FACTORS RELATED TO USE OF THE CENTERS FOR DISEASE CONTROL GUIDELINES FOR PREVENTION OF CENTRAL LINE INFECTIONS IN BONE MARROW TRANSPLANT PATIENTS

by

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ABSTRACT

Central vascular catheters (CVCs) are essential for patients receiving a bone marrow transplant (BMT). Central line infections (CLI) pose a serious threat to BMT patients, causing increases in morbidity, financial expenses, and even treatment-related mortality. Determining best practices in prevention of CLI in BMT patients is vital but understudied. The Centers for Disease Control and Prevention (CDC) has published guidelines, including four specific performance indicators (Pis), for prevention of intravascular catheter-related infections. To date, no published study has examined use of the Pis in the CDC guidelines in the care of BMT patients.

The purpose of this study was to examine practice patterns among US BMT centers and to determine whether select recommendations in the CDC guidelines are used to prevent CLI in BMT patients. Specific aims of this study were to (a) describe self-reported practice patterns for prevention of CLI in participating US BMT centers, (b) to determine the extent of use of the Pis, (c) to determine which other practice factors are associated with self-reported use of the Pis, and (d) to describe self-reported rates of CLI in participating BMT centers.

A survey was mailed to all US BMT centers listed on the BMT InfoNet website. Sixty of 189 BMT centers (32%) participated by completing and returning the survey. The survey assessed practices related to prevention of CLI in BMT patients.

Results of the study indicated (a) that practice patterns for CLI prevention vary among participating BMT centers, (b) that overall self-reported use of three of the four CDC Pis was generally high, (c) that six factors were associated with self-reported use of the Pis, and (d) that most participants could not or would not report CLI incidence rates for their BMT centers.

CLI in BMT patients can be a matter of life and death. Improving patient outcomes by decreasing rates of CLI depends upon tracking and trending rates of CLI, strengthening roles and coordination within the BMT care team, and strengthening BMT center healthcare worker education programs.

This study is dedicated to the bone marrow transplant patients who have enriched my life and contributed to my deep caring about improving the quality of their care.

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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

Central Lines in Bone Marrow Transplant Patients

Autologous bone marrow transplant (BMT) patients, persons who receive their own bone marrow or stem cells, are given life-threatening high doses of chemotherapy to destroy cancer cells. Allogeneic BMT patients, persons who receive donated bone marrow or stem cells, also receive life-threatening doses of chemotherapy and, additionally, receive chemotherapy and/or radiotherapy to destroy their immune systems so they will not reject the donor cells. High doses of drugs or anticancer agents are given intravenously (IV) and must be given in large veins where they are quickly diluted with blood to avoid irritation to the veins and infiltration of chemotherapy into the surrounding tissues, causing severe tissue damage. In many treatment regimens, multiple infusions of chemotherapy agents are given at the same time.

Using peripheral veins for chemotherapy may require frequent changes of IV sites, as small veins do not tolerate toxic agents well. Central lines used for BMT patients generally have three ports (access sites) and lumens (separate channels through which fluids may be infused simultaneously), so multiple infusions can be given at the same time without mixing with each other. The use of central lines avoids the risks of small vein and tissue damage and the need for multiple IV sites.

Throughout treatment, BMT patients have frequent blood draws for lab tests. These blood draws can be taken from a central line without inflicting the pain of a needle stick on the patient.

Multiple supportive infusions are an important part of the BMT treatment regimen. Supportive infusions include (a) antibiotics, (b) fluids and electrolytes, (c) total parenteral nutrition (TPN) during periods of extreme nausea and mucosal damage, (d) blood products, and (e) various other infusions. Accommodating all of these therapies without a central line is not feasible. Thus central lines are not an option; they are essential.

Central line infections (CLI) in BMT patients pose serious threats to patients. Due to the high-dose chemotherapy and/or radiotherapy, BMT patients are immunosuppressed and at considerable increased risk for CLIs during a significant portion of their time in treatment. A CLI can result in (a) increased morbidity, (b) delay of treatment, (c) increased financial expenses related to increased length of stay (LOS) and use of hospital resources, and even (d) increased treatment-related mortality. Determining best practices in prevention of CLI in BMT patients is essential to improving both the care and the survival of patients in this significantly at-risk patient population.

Use of guidelines for the prevention of CLI is presumed to effectively reduce rates of CLI. In 2002, the Centers for Disease Control and Prevention (CDC) published Guidelines for the Prevention of Intravascular Catheter-Related Infections (hereafter known as the CDC guidelines [2002a]). These guidelines contain four performance indicators (Pis) to be used to evaluate the impact of the CDC guidelines on individual institutions. The four Pis are shown in Table 1. There is no currently published literature to support the presumption that use of the CDC guidelines reduces rates of CLI in the BMT patient population.

Specific Aims

Identifying and implementing the most effective interventions for preventing CLI in BMT patients is critical. Preventing CLI will decrease the mortality, morbidity, and financial cost attributable to CLI in BMT patients. The purpose of this study was twofold: (a) to examine variations in practice patterns among US BMT centers and (b) to determine whether select recommendations in the 2002 CDC guidelines are used in a specific, high-risk population of patients, namely BMT patients.

The specific aims of this study are (a) to describe self-reported practice patterns for prevention of CLI in participating US BMT centers, (b) to determine the level of self-reported use of the Pis in the 2002 CDC guidelines among participating US BMT centers, (c) to determine which of the practice factors are associated with self-reported levels of use of the Pis in the 2002 CDC guidelines, and (d) to describe self-reported incidence rates of CLI in participating BMT centers.

Findings of this study will provide information not currently available in any published study. No published study of US BMT centers has examined the extent or the outcomes of use of either the broad range of practices or to the Pis in the CDC guidelines for prevention of CLI (2002a). The findings of this study may be used to identify specific performance targets for improvement of nursing and medical

Table 1. *Performance Indicators in the CDC Guidelines for the Prevention of Intravascular Catheter-Related Infections (2002a)*

Performance Indicators	Abbreviations	Essential Elements Described in the CDC Guidelines (2002a, p. 14)
Educating Healthcare Workers	EHW	Implement both didactic and interactive educational programs for healthcare providers who insert and maintain catheters.
Maximal Sterile Barriers	MSB	Use maximal sterile barrier precautions when placing catheters.
2% Chlorhexidine	2%C	Use chlorhexidine to prep skin at insertion site.
Discontinuing Catheters	DC	Track rates of removing catheters when they are no longer medically necessary.

management of central lines in BMT patients. The ultimate outcome of this study is identification of and support for those practices and practice changes that can effectively reduce morbidity, LOS in the hospital, financial expenses, and mortality due to CLIs in BMT patients.

Conceptual Framework

The study was based on a conceptual model derived from two of the three levels of infection prevention described by Valanis (1999), as shown in Figure 1. This model acknowledges that primary and secondary prevention are important concepts in CLI. While primary prevention (preventing occurrence of CLI) is the main focus of this study, secondary prevention (early detection, appropriate treatment, and on-going education regarding CLI) are also vital parts of reducing the significant deleterious sequelae of CLI in BMT patients. Tertiary prevention (limiting disability and addressing rehabilitation) is not part of this study and, therefore, is not depicted in the conceptual model. This model has not previously been used in studies of CLI in BMT patients.

Recommendations in the CDC guidelines deal mostly with three aspects of the model of infection prevention: (a) breaking the chain of transmission (one aspect of primary prevention), (b) education (one aspect of secondary prevention), and (c) early detection (another aspect of secondary prevention). Three of the Pis address breaking the chain of transmission, one PI addresses education, and one additional CDC recommendation addresses early detection.

The study addressed use by participating US BMT centers of the CDC guidelines by examining self-reported BMT center structure, processes, and outcomes related to

