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# Incidence and risk factors for central vascular catheter-related bloodstream infections in a tertiary care hospital

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**SUMMARY**

This study evaluated the incidence of colonization and infection related to Central Vascular Catheters (CVC) in a tertiary care Greek hospital, as well as risk factors associated with catheter-related bloodstream infection (CRBSI).
A total of 340 CVCs, were studied in relation to patient clinical and epidemiological data, CVC characteristics, and microbiological culture results. Risk factors were assessed. Pulsed field gel electrophoresis was used for the investigation of the clonal relationship of the isolates.
The incidence for CRBSI and catheter colonization (CC) was 11.47 and 19.49 per 1,000 catheter days, respectively. Risk factors independently associated with CRBSI were use of corticosteroids, diabetes mellitus, solid organ neoplasm, long duration of catheterization, and changing the CVC dressing at intervals of 48 hours or more. Risk factors for CC were diabetes mellitus, hospitalization in ICU, and prolonged hospitalization. The predominant microorganisms isolated from CRBSI episodes were coagulase-negative staphylococci.
All patients with CVC require constant infection surveillance and appropriate care by trained medical staff. Use of CVC for the shortest time possible, good hand hygiene and change of CVC dressing at intervals of less than 48 hours are infection prevention practices that need to be followed.

*KEY WORDS:* Central vascular catheters, Epidemiology, Infection, Risk factors.

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## INTRODUCTION

Synthetic central vascular catheters (CVC) have been used in everyday clinical practice for more than six decades now, mainly for providing vascular access and haemodynamic monitoring (Meyers, 1945). However, one of the most common complications associated with CVCs is catheter-related infection (CRI), the most serious being catheter-related bloodstream infection (CRBSI) (Correa and Pittet, 2000; O'Grady *et al.,* 2011). Most CRBSIs emanate from the insertion site, hub or both (Maki *et al.,* 1997).
The incidence of CRBSI varies between 2 and 30 per 1,000 catheter days, depending, among other factors, on local policies for catheter placement and care, type of hospital unit, and duration of catheterization (Fraenkel *et al.,* 2000). The total number of CRBSIs for Western Europe and the USA is estimated to be more than 500,000 cases per year (Crump and Collignon, 2000). These infections independently increase hospital costs and length of stay but have not generally been shown to independently increase mortality (Warren *et al.,* 2006; O'Grady *et al.,* 2011). The respective incidence, as well as the main risk factors for CRBSI in Greek hospitals is not known, as no major

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prospective studies have been conducted thus far. The aim of this study was to evaluate the incidence and the major risk factors of catheter colonization (CC) and CRBSI related to CVC in a tertiary care hospital.

## MATERIALS AND METHODS

### Setting, Patients, Data Collection

A prospective observational study was carried out between July 2004 and January 2008 in Laikon General Hospital, a 500-bed tertiary care-hospital in Athens, Greece. All patients having CVCs were eligible for enrolment in the study, until catheter removal, discharge from the hospital or death. Only the first CVC per patient was included, when multiple or consecutive catheters were placed. Data collected from the medical charts of the patients and from the treating physicians included gender, age, hospital ward at the time of infection, CVC type and insertion site, insertion and removal dates, total duration of catheterization, cause of CVC removal, CVC maintenance details (insertion site dressings, change of connecting lines), use of total parenteral nutrition (TPN), total duration of hospitalization, site of infection, species identification and antimicrobial susceptibility of the pathogen, presence of urinary catheter, mechanical ventilation, any antimicrobial therapy administered up to 30 days prior to recovery of the isolate, and final outcome. In addition, the following comorbid conditions were documented: heart disease (coronary disease, arrhythmias and hypertensive cardiopathy), respiratory disease (chronic obstructive pulmonary disease -COPD, asthma and pneumonia), solid organ neoplasm, diabetes mellitus, renal insufficiency (requirement of dialysis), haematological malignancy, neutropenia (absolute neutrophilic count <500 cells/ L) and immune deficiency.

Exclusion criteria were burn or dermatitis at the insertion site, or any reason for recurrent bacteraemia prior to catheter placement (endocarditis, etc.).

