

## Risk factors and preventive measures for catheter-related bloodstream infections

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### Abstract

**Objective:** To review the risk factors of central venous catheter-related bloodstream infection and the recommendations for its prevention.

**Sources:** PubMed, Cochrane Collaboration and Bireme were reviewed using the following inclusion criteria: studies published between 2000 and 2010, study design, hospitalized pediatric population with central venous catheters and studies about central venous catheter-related bloodstream infection. In addition, reference documents were retrieved from the Centers for Disease Control and Prevention and the Brazilian Health Surveillance Agency.

**Summary of the findings:** Associated risk factors were: duration of central venous catheter use; length of hospitalization time; long-term indwelling central venous catheter; insertion of central venous catheter in intensive care unit; nonoperative cardiovascular disease; parenteral nutrition; and administration of blood products. The preventive measures recommended by studies in the literature are: development of records and multidisciplinary guidelines of care for central venous catheter insertion and maintenance; correct use of central venous catheter insertion technique; use of chlorhexidine-impregnated dressings; early catheter removal; and adoption of continued education programs for the healthcare team.

**Conclusion:** The control of risk factors may lead to a reduction of 40% or greater in the incidence of catheter-related bloodstream infection. Insertion surveillance and special attention to central venous catheter in pediatric populations should guide the standardization of healthcare routines to achieve standards for comparisons within and between institutions.

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### Introduction

In the treatment of hospitalized patients, central venous catheters (CVC) are used for the continuous administration of intravenous fluids, medications and blood products, prolonged parenteral nutrition, chemotherapy, invasive hemodynamic monitoring of arterial blood pressure, central venous pressure and pulmonary artery pressure, measurement of cardiac output, and haemodialysis.<sup>1</sup> CVCs

are also important to obtain vascular access in children that require intensive care, particularly when the patient cannot receive a peripheral catheter.<sup>2,3</sup>

However, inadequate CVC insertion and maintenance may contribute to an increased risk of infections. Catheter-related bloodstream infections (CRBSI) are associated with increases in mortality, morbidity and hospitalization costs

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for pediatric patients.<sup>1,4</sup> Planning and systematic application of preventive measures are essential to reduce the rate of CRBSI and, consequently, improve healthcare quality.

Some of the risk factors of CRBSI in critically-ill children are patient characteristics, exposure to invasive procedures during hospitalization, compromised immunity, infusion of antibiotics and blood products and specific characteristics of the vascular access.

The knowledge of evidence-based interventions may contribute to the reduction of infection risks, and the study of CRBSI epidemiology and the pathogenesis is fundamental to improve healthcare quality in pediatrics.

This review included studies with pediatric patients and found that the adoption of a set of preventive measures reduces CRBSI risks among pediatric populations. The following Medical Subjects Headings (MeSH) terms were used: infection, catheter-related infections, intensive care units, pediatrics, controlled trial, meta-analysis, systematic review, narrative review, cohort and case-control study published in the last 10 years.

### Physiopathology

Two main mechanisms explain the migration of microorganisms to the bloodstream due to CVC insertion and to the time it remains in place<sup>5,6</sup>:

- a) Extraluminal colonization: contaminating microorganisms on the skin, probably assisted by the action of capillarity, penetrate through the skin during the insertion of the catheter or on the days following the insertion.
- b) Intraluminal colonization: migration of the pathogens in the bloodstream due to infections that originated in other places, such as pneumonia; or due to the infusion of contaminated fluids.<sup>5</sup> Microorganism colonization may occur due to the contamination of the catheter hub, its lumen, its guidewire during insertion, the catheter, the connectors to the infusion lines when handling them, or the infusion administered through the catheter.

Once the microorganism has access to the CVC, infection occurs as a result of the capacity of bacteria to adhere to the catheter surface, colonize and develop biofilm,<sup>6</sup> which is formed when the microorganisms are irreversibly attached to the external or internal surface of the catheter and produce extracellular polymers that facilitate their adherence and form a structural matrix. The extension and location of CVC biofilm depend on how long the catheter has been in place: if less than 10 days, biofilm forms on the external catheter surface; in the case of long-term indwelling catheters, biofilm forms on the internal surface.<sup>7</sup> Preventive measures, such as the use of antiseptic techniques for CVC insertion, removal as soon as it is no longer necessary, and even the use of antibiotic-impregnated catheters, should be adopted to prevent biofilm formation.

