Reducing Central Venous Catheter-Related Bloodstream Infections in Children With Cancer

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Children with cancer who have a central venous catheter (CVC) are at increased risk for bloodstream infections. Aseptic technique when using and caring for a CVC can decrease the chance of contamination in this patient population. Staff education on adherence to aseptic technique and strict CVC care guidelines are essential to decreasing bloodstream infections.

Background

Central Venous Catheters and Children With Cancer

CVCs are essential to the treatment and supportive care of children with cancer. The devices have greatly improved the quality of life of children with cancer and increased family satisfaction by minimizing the need for venipunctures and the associated emotional trauma. In addition, CVCs facilitate the long-term delivery of chemotherapy, parenteral fluids and nutrition, blood products, antimicrobials, and analgesics. However, the insertion and maintenance of CVCs are not without associated complications. Potential complications associated with catheter insertion include pneumothorax, air embolism, nerve injury, and catheter malposition. Infection and occlusion remain the two most common complications associated with use and maintenance of central lines (Bagnall-Reeb & Perry, 2002; O’Neill, 2005).

Incidence of Central Venous Catheter Infections

Catheter-related bloodstream infection rates vary widely among patient populations. Differences occur within the pediatric specialty and with catheter type. In the pediatric population, the National Nosocomial Infections Surveillance System (2004) reported that hospital pediatric intensive care units experience the highest rates of infection at 6.6 per 1,000 catheter days. The neonatal intensive care areas have slightly lower rates of catheter infections at 4.7 per 1,000 catheter days (Mahieu, De Dooy, Lenaerts, Ieven, & De Muynck, 2001). Infection rates for CVCs placed in children with cancer range from 1.0–4.58 per 1,000 catheter days (Hengartner, 2005).

Differences in catheter types related to rates of infection also have been studied. CVCs have the highest infection rates at 2.0–4.0 per 1,000 catheter days (Johnson et al., 1986; Wurzel et al., 1988), followed by peripherally inserted central catheters (PICCs) at 0.46–1.3 per 1,000 catheter days (Skiest, Abbott, & Keiser, 2000; Walshe, Malak, Eagan, & Sepkowitz, 2002) and internally implanted lines (i.e., subcutaneous ports) at 0.11 per 1,000 catheter days (Hengartner et al., 2004).

Central line bloodstream infection rates in children with cancer at the study institution were obtained from the Infection Control Service during an 18-month time period (July 2003 through December 2004). A total of 35 catheter-associated bloodstream infections occurred during 6,258 CVC days in patients undergoing bone marrow transplantations. The central line infection rate for this period of time was 5.59 infections per 1,000 line days. In addition, the general hematology-oncology unit had a total of 51 catheter-associated bloodstream infections during 10,434 CVC days from August 2003 through December 2004. The central line infection rate for the general hematology-oncology unit during the 17-month period was 4.89 per 1,000 line days. The findings revealed a central line infection rate higher than reported rates found in the literature.

Causes of Central Venous Catheter Infections

Eggimann and Pittet (2002) reviewed the pathology of catheter-related infections, highlighting the skin insertion site and IV line hub as principle sources of colonization and infection. Numerous risk factors are associated with central line infections (Mermel, 2001; Safdar, Kluger, & Maki, 2002; Safdar & Maki, 2004). The use of a multilumen catheter and multiple CVCs increase the susceptibility to infection (Heard, 2001; Yogaraj, Elward, & Fraser, 2002). The degree of neutropenia (Safdar et al., 2002) and whether patients are receiving immunosuppressive agents also can play a role in developing an infection. History of prior CVC infection and poor nutritional status addressed by parenteral nutrition, particularly lipids, place patients at an increased risk for CVC infection (Gorski, 2004). Wet central line dressings after bathing or showering increases infection risk as well (O’Grady et al., 2002). Impaired skin integrity and concurrent multiple sites of infection also are risk factors. CVC infection risk factors often cannot be avoided.

Failure to use aseptic technique when accessing the line predisposes a patient to infection (Hadaway, 2003). Strict adherence to aseptic technique through staff education programs has reduced the incidence of catheter-related bloodstream infections at numerous hospitals in the United States. Some report a 30%–70% reduction rate in catheter-related bloodstream infections following implementation of a structured education program (Bouza et al., 2003; Eggimann & Pittet, 2002; Parras et al., 1994). The Centers for Disease Control and Prevention (CDC, 2000) and the Infusion Nurses Society (2006) have established standardized guidelines for CVC care; however, guidelines often are forgotten in busy patient settings.