### Microbiological procedures

The definitions of CC and CRBSI published by IDSA were used (Mermel *et al.*, 2009). Briefly, CC was defined as the growth of ≥15 colony forming units (CFUs) in cultures of catheter tips prepared by the semi-quantitative roll-plate method or ≥1000 CFU by the quantitative culture. CRBSI was defined as the isolation of the same organism (i.e. identical PFGE types) from the colonized catheter and peripheral blood in a patient with accompanying clinical signs and symptoms of bloodstream infection without any other apparent source.

From all patients the following specimens for culture were obtained:

1) a swab specimen from the skin area around the CVC insertion site;
2) a swab specimen from the CVC's hub;
3) the distal 5 cm of the tip after CVC removal;
4) aerobic and anaerobic blood cultures, from a different peripheral vein, from all patients suspected for bloodstream infection (BSI).

Skin and hub specimens were obtained during catheter removal in the following order: skin specimen sampling, followed by hub specimen sampling, followed by catheter removal. Skin and hub swab specimens were cultured on 5% sheep blood, MacConkey and Sabouraud agar plates (Bioprepare, 16346, Gerakas, Greece), using a semi-quantitative method. The catheter's tip was cut off and cultured using a semi-quantitative roll method in 5% sheep blood agar plates, and a quantitative method after flushing the interior of the tip with TSB broth and subsequent plating on 5% sheep blood and MacConkey agar plates (Safdar *et al.,* 2005). Blood culture bottles were incubated for 6 days in an automated monitoring system (BactAlert 3D, Organon Teknika, Durham, NC, USA).

All microorganisms recovered from the cultures were identified by standard microbiological procedures, supplemented by the API 20E, API 20GN, API STAPH, and API 20 C AUX (bioMerieux, Marcy L' Etoile, France).

Antibiotic susceptibility testing, depending on species identification, was performed by disk diffusion. Minimum inhibitory concentrations were determined using the E-test method (AB Biodisk, Solna, Sweden) according to the manufacturer's instructions. All susceptibility results were evaluated according to CLSI criteria (CLSI, 2006), and used as a preliminary screening for possible clonal relation of strains belonging to the same species and isolated from different specimens of the same patient.

The macrorestriction profile of total DNA was determined by pulsed-field gel electrophoresis (PFGE) for all strains isolated from different specimens of a patient suspected for CRBSI. Briefly, three to four colonies from an 18 h culture on brain heart infusion agar plates were resuspended in 1 ml PIV buffer (1.0 M NaCl, 10 mM Tris, PH 7.6) mixed with 1.6% low-melting-point agarose, inserted into plug moulds, and allowed to set. Each plug was placed into a 1.5 ml Eppedorf tube containing 2 ml of lysis buffer (6 mM Tris, pH 7.6, 100 mM, EDTA, 1.0 M NaCl, 0.5% Brij-58, 0.2% deoxycholate, 0.5 sarcosine, 20 g/ml Rnase, 1mg/ml lysozyme), supplemented with 50 g/ml lysostaphine for staphylococci, and incubated overnight at $37^0$ C. Lysis buffer was replaced by 2 ml ESB buffer (0.5 M EDTA, pH 9 - 9.5, 1% sarcosine, 100 mg/ml proteinase K), followed by overnight incubation at $50^0$ C. In preparation for digestion, each plug was placed in 2 ml TE buffer (10 mM Tris, pH 7.5, 0.1 mM EDTA) and washed for 20 min at $37^0$ C. This procedure was repeated four times. Chromosomal DNA was digested overnight with 30 U of *XbaI* (New England Biolabs, Beverly, MA, USA) for Gram-negative bacteria or 30 U of *SmaI* (New England Biolabs) for Gram-positive bacteria. All chemicals and reaction reagents were purchased from Sigma-Aldrich Hellas (16346, Athens, Greece), unless otherwise indicated. Electrophoresis was performed in 1% PFGE agarose gels, using a CHEF-DR III apparatus (Bio-Rad, Hemel Hempstead, UK). Conditions were 4.5V/cm, pulse times 5-35 sec, temperature $14^0$ C, for 23 h. Lambda ladder (New England Biolabs) was incorporated as a size standard. Electrophoresis products were visualized by ethidium bromide staining, and compared visually. Pattern assignment was performed as described previously (*Tenover et al.,* 1995).