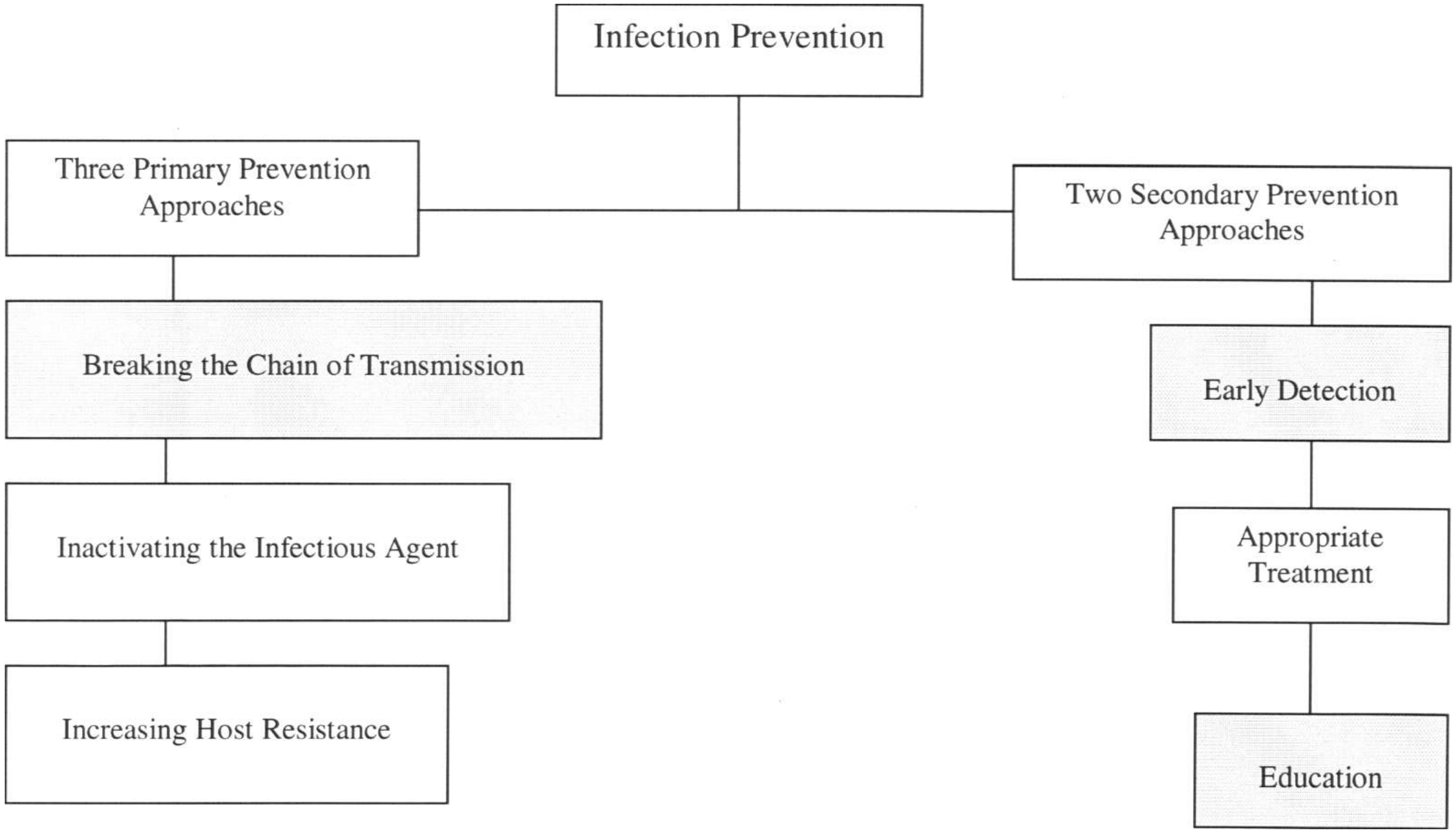

Infection Prevention
Three Primary Prevention Approaches
Two Secondary Prevention Approaches
Breaking the Chain of Transmission
Inactivating the Infectious Agent
Increasing Host Resistance
Early Detection
Appropriate Treatment
Education

Figure I. Conceptual model of infection prevention.

Note: Highlighted boxes are the preventive strategies that were studied in this research.

select recommendations in the guidelines, as shown in Figure 2. This figure is based on Donabedian's model of structure, process, and outcome (1980). Structure, in this context, refers to the physical and human resources, such as BMT center administration, policies, and staff, which influence delivery of healthcare. Process refers to functions, such as quality improvement, staff education, and data collection, which utilize the structures. Outcomes are the results of the processes, which include practice patterns and rates of CLI in BMT patients (Kunkel, Rosenqvist, & Westerling, 2007).

A survey instrument (BMT LIFE) was developed specifically for this study. Each CDC recommendation that relates to one of the Pis is addressed in the BMT LIFE. Alignment of the conceptual model, the CDC recommendations related to the Pis, and the survey content areas is shown in Table 2.

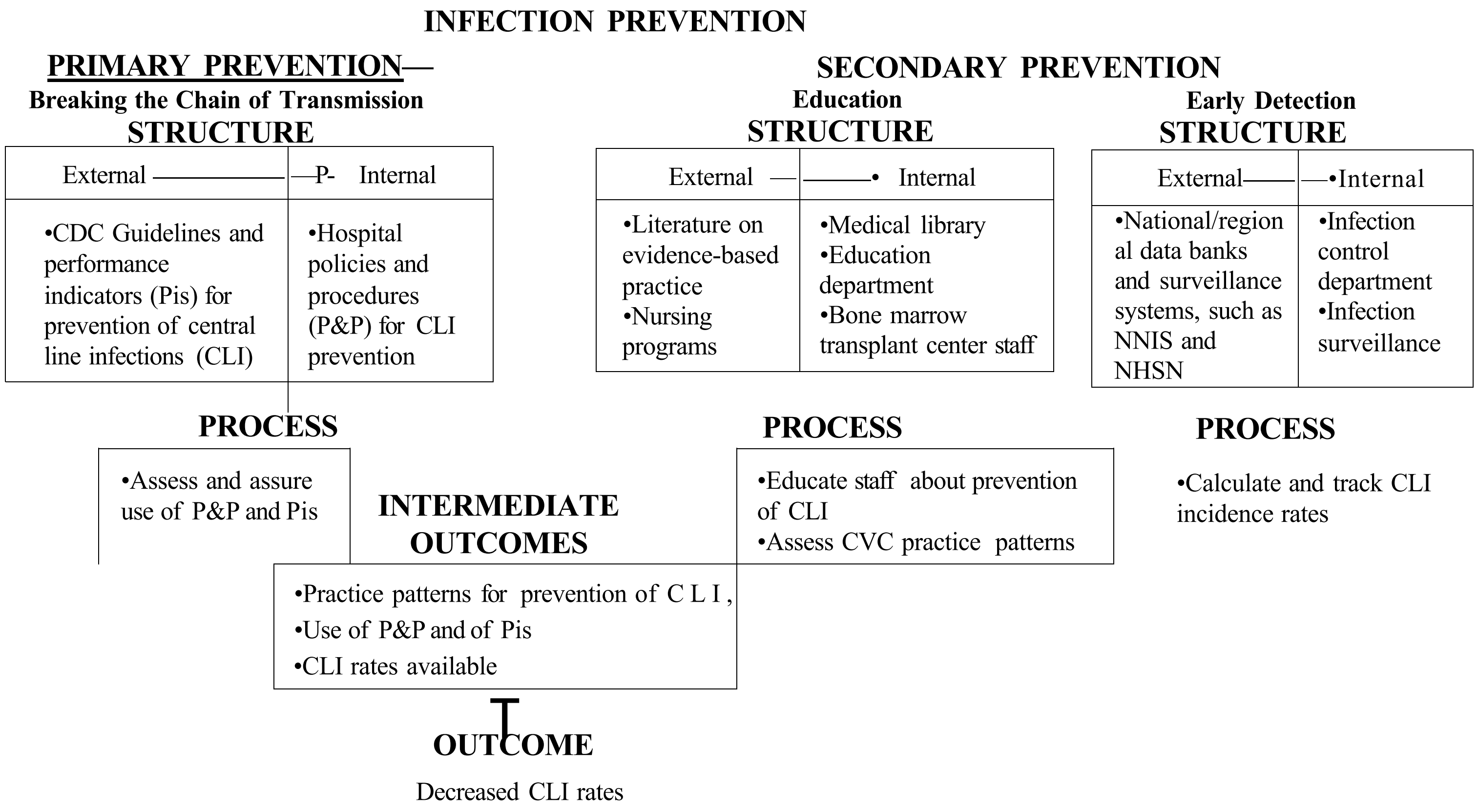

INFECTION PREVENTION
PRIMARY PREVENTION—
Breaking the Chain of Transmission
STRUCTURE
External ——————P- Internal
•CDC Guidelines and performance indicators (Pis) for prevention of central line infections (CLI)
•Hospital policies and procedures (P&P) for CLI prevention
PROCESS
•Assess and assure use of P&P and Pis
SECONDARY PREVENTION
Education
STRUCTURE
External — ———• Internal
•Literature on evidence-based practice
•Nursing programs
•Medical library
•Education department
•Bone marrow transplant center staff
PROCESS
•Educate staff about prevention of CLI
•Assess CVC practice patterns
Early Detection
STRUCTURE
External———•Internal
•National/regional data banks and surveillance systems, such as NNIS and NHSN
•Infection control department
•Infection surveillance
PROCESS
•Calculate and track CLI incidence rates
INTERMEDIATE OUTCOMES
•Practice patterns for prevention of C L I ,
•Use of P&P and of Pis
•CLI rates available
OUTCOME
Decreased CLI rates

Figure 2. Conceptual model of infection prevention showing bone marrow transplant center structure, process and outcomes related to select recommendations in the CDC guidelines for prevention of intravascular catheter-related infections.

Abbreviations: CDC = Centers for Disease Control and Prevention; NNIS = National Nosocomial Infection Surveillance System: CVC = Central venous catheter

Table 2. *Alignment of the Study Conceptual Model of Infection Prevention, the CDC Recommendations Related to the Performance Indicators, and the Survey Content Areas*

Conceptual Model of Infection Prevention	2002 CDC Recommendations Related to the Performance Indicators	BMT LIFE Survey Content Areas
1 - Primary Prevention Approaches		
A - Breaking the Chain of Transmission	General - VIII. B. Prompt removal of nonessential IV catheters	Section D. Catheter insertion, removal, and days in place
	CVC - IV. Maximal sterile barrier precautions	Section D. Catheter insertion, removal, and days in place
	General - VI. A. Cutaneous antisepsis	Section E. Catheter site and catheter care
B - Inactivating the Infectious Agent	N/A	
C - Increasing Host Resistance	N/A	
2 - Secondary Prevention Approaches		
A - Case Finding	N/A	
B - Education	General - I. A. Educating healthcare workers	Section A. Healthcare workers
	General - I. B. Assessing knowledge and usage of healthcare workers	Section A. Healthcare workers

Note: General = general recommendations for use with all intravascular catheters; CVC = recommendations to be use specifically with central venous catheters; N/A = not addressed by the performance indicators; Roman numerals refer to numbered sections in the CDC guidelines.