Catheter hub sites provide bacterial access to the bloodstream through migration along the external and internal surfaces of the catheter (Mahieu et al., 2001; Safdar & Maki, 2004). Hub colonization was identified in numerous studies with adults as a source of contamination resulting in increased bloodstream infection (Luna et al., 2000; Seymour, Dhallu, Moss, Tebbs, & Elliot, 2000). Hub colonization rates vary from 29%–38% in adult patients. Several researchers reported a high incidence of bloodstream infections (up to 60%) in CVCs with hub colonization (Luna et al.; Seymour et al.). Although no pediatric studies were found, Mahieu et al. reported that the incidence of bloodstream infections in neonates was 30 times higher in catheters that had hub colonization compared to catheter hubs that were not colonized. New hub products that use an antiseptic chamber are being studied and hold promise for the future (Rupp et al., 2005).

Educational Programs for Central Venous Catheter Care

A literature review revealed that CVC-related bloodstream infections can be reduced significantly by educational programs that are evidenced based and promote aseptic technique practices. Warren et al. (2004) described a pre- and postintervention observational study designed to determine whether an educational program decreased catheter-associated bloodstream infection rates in the medical intensive care unit of a teaching hospital. The intervention highlighted correct practices to prevent catheter-related bloodstream infection using a mandatory education program for intensive care unit nurses and physicians. The authors concluded that an education-based intervention that includes a mandatory training component could result in substantial decreases in medical care costs and patient morbidity associated with central venous access devices. Eggimann and Pittet (2002) evaluated the impact of an educational program targeted at vascular access care that enforced specific care guidelines for the reduction of catheter-related infections in a medical intensive care unit. The program consisted of slide-show–based educational sessions and bedside training of the entire staff, including physicians. The study demonstrated a decrease in exit-site and bloodstream infections associated with CVCs.

Parras et al. (1994) conducted a study to evaluate an educational program for the prevention of intravascular
line colonization. All caregivers participated in a 45-minute lecture on the CDC guidelines, most frequent violations of the guidelines, pathophysiology and etiology of catheter-related infections, and sampling methodology. Cultures of skin surrounding the catheter insertion site, hubs, and infusion fluids were collected from all patients. Study findings after the educational program demonstrated improved catheter care and reduced skin colonization around the insertion site. Lange et al. (1997) evaluated CVC-related complications in children with chronic illness following implementation of a three-phase, hospital-wide infection control program to reduce infection rates. The education program was directed at four sources of infection: staff, exit site, catheter hub, and access device. Study findings demonstrated a statistically significant decrease in exit-site infection rates postintervention. CVC-related infection rates were reduced from 4.58 per 1,000 catheter days to 3.83 per 1,000 catheter days.

In summary, CVC infections in children with cancer are a serious and costly complication nationwide. Strict adherence to aseptic technique must be enforced when using CVCs. By accomplishing adherence to catheter care guidelines, the incidence of bloodstream infections in children with cancer can be decreased. Previous studies by Eggimann and Pittet (2002), Parras et al. (1994), and Lange et al. (1997) have shown that increasing staff and parental awareness with an educational program that emphasizes aseptic technique can decrease catheter infection rates.

Purpose
The current study had four aims: (a) to decrease CVC-related bloodstream infection rates in children with cancer through a comprehensive educational intervention, (b) to determine if the frequency of catheter hub colonization of CVCs in children with cancer would decrease following the educational intervention, (c) to evaluate nurses’ knowledge of CVC care, and (d) to determine risk factors influencing CVC-related bloodstream infections in children with cancer.

Methods
Sample
The study was conducted in the cancer center of a large children’s hospital in the southwestern United States. The cancer center includes a 36-bed hematology-oncology unit, a 15-bed bone marrow transplantation unit, an outpatient clinic, and a bone marrow transplantation outpatient clinic. More than 15,000 patient visits occur in the outpatient clinics each year. The patient population for the sample included all patients with cancer in the cancer center with a CVC. The convenience sample consisted of 51 catheter hubs from 27 children. CVC types included external CVCs, PICCs, and subcutaneous ports. Patients’ ages ranged from infancy to 18 years and included children of each gender and a variety of races with a diagnosis of cancer.