## STATISTICAL ANALYSIS

Statistical analysis was performed using STATA 6.0 statistical software. Patients with CRBSI were designated as group A, patients with CC were designated as group B, and patients without CC or CRBSI were designated as group C. Continuous variables are expressed as mean ± standard deviation, while categorical variables are expressed with absolute and relative frequencies. The normality assumption of continuous variables was evaluated using the Kolmogorov–Smirnov criterion. For the comparison of continuous variables between the three groups one-way analysis of variance (ANOVA) was performed. If the result from analysis of variance was significant, the post hoc analysis with Bonferroni correction for multiple comparisons was conducted. Fishers' exact tests were used for the comparison of proportions and in order to control for multiple testing a significance level ≤0.016 was set. Data were modelled using multiple logistic regression analysis. Odds ratios and 95% confidence intervals were computed from the results of logistic regression analysis. Two multiple logistic regression analyses were performed with dependent variables those defined from groups B/C and A/C, using stepwise backward elimination with a significance level for removal of $p$=0.10 in order to find the best model fitting our data. All reported $p$ values are two-tailed. Statistical significance was set at $p$<0.05.

## RESULTS

During the study period, a total of 340 patients, with an equal number of CVCs were enrolled in the study. CVC insertion sites included the subclavian (45.9%), the internal jugular (22.3%) or the femoral vein (25.9%), while the Hickman catheters were 5.9%.

Overall, 53 (15.6%) patients were classified as having CRBSI (group A), 90 (26.5%) patients as having CC (group B), and 191 (56.1%) patients did not have either CC or CRBSI (group C). In addition, in six patients (1.8%) bacteraemia was diagnosed but was not related to the CVC present, as another source was detected. Descriptive statistics and univariate analysis, among the three groups, are presented in Table 1.

CRBSI incidence was 11.47 per 1,000 catheter days (95% CI: 8.76-15.02) whereas CC incidence was 19.49 per 1,000 catheter days (95% CI: 15.85-23.96). The mortality rate among group A patients was 11.3% (3 patients with *Staphylococcus aureus*, one patient with *Pseudomonas aeruginosa* and two patients with *Candida spp*. CRBSI). In contrast, none of the patients belonging to the two other groups died.

TABLE 1 - *Characteristics of 334 patients with CVC and univariate analysis of data.*