### Risk factors

Patients in intensive care units (ICU) may have a depressed immune response due to their underlying disease, age (age extremes pose greater risks of infection), poor nutritional status and invasive procedures, such as the use of CVC, urinary catheter and endotracheal tube for mechanical ventilation.<sup>9-11</sup> Underlying diseases and comorbidities, such as neutropenia, mechanical ventilation and other infections while in the ICU, are risk factors of CRBSI in pediatric populations.<sup>12,13</sup>

Some of the main risk factors of infection reported in the studies retrieved in this review were: administration of blood products (3 units or more); cardiac surgery; other non-cardiac comorbidities; prolonged use of CVC (7 or more days); use of hydrocortisone for presumed renal failure; leukopenia (< 5.000 cells/ul)<sup>11</sup>; catheter type and material; insertion site; infusion type; and catheter maintenance.<sup>14</sup>

A study that used multivariate logistic regression to investigate independent CRBSI risk factors in children in a medical-surgical or cardiac pediatric ICU (PICU) found that the independent predictors of infection were: time of use of CVC in ICU; CVC insertion in the ICU; nonoperative cardiovascular disease; gastrostomy tube; parenteral nutrition and administration of blood products. Children with those risk factors should be candidates to adjuvant interventions to prevent infection,<sup>15</sup> such as the use of antibiotic-impregnated catheters, antiseptic-impregnated dressings, and antibiotic and ethanol locks, which seem to potentially prevent CRBSI under special circumstances.<sup>16</sup>

A study of the variables associated with CVC insertion and maintenance in PICU patients detected, using logistic regression analysis, the following CRBSI risk factors: respiratory failure, hospitalization time; intubation time; CVC insertion in the ICU; parenteral nutrition; insertion of more than one catheter ( $p = 0.14$ ); and time of catheter use ( $p = 0.0013$ ).<sup>17</sup>

Patients with and without infection complications associated with peripherally inserted central catheter (PICC) in a hospital in Israel, including infants, children and young adults aged 7 days to 21 years, were studied to evaluate the incidence of PICC insertion complications and possible risk factors. Results suggested that the use of PICC in pediatric populations was safe and may be extended for long periods of time because 177 (63%) of all catheters had no complications. The main reasons for removal were: infection complications (13.6%); mechanical problems (13.6%); and accidental dislodgement (9.3%). Three risk factors for complications were detected: patient age; absence of underlying disease at beginning of the study; and use of PICC for multiple purposes.<sup>18</sup>

Prasad et al. conducted a study that evaluated three risk factor categories associated with the development of CRBSI: type of catheter; exposure to other medical devices;

and exposure to therapeutic agents. A multivariate analysis model was built to detect independent risk factors for CRBSI, which included all the variables for which  $p < 0.20$  initially. The only independent risk factor for infection was the presence of a tunneled catheter. Patients that received antibiotics on the last day of the exposure window were less likely to develop CRBSI. The strict use of an aseptic technique when inserting or handling central catheters may reduce infection rates in the PICU.<sup>19</sup>

One of the risk factors of infection in pediatric populations in the ICU, in contrast with adult care, is catheter insertion site, because there is no evidence of greater infection risk when the catheter is inserted into the subclavian, jugular or femoral vein, as demonstrated for adult patients.<sup>12,17</sup> The venous network is fragile in children, and the use of a CVC to collect material for laboratory tests is common; for that reason, a CVC might be kept for a longer time than necessary to ensure safe venous access. The specific characteristics of pediatric populations should be investigated to improve the quality of healthcare.<sup>20</sup>

When bacteremia progresses into severe sepsis, it may lead to hemodynamic changes and even death.<sup>8</sup> In addition, catheters are often placed in emergency situations, used repeated times and, in general, have to remain in place for a long time.<sup>21</sup> The prevention of catheter-related infections should be carefully observed in patients that have the risk factors described so far.<sup>11</sup>

The detection of avoidable CRBSI risk factors should be the basis for the development of new interventional strategies to reduce catheter-associated sepsis. Of the studies discussed above, the ones in Table 1 are those that detected specific risk factors for pediatric patients, such as length of hospitalization time, length of CVC use, CVC insertion technique, type of catheter and underlying disease.