CHAPTER II

LITERATURE REVIEW

Best Practice and Benchmarking

The concepts of best practice and benchmarking originated in the business world, where best practice refers to documented strategies used by companies considered "best-in-class" in a specific area. "Benchmarking" is a process of seeking and studying best practice strategies for use in quality improvement programs (Bogan & English, 1994).

Best Practice vs. Evidence-based Practice

A common trigger for nursing and medical research is the discovery of varying rates of successful outcomes related to a given procedure. Studies comparing outcomes of different methods for performing the procedure may produce evidence indicating which of several methods is associated with the best outcomes, after controlling for extraneous variables. When the evidence is compelling enough to change practice, or to establish that one method is clearly superior to all others, the superior method may be considered best practice. Application of best practices that are supported by a significant body of careful research results in evidence-based practice.

Development of evidence-based guidelines is a high priority in any industry concerned with the safety of employees and/or consumers. Healthcare applications of evidence-based guidelines are being utilized in many settings to improve the outcomes of patient care. Quality improvement efforts are particularly appropriate where patient morbidity and mortality and high costs for healthcare services are at issue.

Best Practice in Prevention of CLI in BMT Patients

A literature search using Pub Med (National Library of Medicine, n.d.) was conducted to determine the extent of published research or clinical information related to best practice in prevention of CLI in BMT patients. Limits imposed on the search were publication date from January 1, 1990 to April 9, 2007, only items with abstracts, in English, and with human subjects. The results, shown in Table 3, demonstrate the current lack of published information about benchmarking, best practice, or evidence-based practice related to prevention of CLI in BMT patients.

Search number seven in Table 3 included search terms related to (a) evidence-based practice, practice pattern variation, best practice, critical appraisals, and bench marking, plus (b) multiple terms describing central line infections. Forty-seven articles met both sets of terms; 10 were studies, 19 were review articles, 4 were clinical reports, and 14 turned out to be totally unrelated or only minimally related to best practice in CLI prevention. The study topics included implementation of evidence-based practice (Hatler et al., 2006; Warren, Cosgrove, et al., 2006; Young, Commiskey, & Wilson, 2006); decreases in CLI and CLI-related mortality and costs with use of evidence-based guidelines (Berenholtz et al., 2004; Render et al., 2006); lack of coordination between research findings, policies for infection prevention, and current best practice (Jones, 2006; Warren, Yokoe, et al., 2006); the effects of a behavioral educational intervention to increase use of evidence-based CVC management guidelines (Coopersmith et al., 2004); the use of prophylactic antibiotics for gastrointestinal procedures in children with CVCs

Table 3. *Results of a Literature Search for Best Practice Studies of Central Line Infections in Bone Marrow Transplant Patients*

Search Number	Search Strategy	Number of Articles
1	Evidence based practice OR practice pattern varia* OR best practice OR critical appraisal OR bench mark*	21,403
2	Bone marrow transplant OR stem cell transplant OR blood and marrow transplant OR blood cell transplant	32,545
3	Central venous access device OR central line OR central vascular access device OR CVAD OR Hickman OR right atrial catheter OR central venous catheter	16,316
4	Central line infection OR intravascular catheter related infection OR intravascular device related infection OR catheter related bloodstream infection OR exit site infection OR tunnel infection OR pocket infection OR catheter colonization OR catheter associated bloodstream infection OR infusate related bloodstream infection	3,253
5	#1 AND #2	78
6	#1 AND #3	117
7	#1 AND #4	47
8	#2 AND #3	306
9	#2 AND #4	71
10	#2 AND #3 AND #4	56
11	#1 AND #3 AND #4	33
12	#1 AND #2 AND #3	2
13	#1 AND #2 AND #4	0

Note: varia* was used as a search term to pick up derivatives such as variation, variability, etc.; mark* was used as a search term to pick up mark, marking, etc.

or other infection risk factors (Snyder & Bratton, 2002); and the optimum time for removing central lines in bacteremic neonates (Benjamin et a1, 2001).

The review articles focused on (a) risk factors for CLI in pediatric patients (Kline, 2005); (b) cause, diagnosis, and management of CLI (Lee & Johnston, 2006; Mermel et al., 2001; Slaughter, 2004); (c) specific methods of infection prevention (Adams & Elliot, 2007; Bagnall-Reeb, 2004; Bearman, Munro, Sessler, & Wenzel, 2006); (d) evidence and guidelines for CLI prevention strategies (O'Grady, 2002; O'Grady et al., 2002a; O'Grady et al., 2002b); (e) an analysis of patient safety practices (Shojania et al., 2001); (f) the practice of scheduled replacement of CVCs (Timsit, 2000); (g) an evidence-based practice model for CVC selection and site care (Woods, Nass, & Deisch, 2000); (h) the need for literature which addresses the nursing aspects of CVC management (Cook, 1999); (i) the accountability of healthcare providers for control of CLI (Vost & Longstaff, 1997); (j) the best method for culturing catheters (Rello, Jubert, Esandi, & Valles, 1997); (k) placement choices for CVCs in children (Hollyoak, Ong, & Leditschke, 1997); (l) the use of personal digital assistant infectious disease applications (Miller, Beattie, & Butt, 2003); and (m) an institutional protocol for obtaining blood cultures in cancer patients suspected of having an infection (Penwarden & Montgomery, 2002).

The clinical reports addressed (a) positive outcomes of using evidence-based central line care practice in pediatric intensive care units (Morgan & Thomas, 2007); (b) the need for standardization in infection control policy and practice (Morritt et al., 2006); (c) the relationship between compliance with best practice and (1) nurse/physician management and (2) quality improvement programs (Earsing, Hobson, & White, 2005);

and (d) the possibility that sequential antibiotic administration for other infections may also decrease the incidence of CLI (Wilcox, 1998).

In general, these studies, review articles, and clinical reports shed light on the problems associated with CLI and on the use of evidence-based practices which show promise in reducing rates of CLI. The more recent articles, those published since 2002, show a beginning trend to link evidence-based practices to reductions in CLI.

Searches number 12 and 13 yielded meager results. Using the search terms related to evidence-based practice, BMT, and CVCs, yielded two articles: a review of guidelines for managing high-dose-therapy-induced neutropenia (West & Mitchell, 2004) and a case study and review of the literature on pinch-off syndrome - which is a precursor to and cause of mechanical failure in CVCs (Fazeny-Dorner et al., 2003). No article met the search criteria of best practice for CLI in BMT patients. Following completion of data collection and analysis, a follow-up literature review showed one article which did meet the criteria of best practice for CLI in BMT patients (Warren, Cosgrove, et al., 2006). However, the study was a multicenter study of 12 intensive care units and 1 BMT unit, and the 13 units were identified only as Unit A, Unit B, Unit C, and so on. Thus the deidentified unit data precluded relating the findings specifically to BMT patients. The particular vulnerability of BMT patients to CLI highlights the need for examining the use of evidence-based practice to reduce CLI in BMT patients.

CLI in the General Patient Population

CLI causes significant morbidity, mortality, and financial expense in hospitalized patients. This is a particular concern for nursing because use and care of central lines is generally the responsibility of nurses (Roach, Larson, Cohran, & Bartlett, 1995). Morbid effects reported from CLI range from simple phlebitis to septicemia. Estimates are that mortality from nosocomial line infections exceeds 20% in all populations (Charalambous, Swoboda, Dick, Perl, & Lipsett, 1998; Crow, 1996). Table 4 summarizes incidence (the rate of occurrence), attributable mortality (the excess rate of mortality which is due, in a specific patient population, to CLI), and cost data related to CLI reported in one meta-analysis of 13 studies conducted in the United States (n = 8), Germany (n = 2), England (*n* - 2), and Western Australia (*n* = 1); and similar data from three US research studies.

Nosocomial bloodstream infections (BSI) increased two- to three-fold from 1985 to 1995, with the biggest increases occurring in large teaching hospitals. The rising incidence rates are generally attributed to the increased use of central lines, as about 90% of IV catheter-related infections occur in patients with central lines (Cohran, Larson, Roach, Blane, & Pierce, 1996; Crow, 1996). The CDC (2002a) estimated there were approximately 80,000 central venous catheter- (CVC-) associated BSIs each year in the United States, costing $296 million to $2.3 billion annually for the care of these patients.

The Pis in the CDC guidelines (2002a) provide a convenient means for assessing adoption of the guidelines. The literature addressing central line infections and the CDC Pis is sparse. A search using those terms (the central line infection search terms used in search #4 shown in Table 2, and the search term "performance indicators") yielded six publications. Two articles presented the 2002 CDC guideline document (O'Grady et al., 2002a; O'Grady et al., 2002b). One article (Mermel et al. 2001) gives guidelines and Pis for management, but not prevention, of CLI. The Pis in this article were related to the diagnosis and treatment of CLI. An article, by Rudy, Lucke, Whitman, and Davidson

Table 4. *Incidence, Attributable Mortality, and Cost of Central Venous Catheter-Related Infection*

Type of Article: Authors	Incidence	Attributable Mortality	Cost of Local Infection	Cost of Bloodstream Infection
Meta-Analysis: Saint, Veenstra, & Lipsky (2000)	42.7%	4-20%	$399	$6,005-9,738
Research Report: Pittet, Tarara, & Wenzel (1994); Pittet & Wenzel [letter] (1994)	N/A	25%	N/A	$28,690
Research Report: Smith, Meixler, & Simberkoff (1991)	N/A	28%	N/A	N/A
Research Report: Digiovine, Chenoweth, Watts, & Higgins (1999)	N/A	4.4%	N/A	$16,000

(2001), described three different methods of benchmarking for CLI in eight hospitals within a healthcare system in 1998. Braun et al. (2003) used bloodstream infection rates as performance indicators for an evaluation of processes and indicators in infection control (EPIC) study. The variations they found in specifications of infection rates limited the usefulness of rates for comparison and improvement. The sixth article addressed performance status rather than performance indicators. No study published since the release of the CDC 2002 guidelines describes the use of all four of the 2002 CDC Pis to evaluate the impact of adoption of the CDC guidelines.