| *Variable* | *Patient group*† | | | *Comparison between groups p** | | |
|---|---|---|---|---|---|---|
| | *A* *N (%)* | *B* *N (%)* | *C* *N (%)* | *A/C* | *B/C* | *A/B* |
| **Age** (mean ± SD, years)†† | 60.8±18.8 | 64.6±14.7 | 60±16.3 | 1.0 | 0.097 | 0.585 |
| **Males** | 34 (64.2) | 44 (48.9) | 92 (48.2) | 0.039 | 0.912 | 0.075 |
| **Duration of catheterization** (mean±SD, days)†† | 17.9±6.2 | 17.7±10.9 | 10.4±9.0 | **<0.001** | **<0.001** | 1.0 |
| **Hospital location** | | | | | | |
| ICU | 21 (39.6) | 58 (64.4) | 91 (47.6) | 0.301 | **0.008** | **0.004** |
| Internal medicine ward | 22 (41.5) | 16 (17.8) | 59 (30.9) | 0.147 | 0.020 | **0.002** |
| Surgical ward | 3 (2.2) | 2 (5.7) | 5 (2.6) | 0.869 | 0.192 | 0.324 |
| Nephrology ward | 7 (13.2) | 14 (15.6) | 36 (18.9) | 0.335 | 0.500 | 0.695 |
| **Use of corticoid** | 15 (28.3) | 7 (7.8) | 18 (9.4) | **0.001** | 0.823 | **0.001** |
| **Underlying disease** | | | | | | |
| Diabetes mellitus | 13 (24.5) | 22 (24.4) | 25 (13.1) | **0.042** | **0.016** | 0.990 |
| Solid tumor | 4 (7.5) | 6 (6.7) | 4 (2.1) | **0.050** | 0.053 | 0.856 |
| Hematological malignancy | 15 (28.3) | 12 (13.3) | 45 (23.6) | 0.482 | **0.045** | 0.026 |
| **Invasive procedures** | | | | | | |
| Mechanical ventilation | 19 (35.8) | 55 (61.1) | 91 (47.6) | 0.126 | **0.034** | **0.003** |
| Nasogastric tube (NG) | 18 (34.0) | 47 (52.2) | 88 (46.1) | 0.115 | 0.339 | **0.034** |
| Duration of NG tube placement (mean±SD, days)†† | 17.7±8.3 | 18.6±8.1 | 13.9±7.1 | 0.159 | **0.002** | 1.0 |
| Urinary catheter (UC) | 29 (54.7) | 58 (64.4) | 99 (51.8) | 0.708 | 0.051 | 0.251 |
| Duration of UC placement (mean±SD, days)†† | 15.8±8.3 | 17.4± 8.2 | 14.1±7.2 | 0.850 | **0.025** | 1.0 |
| **Catheter insertion site dressing** | | | | | | |
| Sterile gauze | 40 (75.5) | 87 (96.7) | 178 (93.2) | **<0.001** | 0.237 | <0.001 |
| Transparent film | 13 (24.5) | 3 (3.3) | 13 (6.8) | | | |
| **Change of dressing intervals** | | | | | | |
| 24 h | 27 (50.9) | 65 (72.2) | 132 (69.1) | | | |
| ≥48 h | 26 (49.1) | 25 (27.8) | 59 (30.9) | **0.013** | 0.596 | **0.010** |
| **Infusion pump connected to CVC** | 21 (39.6) | 56 (62.2) | 91 (47.6) | 0.301 | 0.022 | **0.008** |
| **3-way port connected to CVC** | 46 (86.8) | 76 (84.4) | 143 (74.9) | 0.066 | 0.073 | 0.695 |
| **Administration sets' replacement time interval** (mean ± SD, days)†† | 2.5±1.4 | 2.2±1.4 | 2.0±1.4 | **0.023** | 0.378 | 0.618 |
| **Parenteral nutrition** | 8 (15.1) | 14 (15.6) | 26 (13.6) | 0.780 | 0.654 | 0.936 |
| **No of antibiotics** | | | | | | |
| No antibiotics | 20 (37.7) | 37 (41.1) | 99 (51.8) | 0.069 | 0.094 | 0.688 |
| One or two antibiotics | 15 (28.3) | 40 (44.4) | 63 (33.0) | 0.516 | 0.064 | 0.056 |
| Three or more antibiotics | 18 (34.0) | 13 (14.4) | 29 (15.2) | **0.002** | 0.860 | **0.006** |
| **Cause for catheter removal** | | | | | | |
| End of therapy or scheduled replacement | 9 (17.0) | 44 (48.9) | 153 (80.1) | **<0.001** | **<0.001** | **<0.001** |
| Local inflammation or fever | 44 (83.0) | 46 (51.1) | 38 (19.9) | | | |
| **Catheter site** | | | | | | |
| Subclavian | 24 (45.3) | 44 (48.9) | 92 (48.2) | 0.708 | 0.912 | 0.677 |
| Internal jugular | 13 (24.5) | 11 (12.2) | 45 (23.6) | 0.891 | **0.025** | 0.057 |
| Femoral | 15 (28.3) | 32 (35.6) | 41 (21.5) | 0.297 | **0.011** | 0.369 |
| Hickman catheter | 1 (1.9) | 3 (3.3) | 13 (6.8) | 0.174 | 0.236 | 0.622 |

†Group A: patients with catheter related bloodstream infection (CRBSI, N=53), Group B: patients with catheter colonization (CC, N=90), Group C: patients without CRBSI or CC (N=191). ††Analysis of variance (ANOVA). *Fishers' exact test, significance level ≤0.016. Significant differences are in bold.