The studies described show evidence that should be taken into consideration to reduce the rates of CRBSI. The insertion of a tunneled CVC carries a lower risk of bacterial colonization, but may be an independent factor of the occurrence of infection.<sup>19,22</sup> The Seldinger technique is safe for CVC insertion, and the success rate is 81.9% for the first puncture site, which reduces the number of subsequent attempts.<sup>2</sup> CRBSI increases hospitalization time and costs.<sup>23</sup> Therefore, preventive measures are essential to reduce infection incidence density.<sup>24</sup> In addition, central venous catheter placement in the ICU, nonoperative cardiovascular disease, presence of gastrostomy tube, parenteral nutrition and blood transfusion are statistically significant risk factors of CRBSI and should be monitored.<sup>15</sup>

### **Preventive measures**

In Brazil, CRBSI is a serious public health problem that demands efficacious surveillance measures to reduce the rates of nosocomial infections. Adequate surveillance of

nosocomial infections (NI) is greatly important because it makes it possible to compare data and similar services,<sup>25</sup> as well as to evaluate the impact of control measures.

### **Guidelines for catheter insertion and manipulation**

According to the Healthcare Infection Control Practices Advisory Committee (HICPAC) and the Centers for Disease Control and Prevention (CDC), hospitals should develop continued education programs to teach appropriate catheter insertion and manipulation techniques.<sup>5</sup> Therefore, process control aims at, for example, ensuring healthcare quality and implementing training programs so that the healthcare team may choose the most appropriate catheter insertion site, evaluate the type of material to be used according to the indicated therapy, perform correct hand hygiene procedures and skin antiseptic techniques, and use dressings that make it possible to visualize the insertion site. The healthcare team should receive regular reports about infection rates, and should discuss and evaluate problems and improvements in CVC manipulation. Knowing the effect of actions on infection rates may contribute to the reduction of CRBSI.<sup>26,27</sup>

A strategy currently used to improve the care of intravenous devices is the adoption of groups of best practices known as bundles. The Institute for Healthcare Improvement (IHI) defined structured recommendations to promote device care that accelerates patient discharge, that is, a group of practices that, when applied together and systematically, may ensure that patients are discharged sooner. The development of successful CVC intervention bundles must combine practices and measures to prevent contamination, migration, adherence and catheter colonization.<sup>16,28</sup>

When evidence-based prevention strategies are applied during catheter insertion, dressing changes and catheter removal, there is a reduction in infection rates.<sup>29,30</sup>

In the United States, a multicenter study of 29 PICUs found a reduction of 43% in infection incidence density (from 5.4 to 3.1 infections per 1,000 CVC-days) after the adoption of infection prevention measures as CVC insertion and maintenance bundles. Some of the preventive practices were: wash hands before the procedure, scrub insertion site with chlorhexidine gluconate, do not use iodine or ointment at the insertion site, prepare trolley or tray with material for insertion using sterile barriers, create insertion checklist, use only polyurethane or Teflon catheters, change gauze dressings every two days unless they are soiled, dampened or loosened, and clear dressings every 7 days.<sup>20</sup>

In a review of 10 studies (eight of which had statistically significant results) that evaluated CRBSI rates before and after the adoption of interventions, nine found a reduction of at least 40% in incidence. Further studies about preventive measures adopted by neonatal ICU and PICU nurses should inform educational and auditing programs according to each institutional profile and the characteristics of the healthcare team.<sup>31</sup>