CLI in ICU Patients

The National Nosocomial Infections Surveillance (NNIS) System, a division of the CDC, tracked and reported rates of hospital-acquired infections. Organized in 1970, the NNIS System began with 62 United States hospitals and grew to around 300 hospitals. The NNIS System unit of measurement for reporting CLI was central line-associated BSI per 1000 catheter days.

The NNIS reports for 2001 through 2004 (CDC, 2001b; CDC, 2002b; CDC, 2003; CDC, 2004) show pooled mean central line-associated BSI rates ranging from 2.9 to 7.9, 2.9 to 7.9, 2.9 to 7.8, and 2.7 to 7.4, respectively, in nine different categories of ICUs for the period from January 1995 to June 2001, June 2002, June 2003, and June 2004 respectively. The overall pooled mean can be calculated for the same time periods at 5.1, 5.0, 4.9, and 4.3, respectively. This steady decrease over the 4 years, 2001, 2002, 2003, and 2004, represents an important trend. Having a uniform way of reporting CLI makes it possible to track trends and investigate possible related factors. Tracking rates of infection over time is recommended in the CDC guidelines.

The calculated central line-associated BSI rates of 5.1, 5.0, 4.9, and 4.3 exclude the burn and respiratory ICU data for all four time periods. NNIS calculations exclude those categories of ICUs for which there were fewer than 20 units included in the NNIS report. There were fewer than 20 respiratory ICUs for all four time periods. Burn units, for the four time periods, numbered 18 for 2001, 19 for 2002, 21 for 2003, and 14 for 2004. Because the burn unit data were not included in calculations for 2001, 2002, and

2004 they were also excluded from calculations for 2003 in order to accurately reflect the BSI rate trend in the other units over 4 years' time. The burn units had the highest rates of BSI for the three years, 2001, 2002 and 2003 with rates of 9.7, 8.8, and 8.5, respectively. In 2004 their CLI rates dropped to 7.0.

NNIS has not tracked the rate of NNIS hospitals' use of CDC guidelines or of the Pis. The slight decrease in rates of CLI in NNIS hospitals from 2001 to 2004 data releases, may be related to a higher level of use of guidelines, or it may simply be due to the effect of having an infection control professional (ICP) in the hospital monitoring rates of CLI. Minimum requirements for NNIS hospitals included having 100 or more beds, 1 fulltime ICP for the first 100 occupied beds, and an additional fulltime ICP for each additional 250 beds (CDC, 2001a).

During 2004-05 NNIS was combined with two other national health surveillance systems to create the National Healthcare Safety Network (NHSN). Data collection is now carried out and reported by NHSN (Tokars et al., 2004). Replacing the former NNIS data summary, NHSN issued its first data summary report, the summary for 2006, in June, 2007 (Edwards et al., 2007). NHSN offered the caveat that comparison of the NHSN data with the last NNIS data could be misleading because units reporting to NHSN are a subset of former members of NNIS. Thus, changes in CLI rates could be due to (a) a change in the characteristics of the units reporting to NHSN, or to (b) an actual change in the rate of CLI. Therefore, NHSN data were not included in the literature review.

CLI in BMT Patients

The problem of CLI in BMT patients is critical and understudied. Published studies of CLI in BMT patients are relatively few. Forty-two studies published between 1990 and 2007 were reviewed. They focused on (a) comparisons of kinds of central line dressings and timing of dressing changes (Benhamou et al., 2002; Brandt, DePalma, Irwin, Shogan, & Lucke, 1996; Shivnan et al., 1991); (b) IV tubing change practices (deMoissac, & Jensen, 1998); (c) types of central venous access devices (Biffi et al., 1999; Biffi et al., 2004; Brodwater et al., 2000; Haire, Stephens, Kotulak, Schmit-Pokorny, & Kessinger, 1995; Lazarus et al., 2000; Leibundgut, Miiller, Miiller, Ridolfi-Luthy, & Hirt, 1995; Madero et al., 1996; Platzbecker et al., 2001; Restrepo et al., 2002; Ulz et al., 1990); (d) use of femoral CVCs (Lazarus, Creger, Bloom & Shenk, 1990; Sovinz et al., 2001); (e) complications associated with CVCs in stem cell and BMT (Meisenberg et al., 1997; Moosa, Julian, Rosenfeld, & Shadduck, 1991; Uderzo et al., 1992); (f) incidence of nosocomial infection, including CLI, and associated pathogens (Adler et al., 2006; Aksu et al., 2001; gelebi, Akan, Ak§aglayan, Ustiin, & Arat, 2000; Dettenkofer et al., 2003; Engelhard et al., 1996; Elishoov, Or, Strauss, & Engelhard, 1998; Keung et al., 1995; Marena et al., 2001; Ninin et al., 2001); (g) risk factors for CLI in home infusion therapy (Tokars et al., 1999); (h) methods of diagnosing catheter-relation bloodstream infections (Abdelkefi et al., 2005; Abdelkefi et al., 2006; Krause et al., 2004); (i) the use of prophylactic antibiotics to prevent CVC-related infections (Lim, Smith, Machin, & Goldstone, 1993; Ljungman, Hagglund, Bjorkstrand, Lonnqvist, & Ringden, 1997; Vassilomanolakis et al., 1995); (j) the use of prophylactic urokinase to prevent complications with Hickman catheters (Solomon, Moore, Arthur, & Prince, 2001); (k) decreased infectious morbidity associated with stem cell transplantation in the outpatient setting (Chandrasekar et al., 2001); (l) timing and techniques associated with central line insertion and replacement (Apsner et al., 1998; Martinez et al., 1999; Miceli et al., 2005; Muhm et al., 1997; Richard-Smith & Buh, 1995); (m) time of occurrence of CLIs (Romano et al., 1999); and (n) patient education (Richard-Smith & Buh, 1995).

Taken together, these studies provide useful information on selection and placement of various types of CVCs, tubing and dressings; risk factors, incidence, and diagnosis of CLI; and use of prophylactic medications and patient education to decrease CLI incidence. What is missing is an assessment of the adoption and the impact of use of the CDC guidelines for preventing CLI among BMT patients. There are no published studies of CLI in BMT patients addressing the CDC Pis.

No data on attributable mortality, morbidity, and cost of CLI in BMT patients were found in a search using Pub Med. With a mortality rate in the general patient population reported at 10- 20% of hospitalized patients who acquire IV catheter-related infections (Charalambous et al., 1998; Crow, 1996), it is possible that the mortality rate in BMT patients who acquire a CLI may be even higher. Due to their immunosuppressed state, BMT patients may be more likely to acquire a catheter-related infection and die from the infection than are patients in the general patient population. The need for effective nursing and medical practice strategies in CLI prevention for this high risk patient population is significant.

Evidence of Practice Pattern Variation in Prevention of CLI in BMT Patients

The 42 studies of CLI in BMT patients from 1990 to 2007 are summarized in Table 5. It is immediately apparent that the studies used multiple different descriptions and definitions for CLI. The terms used to quantify rates of infection were also diverse. Ten of the studies did report results using the terms entry or exit infection (3), catheter-associated bloodstream infection (2) or catheter-related bloodstream infection (5), which are now among the CDC-approved terms for CLI, as found in the CDC guidelines. Only one of those studies calculated the CLIs as the number of infections per 1000 catheter days, the CDC-approved rate of measurement. Therefore, no two studies can be compared in a useful way. The general lack of standardization in literature describing and defining CLI, and in expressing rates of CLI, makes it difficult to draw conclusions from a review of the studies (Zitella, 2003). Table 6 summarizes how CLIs were described and their rates in the 42 studies. Only 6 studies used numbers of infections per 1000 catheter days; 11 studies used the CDC-recommended terms for infection (clinical sepsis, exit site infection, tunnel infection, pocket infection, CA-BSI, CR-BSI); and only 2 studies used both. While useful in showing the extent of the problem of CLI in BMT patients, these studies clearly demonstrate the need for a common language to describe and to quantify CLI in BMT patients.