Mean age of the patients was 61.2 years, and 50.9% were male. Since Laikon General Hospital does not have a pediatrics department all patients were adults. Regarding hospital ward distribution, 50.6% of the patients were admitted in the ICU unit, whereas 29.7%, 16.8% and 2.9% were hospitalized in the internal medicine, nephrology and surgical departments, respectively.

The catheter insertion site was covered either by sterile gauze (91.2%) or semi-permeable transparent film (8.8%). The dressing was changed in 224 patients at time intervals of 24 hours, and in 110 patients at time intervals of ≥ 48 hours. The majority of CVCs were removed either by the end of the therapy (37%), or as a scheduled replacement (23.6%), while in the remaining 39.4% of the patients local inflammation or fever were the cause for removal.

The mean duration of catheterization (CD) was 13.6 ± 9.8 days. Patients with longer CD were more likely to have CC or CRBSI (17.7±10.9 or 17.9±6.2 vs 10.4±9.0, $p<0.001$). In addition, mean CD in individuals with CRBSI and positive hub culture was 21.2 days, whereas the respective mean CD in patients with CRBSI and positive skin culture was 15.3 days ($p<0.001$).

The most common comorbid conditions were surgical intervention (26.5%), haematological malignancy (25%), heart disease (22.4%), respiratory diseases (5.3%) and solid organ neoplasm (1.8%). Moreover, 23.8% and 12.6% of the 340 patients were treated with antineoplastic drugs and corticosteroids, respectively.

Univariate analysis (Table 1) revealed that CRBSI was significantly associated with increased CD, previous use of corticosteroids, diabetes mellitus, solid organ neoplasm, use of semi-permeable transparent film as dressing for the catheter insertion site, change of the dressing at intervals of ≥48 hours, time interval for replacement of administration set and use of three or more antibiotics for therapy. In addition, CC was significantly associated with CD, ICU admission, mechanical ventilation, diabetes mellitus, haematological malignancy, duration of nasogastric (NG) tube and urinary catheter placement and CVC insertion site.

Multivariate analysis revealed that CD, and changing of the dressing at intervals of ≥48 hours were independently associated with CRBSI (Table 2). In addition, patients with diabetes mellitus, solid organ neoplasm or previous use of corticosteroids had greater odds for having CRBSI (Table 2). Patients with diabetes mellitus addi-

TABLE 2 - *Risk factors associated with Catheter Related Bloodstream Infection (CRBSI).*

| *Variables* | *Patients with CRBSI N=53 (%)* | *Patients without CRBSI or CC* N=191 (%)* | *OR (95% CI)†* | *p* |
|---|---|---|---|---|
| **Use of corticoid** | | | | |
| No | 71.7 | 90.6 | 1.0†† | - |
| Yes | 28.3 | 9.4 | 5.48 (2.19-13.7) | **<0.001** |
| **Diabetes** | | | | |
| No | 75.5 | 86.9 | 1.0 | - |
| Yes | 24.5 | 13.1 | 3.61 (1.44-9.06) | **0.006** |
| **Solid tumor** | | | | |
| No | 92.5 | 97.9 | 1.0 | - |
| Yes | 7.5 | 2.1 | 8.00 (1.55-41.28) | **0.013** |
| **Change of dressing** | | | | |
| Intervals of 24h | 50.9 | 69.1 | 1.0 | - |
| Intervals of ≥48h | 49.1 | 30.9 | 2.27 (1.07-4.76) | **0,032** |
| **Duration of catheterization** (mean ± SD, days) | 17.9±6.2 | 10.4±9.0 | 1.16 (1.09-1.23) | **<0.001** |

*CC: Catheter Colonization. †Odds Ratio (95% Confidence Interval). ††Indicates reference category.