**Table 1** - Risk factors of central venous line-related infection

Author/year/country	Type of study	Risk factors for CRBSI	Results
Nahum et al., 2002 <sup>39</sup> , Israel	Prospective randomized controlled cohort study	Randomization of PICU patients that required femoral CVC for over 48 h; tunneled or nontunneled CVC	Bacterial colonization: 11 (22.4%) catheters in nontunneled group and 3 (6.1%) in tunneled group ( $p = 0.004$ )
Cruzeiro et al., 2006 <sup>2</sup> , Brazil	Prospective cohort study	Identification of complications associated with CVC inserted percutaneously using Seldinger technique	Insertion success rate of 81.9% using Seldinger technique in first site chosen for puncture, increased to 100% with the inclusion of second site
Bwersi et al., 2009 <sup>52</sup> , Germany	Prospective cohort study	Comparison of clinical data of 43 pediatric patients with cancer and CRBSI paired with 43 control patients without CRBSI	CRBSI increased hospitalization time in a mean 12 days ( $p < 0.001$ ), which represents a median additional expenses of US\$ 6,970 per infection case
Nowak et al., 2010 <sup>51</sup> , U.S.	Retrospective case-matched cohort study	Comparison of length of PICU stay, mortality and hospital costs in group of critically-ill children with CRBSI and matched controls	CRBSI extended length of stay by 9 days (6.5 days in PICU) and hospital costs by US\$ 33,039
Wylie et al., 2010 <sup>15</sup> , U.S.	Case-control	Multivariate logistic regression to detect independent risk factor of CRBSI and to derive and to validate a prediction rule	Independent CRBSI factors were: duration of central access use, central venous catheter placement in the ICU, nonoperative cardiovascular disease, presence of gastrostomy tube, parenteral nutrition and blood transfusion. The model predicted CRBSI with a positive predictive value of 54% and a negative predictive value of 79%
Prasad et al., 2010 <sup>19</sup> , U.S.	Retrospective case-control	Identification of all CRBSI from Jan 1, 2004 to Jun 30, 2005	Median time from catheter insertion to infection: 9 days. The only independent risk factor of infection was use of tunneled catheter

CRBSI = catheter-related bloodstream infection; CVC = central venous catheter; ICU = intensive care unit; PICU = pediatric intensive care unit.

The use of reports developed systematically, including catheter insertion and maintenance bundles, daily reviews of CVC necessity and the definition of daily goals, resulted in an important decrease in CRBSI rates, from 6.3 to 4.3 per 1,000 CVC-days in a multicenter study that showed that the use of scientific evidence in clinical practice contributed to patient safety, better clinical results and a reduction of costs to treat CRBSI.<sup>32</sup>

The Children's Hospital Boston implemented a CRBSI prevention initiative that included CVC insertion reports,

use of chlorhexidine as the antiseptic of choice for the skin, use of chlorhexidine-impregnated dressing at the CVC insertion site, adoption of CVC insertion and maintenance bundles, use of a CVC insertion kit and use of needleless connector systems. The estimate mean CRBSI rate before the intervention was 7.8 infections per 1,000 CVC-days, which was reduced to 4.7 infections per 1,000 CVC-days in the partial intervention period, greater than the mean rate of 3.5 infections per 1,000 CVC-days in PICUs according to the reference values published by

the National Healthcare Safety Network (NHSN).<sup>33</sup> In the full intervention period, there was a reduction to 2.3 infections per 1,000 CVC-days.

### **Dressings**

The CDC recommends the use of gauze or transparent polyurethane for catheter site dressing.<sup>34</sup> A systematic review of the Cochrane, MEDLINE, Embase and Cancerlit databases retrieved six controlled trials that compared the effects of gauze and tape and/or transparent polyurethane dressings for CVC site. No differences were found in infection incidence between any of the types of dressing used.<sup>35</sup>

Transparent dressings may be the most adequate choice for CVC because they permit daily visual inspection of the site. Gauze dressings should be chosen in cases of bleeding at the insertion site. However, infection prevention is achieved when the healthcare team is prepared for the correct use of dressings, as well as when other preventive measures, such as hand hygiene, are adopted.<sup>36</sup>

Two methods to change dressings have been compared in a study about CVC care in a PICU in the state of Arizona: the use of transparent polyurethane and chlorhexidine-impregnated dressings. Results showed no significant differences in infection rates between the two study groups (from 2.8/1,000 CVC-days at the beginning of data collection to 2.5/1,000 CVC-days at 6 months). The authors concluded that actions to prevent CRBSI should focus not on the use of specific products for CVC care, but rather on the implementation of CVC insertion and maintenance bundles with well-established criteria that may result in better results in the prevention of this complication.