Even with acknowledgement of differences in methods of quantifying and reporting CLI, it seems apparent that some BMT centers have lower rates of CLI than other BMT centers - markedly lower in a few cases. What makes the difference? Some

Table 5. *Rates of Central Line Infections Reported in Forty-Two Studies of Bone Marrow and Stem Cell Transplantation*

Study	Variable of Interest	*N*	Description and Rate of Infection
Ulz et al. (1990)	Complications in Hickman right-atrial catheters	111	Infectious complications - 44% of catheters
Lazarus et al. (1990)	Use of femoral site for CVC	5	Infectious complications - 1 catheter-related Strep infection 1 E. coli bacteremia
Moosa et al. (1991)	Complications of indwelling CVCs in BMT recipients	123	Catheter infection - 15.8% of catheters Catheter removal due to infection - 10.8% of catheters
Shivnan et al. (1991)	Dry sterile gauze dressing changed daily versus transparent adherent dressing changed every 4 days	98	Catheter-related infection - 1% of patients
Uderzo et al. (1992)	CVC-related complications after BMT in children with hematological malignancies	53	CVC-related infections - 31% of CVCs, or 3.1 per 1000 catheter days
Lim et al. (1993)	Hickman catheter-related sepsis following prophylactic teicoplanin	88	Lower incidences of sepsis with teicoplanin
Haire et al. (1995)	Use of double-lumen inferior vena cava catheters for both apheresis and peripheral stem cell transplantations	20	Catheter-related infections - 15% of catheters/patients

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
Keung et al. (1995)	Central venous catheter-related infections	11	Catheter removal due to infection - 57% of catheters (11.5 infections per 1000 catheter days)
Richard-Smith, & Buh (1995)	Effects of timing of catheter placement, and patient education on central line catheter infections	10	Pre-intervention infections - 50% of patients; Post-intervention infections - 16%, 4%, 0% at next 3 consecutive quarterly intervals respectively
Vassilomanolakis et al. (1995)	Effects of vancomycin prophylaxis on CVC-related infections after BMT in patients with malignancies	40 and 46 CVCs	Infected CVCs - 9/46 (20%) CVCs Exit site infections - 5/46 (11%) CVCs CVC-related bacteraemia - 7/46(15%) CVCs
Brandt, DePalma, Irwin, Shogan, & Lucke(1996)	Dry sterile gauze dressing changed daily versus moisture vapor permeable dressings changed weekly	101	Reasons for line removal (percent of patients): Central vascular catheter (CVC) sepsis - 3% CVC sepsis and tunnel infection - 3% Tunnel infection - 5% Suspected CVC sepsis - 14%
Engelhard et al. (1996)	Documented catheter-related infections	242	Septicemia - incidence 7% Colonization - incidence 7% Exit site infection - incidence 3.7%;

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
Elishoov, Or, Strauss, & Engelhard (1998)(same study as Engelhard et al., 1996)	Documented catheter-related infections (same study as above)		Septicemia episodes per 1000 catheter days: Catheter-related 5.28 Unknown origin 4.86 Exit site infection 2.59
Leibundgut et al. (1996)	Complications associated with Broviac catheters in children	32	Septic episodes - 0.26 per 100 catheter days
Madero et al. (1996)	Complications in non-tunneled catheters in children undergoing BMT	62	Entry site infection - 9.6% of patients Catheter-related infection - 12.9% of patients Catheter-related sepsis - 14.5% of patients
Ljungman et al. (1997)	Gram-positive infections after prophylactic teicoplanin	65	No differences between teicoplanin group and control group
Meisenberg et al. (1997)	Complications associated with CVCs used for stem cell collection followed by high-dose chemotherapy and autologous stem cell rescue	156	Early and late presumptive or documented infections of the CVC-6.5% of patients
Muhm et al. (1997)	Percutaneous nonangiographic insertion of Hickman catheters by anesthesiologists and intensivists	53	Suspected or documented infection - 26% of catheters (resulting in removal of 14 catheters per 3333 catheter days)

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
Apsner et al. (1998)	Fluoroscopic guidance for Hickman catheter placement	81	Positive blood cultures - 2.1 / 1000 catheter days Suspected infection - 23 (28.4%) Tunnel infection - 2 (2.5%)
deMoissac & Jensen (1998)	IV tubing change every 24 versus 48 hours	50	Colonized infusate - 5% of IV sets
Biffiet al. (1999)	Use of totally implantable access ports	68	Port removal due to infection - 2.8% of devices
Martinez et al. (1999)	CVC exchange by guidewire for treatment of catheter-related bacteraemia in BMT or intensive chemotherapy patients	17	Catheter-related bacteraemia - 14 episodes
Romano et al. (1999)	Bloodstream infections in children receiving allogeneic BMT	442	CVC-related bloodstream infections - 6% of all CVCs
Tokars et al. (1999)	Risk factors for bloodstream infection in patients with home infusion therapy	827	Bloodstream infections - 0.99/ 1000 catheter days
Brodwater et al. (2000)	Converting implanted ports to tunneled CVCs	67	Persistent neutropenic fever - 2 (3%) Proven catheter infection - 2 (3%) Overall infection rate - 1.2 per 1000 catheter days

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
gelebi et al. (2000)	Febrile neutropenia in patients receiving conventional chemotherapy (CCT) and patients receiving peripheral blood stem cell transplantation (PBSCT)	145	Catheter infections: CCT group (50 pts) - not disclosed PBSCT groups: Alio-6/50 pts (12%) Auto - 3/45 pts (6.7%)
Lazarus et al. (2000)	Use of a single catheter for both collection and transplantation	112	Infectious complications - 2 exit site infections 17 bacteremias
Aksu et al. (2001)	Aerobic bacterial and fungal infections in peripheral blood stem cell transplants	74	Catheter-related infections - 26 Catheter removal due to catheter-related infections - 10
Chandrasekar et al. (2001)	Infectious morbidity after outpatient autologous stem cell transplantation for women with breast cancer	105	Catheter site infections - 5 patients Lines removed for suspicion of infection - 6 patients
M arena et al. (2001)	Incidence of nosocomial infections in stem cell transplant patients	143	Device-associated infection rate for central line-associated bloodstream infections - 0.016 per 1000 catheter days
Ninin et al. (2001)	Bacterial, viral, and fungal infections in adult BMT recipients	446	Catheter-related infections - 9 (2%) of patients
Platzbecker et al. (2001)	Use of double-lumen port	26	2 port systems removed due to early pocket infections

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
Solomon et al. (2001)	Prophylactic urokinase	100	Septicaemic events - 8/52 in urokinase group 9/48 in heparin group Exit site infections - 27/52 in urokinase group 28/48 in heparin group Septic thrombosis - 2/52 in urokinase group 4/48 in heparin group
Sovinz et al. (2001)	Using tunneled femoral CVCs in children	9	Catheter removal due to infection - 1 catheter
Benhamou et al. (2002)	Effects of less frequent catheter dressing changes in pediatric candidates for BMT	112	Bloodstream infections - 13 (11.6%) patients Catheter site infections - 18 (16.1%) patients
Restrepo et al. (2002)	Performance of a hybrid CVC used for both stem cell harvest and transplant support of autologous stem cell transplant patients	82	Catheter-related bloodstream infections (using CDC criteria for CR-BSI) - 18(22%) patients
Dettenkofer et al. (2003)	Nosocomial infections in adult bone marrow and stem cell transplant recipients	351	Catheter- associated infections - 20 (5.7%) patients
Biffi et al. (2004)	Use of an implanted port for both high-dose therapy and transplantation	376	Device-related complications - 2 pocket infections (0.01 per 1000 catheter days 3 port-related bacteremias (0.016 per 1000 catheter days)

Table 5. (*Continued)*

Study	Variable of Interest	*N*	Description and Rate of Infection
Krause et al. (2004)	Use of differential time-to-positivity method and Gram stain-acridine orange leukocyte cytospin test to detect catheter-related bloodstream infection	51	Rate of catheter-related bloodstream infections - 31% of patients
Abdelkefi et al. (2005)	Use of differential time-to-positivity method to diagnose catheter-related bloodstream infection		Catheter-related bloodstream infections - 22 patients had catheter-related bacteremia 16 patients had noncatheter-related bacteremia
Miceli et al. (2005)	Leaving previously inserted ports in place for stem cell transplantation	86	Patient morbidity - No increase in morbidity Increased used of antibacterial and antifungal agents
Abdelkefi et al. (2006)	Use of Gram stain-acridine orange leukocyte cytospin test to detect catheter-related bloodstream infection	245	Test ability to detect catheter-related bloodstream infection - Gram stain detected only 2 Differential time-to-positivity detected 26
Adler et al. (2006)	Comparing implantable ports and Hickman catheters	281	Rates of bloodstream infections - Implantable ports - 1.451 per 1000 catheter days Hickman catheters - 4.656 per 1000 catheter days

Table 6. *Summary of Infection Descriptions and Rates of Central Line Infection in 42 Studies*

Type of Infection	Percent of Patients	Percent of Catheters	Infections/1000 Catheter Days	Other
Colonized infusate (1)		5% of IV sets		
Bacteremia (1)				14 episodes
Persistent neutropenic fever or febrile neutropenia (2)	3 - 12			
Suspicion of or suspected CVC sepsis or infection (2)	14 - 28.4			
Infectious complications (2)	20	44		
Catheter-related sepsis (1)	14.5			
Catheter infection, or catheter-related infection, or port-related infection, or CVC-related infection (8)	1 - 35	16-31	0.01 - 11.5	
Catheter or port removal due to infection or sepsis (7)	8 - 11	2.8-57		2 ports
Suspected or documented infection (2)	8	26	14/3333	
Septic episodes (1)			0.26 / 100	
Entry or exit site infections (3)	5 - 16.1			
Tunnel infections (1)	2.5			
Bloodstream infections (2)	11.6		0.99	
CA-BSI (2)	5.7		0.016	
CR-BSI (5)	22-31			Number of patients - 22

Abbreviations: CVC = central vascular catheter; CA-BSI = catheter associated bloodstream infection; CR-BSI = catheter related bloodstream infection differences may be related to variability, among centers, in aggregate patient demographics, in number and types of BMTs performed, and in practice patterns related to prevention of CLI. No published study has described the variation in practice patterns of CLI prevention among US BMT centers.