TABLE 3 - *Risk factors associated with Catheter Colonization (CC).*

| *Variables* | *Patients with CC N=90 (%)* | *Patients without CC or CRBSI* N=191 (%)* | *OR (95% CI)†* | *p* |
|---|---|---|---|---|
| **Hospital location** | | | | |
| ICU | 64.4 | 47.6 | 1.0†† | |
| Internal Medicine ward | 17.8 | 30.9 | 0.46 (0.22-0.92) | **0.029** |
| Surgical ward | 5.7 | 2.6 | 0.88 (0.16-4.89) | 0.881 |
| Nephrology ward | 15.6 | 18.9 | 0.87 (0.41-1.84) | 0.722 |
| **Diabetes mellitus** | | | | |
| No | 75.6 | 86.9 | 1.0 | - |
| Yes | 24.4 | 13.1 | 1.96 (1.01-3.81) | **0.049** |
| **Duration of catheterization** (mean ± SD, days) | 17.7±10.9 | 10.4±9.0 | 1.10 (1.06-1.15) | <0.001 |

*CRBSI: Catheter Related Bloodstream Infection. †Odds Ratio (95% Confidence Interval). ††Indicates reference category.

tionally had almost a twofold risk for CC (Table 3). Patients hospitalized in the internal medicine departments had 54% lower odds for CC compared to those admitted in the ICU unit (Table 3). For every CD increase of a single day, the likelihood for CC increased by 10%.

The CRBSI episodes were attributed to coagulase-negative staphylococci (CoNS, N=17, 32.2%), *Staphylococcus aureus* (N=11, 20.8%), *Enterobacter spp*. (N=7, 13%), *Candida* spp. (N=6, 11.3%), *Klebsiella pneumoniae* (N=5, 9.4%), *Pseudomonas aeruginosa* (N=3, 5.7%), *Corynebacterium spp*. (N=2, 3.4%) *Acinetobacter baumannii* (N=1, 1.2%) and *Citrobacter freudii* (N=1, 1.2%).

In 19 out of the 53 CRBSI cases, the hub specimen was positive, and the prevalent micro-organism was *Enterobacter spp*. (N=7, 37%), followed by *K. pneumoniae* (N=3, 16%), *P. aeruginosa* (N=3, 16%), *C. albicans* (N=3, 16%), and *C. parapsilosis* (N=3, 16%). In contrast, in 29 of the 53 CRBSI cases, the skin specimen was positive, and the most common microorganism was CoNS (N=16, 55%), followed by *S. aureus* (N=11, 38%) and *Corynebacterium spp*. (N=2, 7%). In the remaining 5 CRBSI cases, neither the skin nor the hub specimens were positive.

PFGE analysis revealed that clonal relationship was detected mainly among Gram-negative bacteria (data not shown). More particularly, all three CRBSI episodes attributed to *P. aeruginosa* were caused by the same isolate. In addition, the same *E. aerogenes* strain was responsible for three of the six CRBSI episodes attributed to *Enterobacter* spp. Regarding Gram-positive bacteria, clonal relationship was detected only among *S. aureus*, where two CRBSI episodes were caused by a single strain, and two different ones were caused by another strain. All other CRBSI episodes, caused by either Gram-negative or Gram-positive pathogens were attributed to unique pathogens (not clonally related).

## DISCUSSION

The mortality rate among patients with CRBSI was 11.3% in our study, comparable to previously reported rates (Pittet *et al.*, 1994; Jarvis, 1996, Klevens *et al.*, 2007), although the actual incidence of CRBSI (11.47 per 1000 catheter-days) was higher than those reported in other studies (Maki *et al.*, 2006). This high incidence-low mortality combination could be due to the fact that more than 30% of the CRBSI episodes were caused by low-virulent status Gram-positive bacteria (*Co*NS or *Corynebacterium spp*.).