Nurses throughout the hospital participated in the educational intervention, introducing the study guidelines that focused on aseptic technique. In-service classes were mandatory for cancer center nurses. Nurses in other areas who participated in CVC care for this patient population were invited to attend the educational intervention.

Educational Intervention
The planned intervention for the current study was a structured educational program aimed at staff nurses providing CVC care to children with cancer. The structured educational program taught strict adherence to aseptic technique, measures to ensure optimal CVC maintenance, and practices to reduce catheter hub colonization.

The one-hour educational program included a didactic component, hands-on clinical simulation, and pre- and posteducation assessment to evaluate learning. The didactic content included incidence, causative organisms, and costs associated with bloodstream infections. Using the established guidelines, the research team developed a video demonstrating correct aseptic technique practices that was viewed by nursing staff. Hands-on clinical simulations were used to provide aseptic technique instruction and practice of newly developed CVC care guidelines. Nursing staff completed the pre- and posteducation assessment evaluation on the day of the structured educational program. Parents received a fact sheet on the new CVC guidelines. The importance of the parents’ role as advocates for proper care techniques was stressed. An overview of the content for the educational program is found in Figure 1.

Procedure
The current study was conducted in three phases. Phase I allowed for reassessment of the incidence of catheter hub colonization in a cohort of children with cancer who had a CVC; it was completed within four weeks of study implementation. During phase 2, the
A comprehensive educational intervention program was implemented. Phase 3 provided reinforcement of the guidelines and ongoing monitoring of CVC-related bloodstream infections for six months. Reassessment of hub colonization occurred within three months following the educational intervention.

**Phase 1:** Patients were selected from a convenience sample of patients from hematology-oncology and bone marrow transplantation inpatient units and outpatient clinics. Data collection continued until 51 catheter hub cultures were obtained. To be included in the study, patients had to have had CVC placement for more than seven days, have expected duration of the catheter of at least three months, and be afebrile with negative blood cultures at the time of the culture. Informed consent and child assent were obtained from the parents prior to enrolling patients into the study and collecting the hub culture.

Baseline cultures of the CVC hubs were obtained to determine the incidence and degree of colonization in this population. Hub colonization was defined as the presence of microorganisms cultured from the distal end (hub) of the catheter lumen after removal of the injection cap. Cultures were obtained before the educational intervention and again within three-and-a-half months following the intervention on the same patient population to determine whether the colonization rates had decreased after the intervention.

Study investigators and a trained research nurse used a sterile culturette to collect the hub culture sample. The swab was moistened with the transport media contained within the culturette. After removing the injection cap from the catheter hub, a culture was obtained by swabbing the threaded area of the catheter hub. The cultures were hand-delivered to the microbiology laboratory for testing. In the microbiology laboratory, a semi-quantitative culture for bacteria and fungus was obtained by the microbiologist using standard laboratory procedures. Demographic information, testing results, and previously described risk factors were recorded for each study subject. The data collected in the study were used for research purposes only and did not initiate any changes in the medical management of the patients.

**Phase 2:** Phase 2 began when 51 hub cultures were collected. The educational intervention was introduced to all healthcare professionals working in the cancer center. A mandatory one-hour educational program for all staff nurses included a didactic component, hands-on clinical simulations, and a written pre- and post-test to assess learning. A pre- and post-test was used to validate effective education as well as performance evaluation. The post-test was administered at the completion of the education program. Study investigators who were pediatric oncology nurse experts taught the educational program to staff. A lecture and fact sheet were used to reinforce the importance of aseptic technique for CVC care that were the basis for the newly developed CVC care guidelines. Aseptic technique, including cleaning the hub of the catheter, was emphasized throughout the educational session. An educational fact sheet describing the new practice guidelines for CVC care was shared with other departments throughout the hospital and nursing staff representatives of the home care agencies used by this patient population. Identification of the home care agencies was solicited from the cancer center case managers. Parents were provided a fact sheet describing the new CVC care guidelines and were encouraged to be active advocates for their children in regard to compliance with the new guidelines. Spanish-speaking parents were given information on the new CVC care guidelines in their native language.