Guidelines for Prevention of CLI

In 1995, the CDC issued guidelines for prevention of CLI. The guidelines were later published (Pearson, 1996) and made available to healthcare workers and the general public. The following year, three organizations (the CDC, the Infectious Diseases Society of America, and the American Society for Blood and Marrow Transplantation) co-sponsored and began working on a set of guidelines aimed at preventing opportunistic infections in hematopoietic stem cell transplant recipients. Main CVC infection prevention recommendations of this guideline were to (a) implement the CDC guidelines (1996), (b) avoid tap water contamination of the CVC site, and (c) protect the end cap of needleless IV access devices from tap water contamination during bathing (Centers for Disease Control and Prevention, Infectious Disease Society of America, American Society of Blood and Marrow Transplantation, 2000; Dykewicz, 2001).

The CDC issued new CLI prevention guidelines in its Morbidity and Mortality Weekly Report of August 9, 2002 (CDC, 2002a), and these have now replaced the guidelines published in 1996. Each of the two CDC documents represents a synthesis of hundreds of studies to determine optimum infection prevention practices for insertion and care of intravascular catheters. Although these guidelines are not specifically directed at preventing infections in the BMT patient population, they may represent at least minimum standards of evidence-based practice for insertion and care of central lines in BMT patients.

The CDC categorized the individual recommendations (2002a, p. 13) according to the level and kind of evidence which support each recommendation, as follows:

"Category IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies.

"Category IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies, and a strong theoretical rationale.

"Category IC. Required by state or federal regulations, rules or standards.

"Category II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale.

"Unresolved issue. Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists."

Only category 1A recommendations were surveyed in the present study.

An important addition to the 2002 CDC guidelines was the identification of the Pis, which were intended to be used to monitor local implementation of the new guidelines. Other changes included the addition or deletion of some guidelines, the reassignment of some guidelines to different levels of emphasis (categories) based on the updated literature review, and other minor modifications.

Other Factors

Other factors, either not addressed or not fully specified in the CDC guidelines, may be related to CLI. Literature supports several such factors, including nurse staffing patterns, educational preparation of the RNs, use of mid-level providers, prophylactic anticoagulant use, and availability of BMT center CLI rates. Factors related to CLI rates are assumed to be related to levels of use of guidelines for prevention of CLI.

Nurse Staffing Patterns

With the current nursing shortage, nurse managers in hospitals have had to create new staffing matrices, delegating some nursing duties to unlicensed assistive personnel, or increasing the patient-to-nurse ratio. Understaffing has been linked to nurse reports of low quality patient care (Aiken, Clarke, & Sloane, 2002), higher risk of post-surgical complications (Kovner & Gergen, 1998; Pronovost, et al., 2001), higher rates of mortality and failure to rescue (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002), and increases in both hospital-acquired infections, in general (Vicca, 1999), and CVC-related bloodstream infections, in particular (Fridkin, Pear, Williamson, Galgiani, & Jarvis, 1996). Understaffing also increases the likelihood of failure to adhere to protocols, policies, and guidelines that may require additional patient-care and documentation time (Pittet, Mourouga, & Perneger, 1999).

Educational Preparation of the RNs

A nursing shortage stimulates development of new programs to prepare nurses. Two-year associate degree programs see greater increases in enrollment because they can produce new RNs more quickly than 4-year baccalaureate programs. A landmark study of outcomes for over 200,000 general, orthopedic, and vascular surgery patients in 168 hospitals reported lower mortality and failure-to-rescue rates in hospitals with higher proportions of nurses with baccalaureate or higher degrees (Aiken, Clarke, Cheung, Sloane, & Silber, 2003). Percentage of RNs with baccalaureate (BSN) preparation may be associated with levels of use of guidelines.

Use of Mid-level Providers

Mid-level providers are used in many hospital settings and include nurse practitioners (NPs), clinical nurse specialists (CNSs), and physicians' assistants (PAs). Both NPs and CNSs are advanced practice nurses (APNs). PAs may be but generally are not nurses. Use of mid-level providers is increasing in many clinical areas, and current literature is particularly supportive of the APN roles and their positive effects on patient outcomes and cost of care (Brooten et al., 2002; Fulton & Baldwin, 2004). Use of mid-level providers may be associated with levels of use of guidelines.

Use of Prophylactic Anticoagulants

Low-dose anticoagulants have been shown to reduce the occurrence of venous catheter-associated thrombosis, a risk for patients with central lines (Boraks, et a., 1998). Use of prophylactic anticoagulants to prevent catheter-related thrombosis may help to prevent clot formation on the distal end of the catheter and thereby prevent the development of an environment in which bacteria readily grow (Polderman & Girbes, 2002; Randolph, Cook, Gonzales, & Andrew, 1998; Timsit et al., 1998). Use of prophylactic anticoagulants may also be associated with use of guidelines.

Availability of BMT Center Rates of CLI

Having access to CLI rates is essential to improvement in central line care. ICUs in the NNIS System had access to their rates of CLI, and the trends showed incremental improvement. The slight downward trend in their CLI rates in the last 3 years of NNIS reports (CDC, 2001b; CDC, 2002b; CDC, 2003) may have been associated with knowledge of their rates and a corresponding increase in use of guidelines.

Use of Guidelines in Prevention of CLI

A literature search on CLI and the use of guidelines yielded disappointing but not unexpected results. The search strategy included various terms for CLI plus various terms for use of, or adherence to, guidelines. The result of the search was a list of 66 journal articles, 11 of which were at least somewhat related to guidelines for prevention of CLI.

Table 7 shows the topics of the articles and the guidelines mentioned in each article. Two reviews and one clinical trial addressed the use of prophylactic antibiotics (Bagnall-Reeb, 2004; Sandoe et al., 2003; van de Wetering & van Woensel, 2003). Two studies examined educational interventions to increase use of guidelines (Coopersmith et al., 2004; Eggimann et al., 2000). One study and one presentation of guidelines focused on diagnosis of CLI (Fatkenheuer et al., 2003; Raad et al., 2004). Finally, two review articles encouraged the use of guidelines (Parker, 2002; Rosenthal, 2003); one study compared local to national rates of CLI (Askarian, Hosseini, Kheirandish & Memish, 2003); one study used electronic prompts to increase use of guidelines (Rijnders, Vandecassteele, Wijngaerden, Munter, & Peetermans, 2003); and one study compared the outcomes of insertion of tunneled central lines by a trained clinical nurse specialist (CNS) to the outcomes of central line insertion by multiple junior medical staff persons (Fitzsimons et al., 1997). No article mentioned use of the 2002 CDC guideline Pis; however, one article presented two other guidelines for preventing

Table 7. *Results of a Literature Search on CLI and the Use of Guidelines*

Topics	Guidelines Mentioned	References by Type (Country, if not US)
Antibiotic lock technique - considering broader use than the CDC recommends	CDC Guidelines (2002)	Review - Bagnall-Reeb(2004)
Using behavioral educational interventions to improve compliance with evidence-based guidelines of CVC management	Use of evidence-based guidelines advocated, but no specific guideline identified 2002 CDC Guidelines cited, but not named in the text, in reference to incidence and prevention of catheter-related bloodstream infections 1996 CDC Guidelines cited, but not named, in reference to use of stopcocks	Study - Coopersmith et al. (2004)
Diagnosing catheter-related bloodstream infection (CR-BSI) by differential time to positivity, using a specific guideline to define CR-BSI	Infectious Diseases Society of America guidelines (2001)	Study - Raad et al. (2004)
Comparing two methods of perioperative antibiotic prophylaxis for prevention of catheter-related colonization and infection, in spite of guidelines which state no prophylaxis is needed	UK Department of Health guidelines (2001)	Clinical trial - Sandoe et al. (2003) (UK)
Presenting guidelines for diagnosis and management of catheter-related infections in neutropenic patients	Guidelines of the Infectious Diseases Working Party (AGIHO) of the German Society of Hematology and Oncology (DGHO) (2003)	Practice guidelines - Fatkenheuer et al. (2003)

Table 7. *(Continued)*

Topics	Guidelines Mentioned	References by Type (Country, if not US)
Using electronic prompts to improve physician compliance with guidelines for treatment of catheter-related bloodstream infections	Infectious Diseases Society of America (IDSA) - Guidelines for the Management of Intravascular Catheter-related Infections (2001)	Study - Rijnders, Vandecasteele, Wijngaerden, Munter, & Peetermans (2003) (Belgium)
Comparing local device-associated nosocomial infection rates to rates published in the National Nosocomial Infections Surveillance System reports	National Nosocomial Infections Surveillance System (NISS) methods for monitoring and observations of catheter-related bloodstream infections (NISS report for January 1992 to June 2001) (2001)	Study - Askarian, Hosseini, Kheirandish, & Memish (2003) (Iran)
Determining efficacy of administering prophylactic antibiotics to prevent Gram-positive catheter-related infections	Hospital Infection Control Practices Advisory Committee (HICPAC) Recommendations for the Prevention of Nosocomial Intravascular Device Related Infections (1990) (use of guidelines not specifically addressed, but statement made that infections are increasing despite availability of the international HICPAC guidelines; implication that guidelines are either not being followed or are not sufficient)	Review (Cochrane Database of Systematic Reviews) - van de Wetering & van Woensel (2003)
Highlighting, and urging compliance with, three different guidelines or standards for preventing catheter-related infections	CDC guidelines (2002a) American Association of Blood Banks's *Technical Manual* (1999) Intravenous Nurses Society's *Infusion Nursing Standards of Practice* (2000)	Review - Rosenthal (2003)

Table 7. *(Continued)*

Topics	Guidelines Mentioned	References by Type (Country, if not US)
Highlighting and recommending use of three guidelines for preventing catheter-related bloodstream infections	CDC guidelines (Draft) (2001) Department of Health (2001) Infection Control Nurses Association (ICNA, 2001)	Review - Parker (2002)
Examining effects of an educational campaign to increase compliance with guidelines for hand hygiene, site care, and line insertion, replacement, and removal	Institutional guidelines prepared by staff within the study hospital	Study - Eggimann et al. (2000)
Having a specially trained clinical nurse specialist (CNS) insert percutaneous tunneled CVCs, using predetermined guidelines	Institutional guidelines - Guidelines for practice by the CNS	Study - Fitzsimons et al. (1997)

infectious complications following chemo- and or radiotherapy and stem cell transplantation (Bertz et al., 2003).