A study evaluated the efficacy and safety of a chlorhexidine gluconate-impregnated dressing in reducing CVC colonization and CRBSI in neonates and children after cardiac surgery. Seventy-one patients aged 0 to 18 years were randomly assigned to the control group (polyurethane dressing), and 74, to the study group (impregnated dressing). There were no significant differences between groups in age, sex, pediatric risk of mortality score or cardiac severity score. CVC colonization was found in 21 patients in the control group (29%) and 11 patients (14.8%) in the study group ( $p = 0.0446$ ; relative risk [RR] = 0.6166, 95% confidence interval [95%CI] 0.3716-1.023). Three patients had CRBSI (4.2%) in the control group, and four (5.4%) in the study group. The chlorhexidine-impregnated dressing was safe and significantly reduced CVC colonization rates in infants and children after cardiac surgery.<sup>38</sup>

### **Antisepsis**

One of the most important CRBSI prevention measures is the use of an antiseptic agent to prepare the skin at the

CVC insertion site.<sup>34</sup> Chlorhexidine, polyvinylpyrrolidone-iodine (PVP-I) and 70% alcohol are the agents used in healthcare centers to prevent CRBSI. In 2003, a study about nosocomial bacteremia surveillance conducted in England enrolled 17 teaching and 56 nonteaching hospitals. The use of CVC was the most frequent source of bacteremia, which corresponded to 38.3% of infections in teaching hospitals versus 22.3% in the nonteaching hospitals ( $p < 0.001$ ). Their conclusions reinforced the need to choose and use an appropriate antiseptic agent and to follow the CDC and Epic2 recommendations, which are evidence-based guidelines to prevent CRBSI in hospitals of National Health Service (NHS) in England.<sup>39</sup>

A systematic review concluded that randomized studies with the power to determine the efficacy of several interventions for CVC care should be conducted. Studies indicate that chlorhexidine is better for antisepsis than PVP-I to reduce the risk of infection associated with the insertion site.<sup>38,40</sup> However, no recommendation can be made for the use of chlorhexidine in preterm infants or infants younger than 2 weeks.<sup>39,41</sup> Safer findings are necessary to define the type of solution formula and concentrations for pediatric patients.<sup>41,42</sup>

### **Catheter types**

A randomized controlled trial evaluated the efficacy and safety of tunneled CVC without a cuff in the prevention of CRBSI in critically-ill children. The authors found bacterial colonization in 11(22.4%) catheters in the nontunneled CVC group and in 3 (6.1%) in the tunneled CVC group ( $p = 0.004$ ). The main pathogens were coagulase-negative staphylococci, *Pseudomonas* spp. and *Klebsiella* spp. The authors found bacterial colonization in 11 (22.4%) catheters in the nontunneled CVC group and in 3 (6.1%) in the tunneled CVC group ( $p = 0.004$ ). Proximal segment colonization was found in 7 (14.2%) of the nontunneled CVC and in 2 (4.8%) of the tunneled CVC ( $p = 0.07$ ). Colonization of the distal segment was found in 9 (18.3%) nontunneled CVC and in 3 (6.1%) tunneled CVC ( $p = 0.053$ ). The use of tunneled CVC in the femoral insertion site is safe and significantly reduces the rate of CVC colonization in critically-ill children.<sup>22</sup>

### **Surveillance**

International and Brazilian regulating agencies, such as HICPAC, CDC and the Brazilian Health Surveillance Agency (Agência Nacional de Vigilância Sanitária, ANVISA) have published CRBSI surveillance and prevention guidelines and recommendations of best practices to be adopted during CVC insertion, maintenance and removal.<sup>42</sup>

Insertion and dressing practices should be controlled, and their effects on CRBSI rates should be evaluated, as they may provide data about CVC insertions in pediatric

populations with a focus on events associated with infections. Controlled studies with pediatric populations are rare in Brazil, but the development of infection markers and infection control according to the guidelines issued by ANVISA may favor the definition of more specific prevention strategies for those populations, as well as to promote the application of the recommended measures to prevent CRBSI.

Table 2 summarizes the studies discussed above, which investigated aspects associated with the implementation of preventive measures to be adopted during CVC insertion and maintenance, as well as reports and novel technological approaches, such as the use of antiseptic-impregnated dressings, to decrease CRBSI rates. The studies described below systematize the implementation of preventive measures that had a substantial effect on CRBSI rates,