**Phase 3:** Catheter-related bloodstream infections were tracked monthly for six months after the educational program was completed. The hospital infection control service routinely monitored bloodstream infection rates by reviewing daily hospital microbiology reports. The infection control service notified a member of the research team of each patient in the study population who developed a positive blood culture. Upon notification of a positive blood culture result, a member of the research team documented demographic data, testing results, and risk factors for those study subjects.

Within three and a half months after the intervention, catheter hub colonization was reassessed as described in phase 1. Repeat cultures were obtained on the patients participating in the initial hub colonization assessment. The same procedure for obtaining the hub culture was followed. Every three months after the initial intervention, the new CVC guidelines were reinforced with staff using fact sheets and feedback on current bloodstream infections rates.

**Study Measures**

**Identification of central venous catheter infections:** The hospital’s infection control service monitored two types of data on all central line infections: healthcare-related infections and catheter-related bloodstream infections. The CDC has defining criteria for bloodstream infections (2000); data collected in the study included laboratory-confirmed bloodstream infections using the guidelines.

**Risk factor surveillance data:** Several risk factors associated with CVCs were identified in the literature. The risk factors monitored during the current study and evaluated as influencing variables included presence of a multilumen catheter or multiple CVCs; degree of neutropenia; use of immunosuppressive agents; history of prior CVC infection; poor nutritional status; receiving parenteral nutrition, particularly lipids; administration of propofol; presence of wet catheter dressings; impaired skin integrity; and multiple sites of infection.

**Demographic data:** A member of the research team recorded demographic data and patient risk factors associated with catheter-related bloodstream infections.
Data collection tools included patient demographic information, testing results, and associated risk factors. A separate tool was used for each hub culture collected and for each patient experiencing a positive blood culture during phase 3. Documented demographic information included study identification number, patient name, medical record number, age, gender, primary diagnosis, CVC type, number of days with a CVC, and date and time of sample collection. Test results collected included whether or not the cultured hub was colonized and a semiquantification of the colonization.

Pre- and Posteducation Assessment

A 15-question knowledge assessment tool was used as a pre- and post-test. A third of the test questions were taken from the pre- and post-test of an educational module produced by BJC HealthCare (2001). The remainder of the questions was developed from the content in the educational intervention and contained information relating to the newly developed guidelines. Content validity of the questionnaire was established by pediatric oncology expert review.

Statistical Methods

The primary aim of the current study was to determine if a comprehensive CVC educational program decreased infection rates in children with cancer. Following the application of the educational program, monthly surveillance of catheter-related bloodstream infections was tracked for six months to calculate the rate of infection. General loglinear analysis was used to determine if the six-month CVC infection rate was statistically significant to the historical 18-month CVC infection rate.

The test for two binomial proportions was used to determine if hub colonization rates significantly decreased following a comprehensive educational program. In addition, 95% confidence intervals were constructed to determine the bounds of the proportions.

Paired t tests were used to determine the pre- and posteducation assessment of the nursing staff. The chi-square test was used to identify the risk factors that were associated with CVC infections in children with cancer. Two-tailed p values of less than 0.05 were considered to be statistically significant.

Findings

Twenty in-service classes were offered to the target audience of pediatric oncology nurses to enhance attendance at the education intervention. A total of 121 nurses attended the educational intervention from patient care areas throughout the hospital. Ninety of the nurses attending the classes were from the cancer center; 31 nurses were from the postanesthesia care unit, nutritional support team, diagnostic imaging, emergency center, and float pool. As expected, the pre- and posteducation assessment of nursing staff revealed the post-test mean score of 87%, which was significantly higher than the pretest mean score of 72% (p < 0.001).

A convenience sample of 27 children with cancer and a CVC were recruited for the study, including 14 boys and 13 girls. The mean age of the patients was 8.2 years, with a range of 0.5–16.2 years. Leukemia was the diagnosis for 78% of the patients; 22% of the patients were diagnosed with a solid tumor. Patient demographics are shown in Table 1.