A second literature search, adding various search terms for BMT to the terms for CLI and use of guidelines, produced only one article. The previously mentioned article by Bertz et al. (2003) and the article from this second search are shown in Table 8. The first article is merely a presentation of a set of guidelines. The second article describes a study implementing diagnostic guidelines or criteria for nontuberculous mycobacteria infection (Weinstock, Feinstein, Sepkowitz, & Jakubowski, 2003). No article was found to describe the practice, or the results, of implementing the 2002 CDC guideline Pis.

Translating research evidence into evidence-based practice for prevention of CLI is challenging. It requires persuasive and on-going education of care providers; changes in protocols for central line selection, insertion, use, and care; and on-going surveillance of practice patterns for use of new protocols and guidelines. Evaluation of CLI prevention guidelines must be measured by two endpoints - (a) institutional adoption of the guidelines and (b) changes in institutional rates of CLI.

The literature reviewed for the present study makes it clear that the CDC guidelines, though they are the most complete and well researched guidelines published currently, have not been widely adopted in BMT centers. The present study focused on identifying patterns in care of central lines, patterns in use of the CDC Pis, factors associated with those patterns, and patterns in rates of CLI.

Table 8. *Results of a Literature Search on CLI and the Use of Guidelines in BMT Patients*

Topics	Guidelines Specified	References by Type (Country, if not US)
Presenting guidelines for antibiotic therapy for infectious complications following high-dose chemo- and or radiotherapy and stem cell transplantation	Guidelines of the Infectious Diseases Working Party (AGIHO) of the German Society of Hematology and Oncology (DGHO) (2003)	Practice Guidelines - Bertz et al. (2003) (Germany)
Implementing guidelines/criteria to distinguish nontuberculous mycobacteria (NTM) infection from NTM colonization in hematopoietic stem cell transplant patients	American Thoracic Society and CDC diagnostic criteria for NTM infection (no dates specified)	Study - Weinstock, Feinstein, Sepkowitz, & Jakubowski (2003)

CHAPTER III

DESIGN AND METHODOLOGY

Study Design

This study used an exploratory, descriptive approach to examine variations in self-reported practice patterns among US BMT centers with regard to prevention of CLI, in general, and to use of specific recommendations in the 2002 CDC guidelines for preventing central line infections (2002a) in particular. The study also examined factors related to self-reported use of the CDC guidelines, as well as self-reported rates of central line infections in US BMT patients.

In keeping with the epidemiologic focus and the conceptual model based on epidemiologic principles of infection prevention shown in Figure 1, this study was population-based and observational. Retrospective cross-sectional data from a cohort of US BMT centers were collected and analyzed using a descriptive correlational design.

Wood and Brink (1998) identify the following six basic assumptions for correlational designs, (a) Covariance of the study variables in similar populations has not been demonstrated in previous studies, (b) An applicable conceptual framework supports the relationships between the study variables, (c) No existing tested theory predicts the relationships to be studied between the variables, (d) The study variables are known to exist and can be studied in the target population, (e) The study sample represents the target population, (f) The variables are studied as they exist and are not manipulated.

This study met the six assumptions listed above for a correlational design, as follows: (a) The question of use of CDC guidelines, specifically use of all four Pis in the 2002 CDC guidelines, among BMT centers has not been studied. That is to say, use of various guidelines, including the CDC guidelines, has been encouraged and recommended, but no single published study of CLI has addressed usage or factors related to usage of the group of recommendations identified as Pis in the CDC guidelines (2002a). (b) The variables identified as Pis in the 2002 CDC guidelines were organized using the conceptual model for infection prevention, as shown in Table 1. (c) There is no published study that tests predictive theories about possible relationships between the variables, (d) The variables exist in the BMT patient population and can be studied, (e) The targeted population was US BMT centers, and all 202 US BMT centers listed on the BMT InfoNet website were invited to participate, (f) The variables were studied as they existed, with no manipulation.

The study population was US BMT centers, and the outcome of interest, or dependent variable (DV), was use of the Pis in the 2002 CDC guidelines. The predictors, or independent variables (IVs), were classified as (a) four demographic and organizational factors and (b) five practice factors. The demographic and organizational factors variables were (a) type of transplant unit, (b) type(s) of transplants performed in 2005, (c) years in practice, and (d) number of transplants performed to 2005. The practice factors, which may be associated with levels of use of the Pis, were (a) staffing patterns, (b) educational preparation of RNs, (c) use of mid-level providers, (d) use of prophylactic anticoagulants, and (e) availability of BMT center CLI rates.

The investigator surveyed US BMT centers regarding use of the 2002 (the most current) CDC Pis and central line care practice recommendations, other CLI prevention strategies, and self-reported rates of CLI. The data were used to detect variations in practice patterns, levels of use of the 2002 CDC Pis, and rates of CLI among the studied BMT centers. Surveys were addressed, by name, to a BMT coordinator in each BMT center. Specifically, the information collected was used to identify (a) self-reported practices for prevention of CLI in participating US BMT centers, (b) self-reported behaviors representing levels of use of the Pis and other CDC line care recommendations in participating BMT centers, (c) factors which may be associated with self-reported levels of use of the 2002 CDC Pis in participating BMT centers, and (d) self-reported rates of CLI in participating BMT centers.

Research Questions

This study proposed to answer four research questions.

1. What are the self-reported practices for prevention of CLI in participating US BMT centers?
2. What are the self-reported levels of use of the Pis in the 2002 CDC guidelines among participating US BMT centers?
3. Which factors are associated with self-reported levels of use of the Pis in the 2002 CDC guidelines in participating US BMT centers?
4. What are the self-reported rates of CLI in participating US BMT centers?

Figure 3 shows the conceptual model for the study design. Research question 3 was answered by analyzing the variables and the associations among the variables as depicted in the figure.

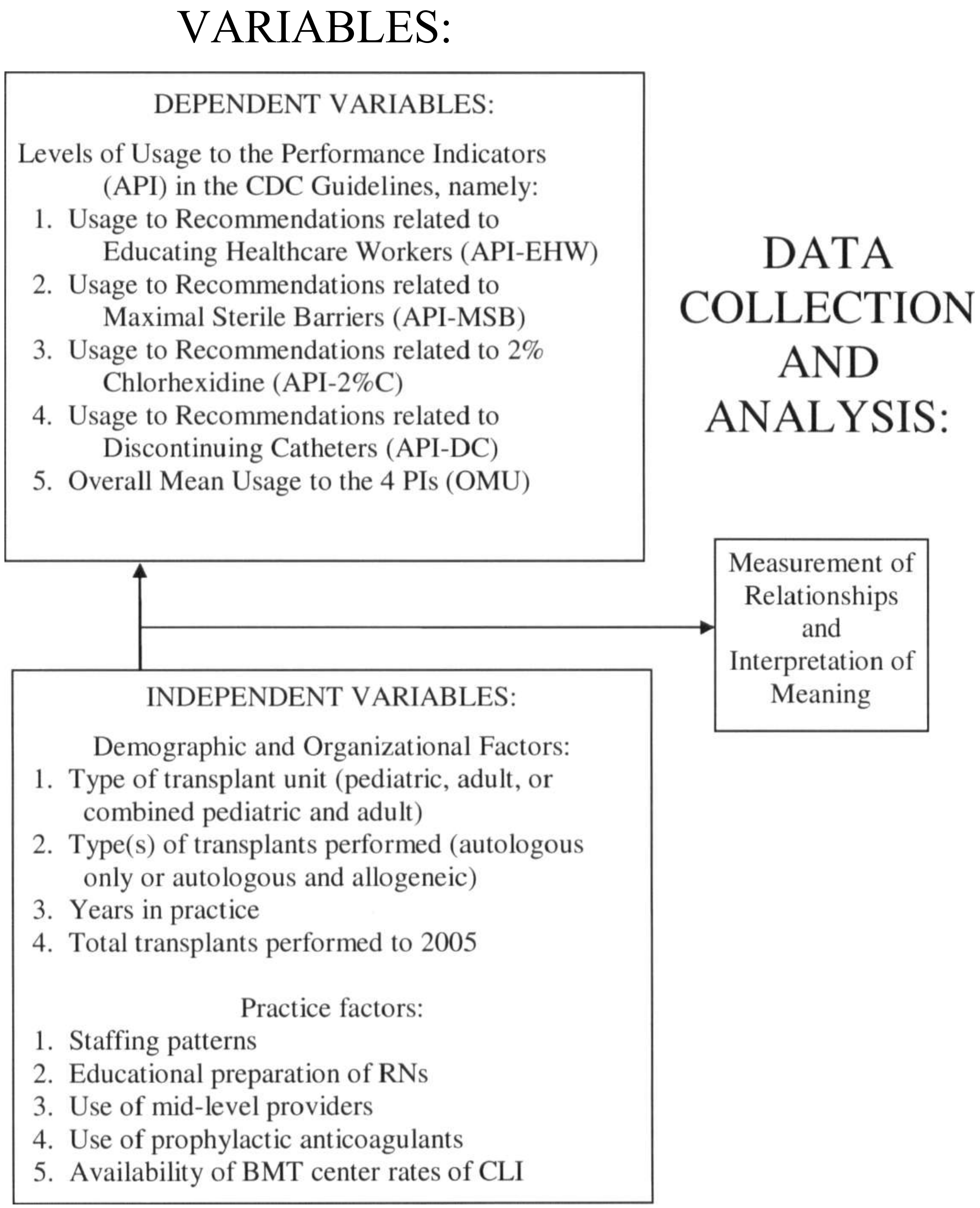
Population and Setting

The population for this study consisted of all US BMT centers listed on the BMT InfoNet website (BMT InfoNet, n.d.) as of June, 2006. Participants were nurses or other personnel in the BMT centers. The setting was the BMT center. Participants completed a mailed survey and returned it by mail to the investigator.