Duration of catheterization is a well-known risk factor for CRBSI (Reed *et al.,* 1995, Yoshida *et al.,* 2011). The present study showed that for every one-day increase in duration, the likelihood of CRBSI increased by 16%. For this reason, CVCs should not be kept more than absolutely necessary. When more prolonged CD is required, with longer treatment intervals, use of Hickman

catheters, related to a lower incidence of CRBSI (0.20 per 1,000 catheter-days), should be considered (Fuchs *et al.,* 1984; Richet *et al.,* 1990, O'Grady *et al.,* 2011). In addition, our study showed that there was a significant difference in CD between patients with CRBSI and positive skin culture and those with CRBSI and positive hub culture. It is obvious that early detection of the local skin inflammation, together with symptoms and signs of a possible bloodstream infection, resulted in earlier removal of the catheter, thus eliminating the source of infection. Nevertheless, a total of 84 catheters were removed needlessly after a suspicion of CRBSI that was not confirmed (data not shown). A diagnostic method of CRBSI without catheter removal is not being used routinely in our hospital, thus increasing the number of investigational catheter removals.

Multivariate analysis revealed that from all the comorbid factors examined, only previous use of corticosteroids, diabetes mellitus and solid organ neoplasm (all conditions leading to immunosuppression) were independently associated with CRBSI. This observation is in line with a previous study indicating that especially solid tumor patients with CVCs were statistically more likely to have a CRBSI episode (Raad *et al.,* 2007). Transparent film coverage of the catheter insertion site was associated in our study with CRBSI and CC, a situation that has also been described before (Prager and Silva, 1984, Webster *et al.,* 2011). Covering the skin with waterproof membranes results in proliferation of the skin flora, and especially Gram-negative microorganisms and *Candida* spp., thus increasing colonization and infection risks (Prager and Silva, 1984; Hoffmann *et al.,* 1992). Nevertheless, logistic regression analysis did not confirm this observation, most probably due to the small number of patients receiving this transparent film dressing (29 versus 305 for the sterile gauze dressing, which seems to be the standard procedure used in our hospital). It should be noted however that irrespective of the dressing material, increased risk for CRBSI is higher when the interval time for dressing change is longer than 48 h, an association confirmed by multivariate analysis also. In that respect, change of the dressing no later than 48h seems to be an active measure for CRBSI control.

The lack of correlation of CRBSI with haematological malignancies may be attributed to the fact that all haematological patients were treated with the utmost nursing care and were under an intense infection surveillance program. The personnel involved with the care of the CVCs of haematological patients were very well-trained and adhered to strict protocols concerning the insertion and maintenance of CVCs. Maximal sterile barrier precautions were used for the insertion of CVCs, hand hygiene was ceremoniously performed and sterile gloves were used for inserting, accessing and dressing every CVC. Well-staffed, qualified and experienced teams for CVC insertion and management have been demonstrated to be major factors in preventing CRBSI by previous studies (Sherertz *et al.,* 2000; Raad *et al.,* 1994).

The site of CVC insertion is a recognized risk factor, and jugular vein catheters are considered more prone to cause CRBSI (Merrer *et al.,* 2001; Lorente *et al.,* 2005; Nagashima *et al.,* 2006). Accordingly, in the present study, placing the catheter in the jugular, but also in the femoral vein, was associated with a higher incidence of CRBSI in comparison with other insertion sites. Admission in the ICU was associated with CC, but not CRBSI, a situation possibly attributed to prolonged hospitalization and increased CD. Nevertheless, heavy antibiotic use, a common practice in the ICUs, may have confined the pathogens in the CVC synthetic material and protected the patients from establishing a CRBSI episode due to this colonization, but without actually eradicating the pathogen from the CVC.

A clonal relationship was mainly detected between Gram-negative pathogens, and to a lesser extent *S. aureus* among Gram-positive ones. In addition, it seems that CoNS or *Corynebacterium spp*. CRBSIs were caused by the patients' microflora of the skin area around the insertion site, whereas Gram-negative CRBSIs may have been caused by the personnel hands infecting the hub.

In conclusion, this study disclosed the incidence of CRBSI among inpatients of a tertiary care hospital in Athens, Greece, and revealed risk factors for CRBSI, factors related to patients' own conditions, but also to medical personnel practice that need to be improved. The continuous surveillance of the epidemiology of CRBSI is essential in taking active measures for infection prevention and control, such as education of medical personnel and strict hygiene practice.

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