To determine catheter hub colonization incidence and whether the educational intervention influenced the incidence, 51 catheter hubs were cultured prior to the educational intervention. Fifty-seven percent (n = 29) of the catheter hubs were culture positive. After the educational intervention, 39 catheter hubs were cultured from 20 children of the original group of 27 children. Of the 27 children with 51 CVC hubs participating at baseline, 4 of the children had died (7 catheter hubs) and 3 had their lines removed (6 catheter hubs). The remaining 20 children had a total of 39 CVC hubs; 7 of those children had their catheters replaced (12 catheter hubs) and a new catheter inserted. The proportion of culture-positive hubs postintervention was reduced to 36% (n = 14). The two-proportion test procedure showed significant reduction (p = 0.043) in culture-positive hubs following the intervention. Coagulase-negative staphylococcus

Table 1. Demographic Characteristics

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<th>Characteristic</th>
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<tbody>
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<tr>
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<td>Days with central venous catheter*</td>
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<tr>
<td>More than 90</td>
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*Children could have more than one catheter with multiple hubs over time.
was the most common colonizing organism found on pre- and postintervention hub cultures. Of preintervention positive cultures, 45%, 14%, 3%, and 7% were colonized with two, three, four, and five organisms, respectively. Postintervention, 29%, 0%, 7%, and 7% of the positive cultures were colonized with two, three, four, and five organisms, respectively (see Table 2). CVCs were in place an average of 75.3 days preintervention and 128.3 days postintervention; however, this was not a factor in the colonization rate. None of the risk factors were significant with colonization rate as determined by the chi-square tests.

To determine whether bloodstream infection rates were influenced by the educational intervention, infection rates were monitored on a monthly basis for six months after the intervention. Postintervention infection rates reduced from 5.59 to 3.35 per 1,000 catheter days for patients undergoing bone marrow transplantation and from 4.89 to 3.00 per 1,000 catheter days for general patients with cancer. A loglinear model showed a significant reduction (p < 0.001) in infection rates following the educational program for patients undergoing bone marrow transplantsations and general patients with cancer. Bloodstream infection rates 12 months after the intervention indicated a continued decline in the bone marrow transplantation unit to 2.51 per 1,000 catheter days and a sustained drop in the oncology unit to 3.09 per 1,000 catheter days. The sustained decline in bloodstream infection rates can be contributed to continual feedback to staff on monthly infection rates and ongoing reinforcement of aseptic technique in nursing practice.

**Discussion**

The results of the current study demonstrated that a comprehensive educational program increased nurses’ knowledge of CVC care. Nurses were interested in learning aseptic technique and promoting improved patient outcomes related to bloodstream infections. None of the parents refused to participate in the nursing research study. Parents expressed joy that nurses were interested in minimizing catheter-related bloodstream infections. Many parents actively advocated for their children by reminding staff that they were participating in the study prior to manipulation of the CVC lines.

The catheter hub evaluation represents the first study to determine the incidence of catheter hub colonization in CVCs in children with cancer. Study findings demonstrated reduced CVC hub colonization from 57%–36% after the educational intervention. In addition, the bloodstream infection rates were reduced significantly in the patients undergoing bone marrow transplantations and general patients with cancer after the educational intervention. An additional six months of monitoring the infection rates was done to see if the decreased rates were sustained. Study investigators were surprised by the number of organisms cultured from the catheter hubs. Although as many as five organisms were identified from one culture postintervention, study findings did demonstrate a decrease in total number of cultures positive with 3, 4, and 5 organisms. Finding coagulase-negative staphylococcus as the most common colonizing organism was consistent with the literature.

Limitations of the current study included the use of a convenience sample at a single institution, the number of lost catheter hubs, and no control of individuals providing care to the CVC. Study investigators recommend further studies with larger sample sizes for generalizability of study findings. Additional research to evaluate the relationship between hub colonization and subsequent bloodstream infections also is recommended.

**Implications for Nursing**

The development of a structured educational program into a central orientation program enhances nurses’ knowledge, adherence to aseptic technique, and CVC care. Providing nurses with a structured educational program that emphasizes strict adherence to aseptic technique reinforces previously learned skills and increases awareness of the most current recommendations for CVC care. Providing nurses with current literature related to bloodstream infection rates and CVC care recommendations enhances knowledge and adherence to aseptic technique. Patient and family involvement in practice changes also is important because they have the most to gain. The study shows that incorporating catheter hub cleaning into CVC care policies and procedures improves patient outcomes in regard to bloodstream infections. Demonstrating positive results of changes in practice encourages nurses to continue following the

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Postintervention

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recommendations and to use strict aseptic technique with CVC care. Most importantly, nursing practices that enhance the use of aseptic technique for the care of CVCs can decrease healthcare-associated bloodstream infections in children with cancer and ultimately improve patient outcomes.

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Digital Object Identifier: 10.1188/09.ONF.232-238

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