**Table 2** - Measures to prevent catheter-related bloodstream infections

Author/Year/Country	Type of study	Preventive measures	Results
Levy et al., 2005 <sup>38</sup> , Israel	Prospective randomized controlled cohort study	Use of transparent polyurethane dressing (control) or chlorhexidine-impregnated dressing (study group)	Lower rates of infection and colonization of CVC segment in chlorhexidine group ( $p = 0.04$ )
Bhutta et al., 2007 <sup>13</sup> , U.S.	Prospective cohort study	Inclusion of maximum barrier precautions for insertion, use of antibiotic-impregnated CVC, annual hand hygiene campaigns, and use of chlorhexidine for skin disinfection	Infection rate decrease from 9.7/1,000 CVC-days in 1997 to 3.0/1,000 CVC-days in 2005, and reduction of 75% in number of cases (95% confidence interval 35 to 126%)
Costello et al., 2008 <sup>33</sup> , U.S.	Retrospective cohort study	Comparison of CRBSI rates in three periods from 2004 to 2006 and implementation of CRBSI intervention bundle	Reduction of estimate mean CRBSI rate from 7.8 to 4.7 infections per 1,000 CVC-days in the partial intervention period and to 2.3 infections per 1,000 CVC-days in the full intervention period
McKee et al., 2008 <sup>27</sup> , U.S.	Prospective cohort study	Evaluation before and after intervention, which included team education, development of insertion kit, CVC insertion checklist, interruption of procedures that did not follow guidelines, and feedback to PICU	Before intervention: mean monthly CRBSI rate was $5.2 \pm 4.5$ cases/1,000 CVC-days 24 months after intervention: Mean monthly CRBSI was reduced to $2.7 \pm 2.2$ cases/1,000 CVC-days
Hatler et al., 2009 <sup>37</sup> , U.S.	Prospective cohort study	Use of transparent or chlorhexidine-impregnated dressing at CVC site	No significant differences in CRBSI rates associated with transparent dressing or chlorhexidine-impregnated dressing
Jeffries et al., 2009 <sup>32</sup> , U.S.	Multicenter prospective cohort study	Implementation of protocols with preventive measures in CVC insertion and maintenance, including daily review of CVC necessity and definition of goals	CRBSI rate was reduced from 6.3 to 4.3 per 1,000 CVC-days at the end of protocol implementation. Hospitals sustained improvement for 12 months and prevented 198 deaths
Vilela et al., 2010 <sup>48</sup> , Brazil	Prospective cohort study	Direct and indirect educational and procedural measures in three phases: 1) before intervention, from 2003 to 2004; 2) early post-intervention cohort, from 2004 to 2005; 3) late post-intervention period, from 2005 to 2006	CRBSI ID was 22.72 per 1,000 CVC-day in phase 1 and was reduced to 6.81 and 5.87 per 1,000 CVC-days in phases 2 and 3 ( $p < 0.01$ )

with significant two- to threefold reductions of number of cases and incidence densities 50% to 75% lower than previously found.

### Infection rates and microorganisms

With the increase of CVC in pediatric populations, CRBSI has become a significant complication in the ICUs that treat infants and children.<sup>2,3,43</sup> The frailty of the venous system of pediatric patients makes it difficult to obtain multiple accesses and to administer and maintain intravenous medications. Because medications are not dispensed in specific doses for pediatric patients, bottles and containers have to be handled for dilution and dispensation, and the infusion lines for the administration of the prescribed doses. These factors contribute to the greater prevalence of CRBSI in this population.<sup>44</sup>

According to the CDC HNSN of 2009, mean CRBSI rate in PICU was 1.3 to 3.0 per 1,000 CVC-days. In other hospital wards for noncritical care, this rate ranges from zero to 1.9 per 1,000 CVC-days.<sup>9</sup>

A review study found a variation in CRBSI incidence densities in countries with limited resources, from 1.6 to 44.6 cases per 1,000 CVC-days in adult and pediatric ICU, and from 2.6 to 60 cases per 1,000 CVC-days in neonatal ICU.<sup>45</sup> This heterogeneity is associated with factors such as the methods used for data collection, criteria do define sepsis, differences between populations under evaluation and between the types of practices and reports used in each institution. Moreover, higher infection rates are expected in places with poor healthcare structures. CRBSI prevention and control in developing countries should be broadly and adequately implemented to achieve the reference standards found in developed countries. The CRBSI incidence density published by the CDC NHSN ranges from zero to 22.62 cases per 1,000 CVC-days. The rates in developing countries are above the 90th percentile when compared with American data. Public national and global healthcare policies should ensure that healthcare services have the resources and necessary support to provide good quality healthcare.<sup>45</sup>

A 2010 study with PICU teams in the United States found variations in reported CRBSI rates, from 2.2 to 7.9 infections per 1,000 CVC-days, because healthcare professionals are inconsistent or uncertain about surveillance criteria used to report infection rates.<sup>46</sup> CRBSI surveillance should be standardized to improve the quality and validity of this marker and to lead to more efficacious prevention.

