVCs)*

	Year			
	2009	2010	2011	*P* value
Number of CVCs	2098	2284	2340	
Number of catheter-days	19 607	19 954	19 774	
Type of CVC, % (*n*)				<0·001
Standard	75·4 (1581)	75·2 (1718)	73·7 (1724)	
Swan Ganz	10·2 (213)	11·5 (262)	8·9 (209)	
Epicutaneous	5·9 (123)	4·8 (110)	4·0 (93)	
Other	8·6 (181)	8·5 (194)	13·4 (314)	
CVC siting, % (*n*)				0·064
Subclavian vein	21·2 (444)	21·1 (483)	20·1 (470)	
Jugular vein	49·0 (1026)	49·6 (1134)	51·0 (1194)	
Femoral vein	19·5 (408)	21·3 (487)	20·7 (485)	
Other	10·3 (215)	7·9 (180)	8·2 (191)	
Parenteral nutrition, % (*n*)	19·7 (413)	20·2 (462)	20·3 (474)	0·870
Number of lumens; % (*n*)				<0·001
1	11·9 (249)	9·4 (215)	10·6 (249)	
2	12·8 (269)	18·0 (410)	18·2 (426)	
$\geqslant 3$	75·3 (1580)	72·6 (1659)	71·2 (1665)	
Hospital setting, % (*n*)				<0·001
ICU	32·3 (677)	33·4 (762)	35·8 (838)	
Operating theatre	39·3 (824)	36·6 (835)	34·6 (809)	
Recovery room	8·1 (170)	8·3 (189)	7·5 (175)	
Neonatal ICU	5·9 (123)	4·7 (107)	4·2 (98)	
Interventionist radiology	6·2 (131)	7·0 (160)	9·4 (219)	
Paediatric operating room	1·0 (20)	2·2 (50)	2·6 (60)	
Other	7·2 (152)	7·9 (181)	6·0 (141)	

ICU, Intensive care unit.

Table 3. *Compliance with recommendations during insertion and maintenance of central venous catheters*

Recommendation	2009	2010	2011	*P* value
Insertion, % (*n*)	(*N* = 140)	(*N* = 131)	(*N* = 127)	
Hand hygiene	87·1 (122)	99·2 (130)	100 (127)	<0·001
Skin disinfection with AC	35·7 (50)	42·0 (55)	65·4 (83)	<0·001
Use of mask	92·9 (130)	97·0 (127)	88·2 (112)	0·162
Use of gown	75·0 (105)	90·8 (119)	96·9 (123)	<0·001
Sterile cloth	93·6 (131)	95·4 (125)	84·3 (107)	0·009
Use of sterile gloves	98·6 (138)	100·0 (131)	100·0 (127)	0·178
Use of cap	92·1 (129)	96·2 (126)	92·9 (118)	0·765
Bandaged application	62·9 (88)	55·0 (72)	78·7 (100)	0·008
Aseptic technique	90·0 (126)	84·7 (111)	82·7 (105)	0·084
Maintenance, % (*n*)	(*N* = 45)	(*N* = 54)	(*N* = 61)	
Hand hygiene	51·1 (23)	66·7 (36)	72·1 (44)	0·029
Port disinfection with AC	33·3 (15)	40·7 (22)	45·9 (28)	0·197

AC, Alcoholic chlorhexidine.

There were some differences in the patients' factors and the types of catheters used between each year. These were generally minor in absolute terms, but reached statistical significance due to the large sample size. Risk factors that changed significantly showed a tendency to increase throughout the study, but did not result in a reduction in infections. For this reason, we did not deem it necessary to adjust the RR values for these factors.

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Table 4. *Incidence density of catheter-related bloodstream infection, 2009–2011*

Year	Semester density rate[a]		Year density rate[a]	RR (95% CI)
	Jan.–June	July–Dec.		
2009	6·30	–	–	–
2009	–	5·27	–	–
2009	–	–	5·75	1
2010	4·18	–	–	–
2010	–	4·57	–	–
2010	–	–	4·38	0·76 (0·57–1·01)
2011	2·27	–	–	–
2011	–	4·63	–	–
2011	–	–	3·46	0·60 (0·44–0·81)

RR, Rate ratio; CI, confidence interval.
[a] Episodes/1000 days of central venous catheter.

The study has some limitations that are mostly associated with the design. We were unable to confirm a causal relationship between the reduction of CR BSIs and the programme. A part of the observed improvement could possibly be attributed to increased motivation of workers encouraged by taking part in the study, also known as the Hawthorne effect. However, the increase in compliance with recommendations over the study period was progressive and accompanied by a decrease in the numbers of CR BSIs, suggesting that the intervention was highly associated with the outcome. Further, no CR BSI data were available for periods before implementation of surveillance and as a consequence we had to consider the first year of surveillance as the baseline for comparison purposes. Finally, the sample of observed insertion procedures was about half of the expected number. The necessity of the doctors that will perform the procedure to call the preventive medicine staff and the subsequent delay to attend the procedures that are frequently brief in duration, are inherent weaknesses for measurements carried out by external observers, and perhaps detract from the achievement of a larger number of subjects. Nevertheless, our experience was that the surveillance yielded highly reliable data.

In conclusion, the programme provided essential epidemiological data on the burden of CR BSIs in a tertiary hospital and improved overall compliance with practice recommendations for CVCs, which resulted in a sustained decrease in the CR BSI rate. The procedures now in place, remain a target for improvement, particularly hand hygiene and port disinfection. It is our view that such programmes for prevention and control of healthcare-associated infections need to be adequately resourced to facilitate surveillance in all hospital areas of the four leading sites of such infections notably surgical wounds, catheter-associated urinary tract infections, CR BSIs, and ventilator-associated pneumonias.

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DECLARATION OF INTEREST

None.

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