In Brazil, data about nosocomial infection surveillance in the state of São Paulo have been published since 2004 and, according to an analysis conducted in 2008, CRBSI incidence density per 1,000 CVC-days was zero, 2.72, 6.66, 11.55, and 17.86 in the 10th, 25th, 50th, 75th and 90th percentiles, and the CVC use rate in PICU ranged from 16.94 (10th percentile) to 69.86 (90th percentile).<sup>47</sup>

A prospective cohort study in a PICU found a decrease in CRBSI incidence density from 22.72 to 6.81 and 5.87 cases per 1,000-day ( $p < 0.01$ ) after an intervention that consisted of an educational program and the publication and discussion of a set of norms for CVC insertion, distribution of guidelines, interdisciplinary discussion about risk factors of sepsis and the establishment of a multidisciplinary intervention team made up of PICU physicians and nurses and the Nosocomial Infection Control Service.<sup>48</sup>

According to the Clinical Practice Guidelines for the Diagnosis and Management of Intravascular Catheter-Related Infection,<sup>49</sup> about 34% of CRBSI in children are caused by coagulase-negative staphylococci, and 25%, by *S. aureus*. In neonates, 51% are due to coagulase-negative staphylococci. *Candida sp.*, *Enterococcus* and gram-negative bacilli are found in cultures.

The profile of microorganisms and infection rates may vary according to the healthcare unit and the characteristic of its patient population. Preventive strategies adopted by a healthcare team may have their efficacy evaluated by means of infection incidence density. Epidemiological surveillance should be conducted by a trained team that follows predetermined reporting criteria.

### Costs

CRBSI is a frequent cause of mortality and morbidity in the ICU.<sup>50,51</sup> In the U.S., a study found that CRBSI is also associated with longer hospitalization times and higher treatment costs, ranging from US\$ 3,700 to US\$ 29,000 per event.<sup>52</sup>

In an American hospital for intensive treatment of children and adolescents, median hospital costs were significantly higher among patients with CRBSI, at US\$ 185,397 (with CRBSI) versus US\$ 152,358 (without CRBSI) ( $p = 0.048$ ). Mean total cost difference was US\$ 33,039 higher in patients with CRBSI than in patients without infection. The use of preventive strategies had a substantial impact on healthcare quality and health promotion.<sup>24</sup>

In the pediatric oncology unit of the Children's Hospital of the University of Bonn, Germany, infection led to a 12 day increase in mean hospital stay ( $p < 0.001$ ), which resulted in an increase of € 4,400 (US\$ 6,970) for each patient with infection, that is, a substantial increase of financial resources required for patient treatment. The daily calculation of financial expenses for hospital treatment took into consideration human resources, laboratory tests (including microbiological tests), medications, blood products, nutrition, radiology, transportation and management costs.<sup>23</sup>

In Brazil reporting infection markers according to the criteria established by ANVISA for primary bloodstream infections was made compulsory in 2010 for all healthcare

services in the country. Based on the application of these parameters for infection surveillance, more reliable information will be obtained about annual expenses with CRBSI in the country.<sup>53</sup>

When healthcare services invest in prevention against healthcare-related infections by establishing strategies such as preparing professionals to define criteria to select CVC insertion type and site and to follow the guidelines for strict hand hygiene, the result is a significant reduction in hospitalization costs.

### Final considerations

Nosocomial infections related to central venous devices are important adverse events in pediatric populations, particularly in the ICU.

This review of the literature retrieved intervention studies in which CRBSI was associated with longer stay in hospital and higher financial costs for the institution.

The procedures adopted for pediatric populations, based on studies of risk factors, preventive measures, new technologies and other actions to decrease the risk of infection, are derived from studies with adult populations.

The risk factors of these infections should be evaluated to develop specific CRBSI prevention. Healthcare services that treat patients with CVC should have active infection control programs for infection surveillance and should develop preventive guidelines. Moreover, a permanent multidisciplinary educational approach should be adopted, and norms for CVC insertion and maintenance should be established to reduce CRBSI in the PICU.

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