A list of all 202 US BMT centers registered with the BMT InfoNet was obtained from the BMT InfoNet website on June 26-27, 2006. A survey was sent to each transplant center. Aggregate data were collected from the BMT InfoNet website and from each participating BMT center, and no individual patient data were solicited or used. Therefore, the study participants are the BMT centers and not individual BMT patients. All US BMT centers listed on the BMT InfoNet website at June 26-27, 2006 were invited to participate. The only exclusion criteria were non-US BMT centers, US BMT centers not listed on the BMT InfoNet website, BMT centers listed on the website but with inadequate demographic data, and BMT centers listed on the website but found to be no longer in business. The informant in each participating BMT center had to be able to read, write, and speak English. In all, 189 BMT centers met inclusion criteria.

Minimum Sample Size

Sample size, when converted to a response rate, determines, to a large extent, the usefulness of study results. Response rate, an umbrella term, encompasses a family of



VARIABLES:

DEPENDENT VARIABLES:

Levels of Usage to the Performance Indicators (API) in the CDC Guidelines, namely:

1. Usage to Recommendations related to Educating Healthcare Workers (API-EHW)
2. Usage to Recommendations related to Maximal Sterile Barriers (API-MSB)
3. Usage to Recommendations related to 2% Chlorhexidine (API-2%C)
4. Usage to Recommendations related to Discontinuing Catheters (API-DC)
5. Overall Mean Usage to the 4 PIs (OMU)

DATA COLLECTION AND ANALYSIS:

Measurement of Relationships and Interpretation of Meaning

INDEPENDENT VARIABLES:

Demographic and Organizational Factors:

1. Type of transplant unit (pediatric, adult, or combined pediatric and adult)
2. Type(s) of transplants performed (autologous only or autologous and allogeneic)
3. Years in practice
4. Total transplants performed to 2005

Practice factors:

1. Staffing patterns
2. Educational preparation of RNs
3. Use of mid-level providers
4. Use of prophylactic anticoagulants
5. Availability of BMT center rates of CLI

Figure 3. Conceptual model for the study design.

rates. The American Association for Public Opinion Research (AAPOR) defined 12 components of outcome rates and combined them in formulae as response rates, cooperation rates, refusal rates, and contact rates (2006). This study calculated the response rate as the number of completed surveys plus partially completed surveys divided by the number of completed and partial surveys plus the number of refusals, non-contacts and contacts with failure to return surveys. BMT sites found to be out of business were not included in the denominator. AAOPR identifies this rate as Response Rate 6, or "the maximum response rate" (p. 33).

Because not all 202 centers could be expected to respond, it was important to explore the minimum sample size needed for this study. A decision-based strategy (Pedhazur & Schmelkin, 1991) is often used to determine how many participants to attempt to recruit. This strategy is based on first identifying effect size (ES), Type I error (alpha), and Type II error (beta); plotting them on a matrix or master table (Kraemer & Thiemann, 1987); and then locating the corresponding sample size on the table.

It would be ideal to calculate the number of participants needed to have sufficient power to detect an association between levels of use of the Pis in the 2002 CDC guidelines and factors thought to be related to levels of usage, and then to recruit exactly that number of participants. However, there was a limited number of US BMT centers, and it would have been difficult to recruit the optimum number of participants. Given the relatively small number of potential participants and the fixed size of the target population, it was more reasonable to begin with a discussion of sample size and work back, through Type I and Type II error, to identify a detectable ES (Cohen, 1988, p. 15).

Survey research using mailed surveys tends to have a lower participant response rate than research using face-to-face or telephone interviews, sometimes achieving only a 25-30% response rate (Burns & Grove, 1997; Waltz, Strickland & Lenz, 1991). Table 9 shows the results of a review of recent nursing and allied healthcare studies using mailed surveys. Of the nine studies, only three had response rates greater than 50%. Response rates ranged from 24 to 77%, with an average of 47.3%. Burns and Grove suggest that a response rate less than 50% imposes serious question as to the representativeness of the sample, thereby limiting the generalizability of a study's findings.

Table 10 presents a review of recent nursing and allied healthcare studies using telephone surveys. In the seven studies cited, most response rates were greater than 50%, and the average response rate was 58.4%. While the higher rate of response is appealing, the format and content of a survey weighs in on the decision of which mode to use. Some of the data for this study had to be calculated or obtained from someone at the BMT center other than the informant. At least two telephone calls, and potentially several more, would have been required to gather all of the data by telephone. In addition, a consent form for use of the data would need to have been mailed to each participant and then returned to the investigator. Using a mailed survey with telephone follow-up seemed a more practical approach for this study.

Improving Response

Dillman (2000) has identified several methods for increasing the response rate for mailed surveys to the 70 to 78% range. A 50 to 70% response rate, a relatively high response rate for mailed surveys, would yield 101 to 143 of the 202 BMT centers. Key concepts for improving the rate of survey return include providing rewards, reducing

Table 9. *Response Rates in Recent Nursing and Allied Healthcare Studies Using Mailed Surveys*

Study - Journal	*N*	RR	Subject of study	Comments
Siem, Wipke-Tevis, Rantz, & Popejoy (2003) - *Ostomy/Wound Management*	68	77%	Skin assessment and pressure ulcer care in hospital-based skilled nursing facilities	
Martin & Larson (2003) - *Oncology Nursing Forum*	263	53%	Chemotherapy-handling practices of outpatient and office-based oncology nurses	Incentive used: a raffle of two annual Oncology Nursing Society memberships
Vande Vusse, Hanson, Fehring, Newman, & Fox (2003) - *Journal of Nursing Scholarship*	334	24%	Couples' views of the effects of natural family planning on marital dynamics	
Criste (2003) -*AANA Journal*	133	30%	Do nurse anesthetists demonstrate gender bias in treating pain?	
Carr, Gareis, & Barnett (2003) - *Journal of Women's Health*	98	50%	Characteristics and outcomes for women physicians who work reduced hours	
Porterfield et al. (2003) - *Journal of Health Care for the Poor and Underserved*	1273	59%	Caring for the underserved: Current practice of alumni of the National Health Service Corps.	
Lyons, Lapin, & Young (2003) - *Journal of Allied Health*	787	49%	Job satisfaction of nursing and allied health graduates from a mid-Atlantic university	
McKenna, Smith, Poole, & Coverdale (2003) - *Journal of Advanced Nursing*	551	47%	Horizontal violence (or bullying): experiences of RNs in their first year of practice	
Haugsdal, & Scherb (2003) - *Journal of the American Academy of Nurse Practitioners*	414	37%	Using nursing interventions classification to describe the work of the nurse practitioner	

Table 10. *Response Rates in Recent Nursing and Allied Healthcare Studies Using Telephone Surveys*

Study - Journal	*N*	RR	Subject of study	Comments
Hsu etal., (2004) - *Medical Care*	695	69%	Patients' knowledge of cost-sharing and its influence on behavior	
Johnson, Saha, Arbelaez, Beach, & Cooper (2004) - *Journal of General Internal Medicine*	6299	54%	Patients' perceptions of bias and cultural competence in health care	
McCormack, & Uhrig (2003) - *Medical Care*	3738	76%	Beneficiary knowledge of the Medicare program	
Braun et al. (2003) - *Medical Care*	606	65%	Patients' use of self-referral vs. primary care physician referral	
Peerson, Aitken, Manias, Parker, & Wong, (2002) - *Journal of Advanced Nursing*	30 hospitals 6 agencies	43% 23%	Hospital and agency managers' perceptions of agency nursing	
Kozlowski et al. (2002) - *American Journal of Epidemiology*	3383	70%	Feasibility of using random digit dialing telephone interviews to locate participants for a study of smoking-related behaviors	
Brogger, Bakke, Eide, & Gulsvik, (2002) - *American Journal of Epidemiology*	171	67%	Comparison of the use of telephone and mail surveys in epidemiology	Participants - 1% random sample of previous mail surveys. More complete answers given by telephone than by mail. Nature of the questions asked may affect completeness of participants' answers.

social costs to participants, and establishing trust. Each of the following strategies, recommended by Dillman, was used to increase the response rate in this study:

1. Providing a reward
    a. Demonstrating positive regard in the cover letter
    b. Providing a small reward for the person in each BMT center who fills out the survey instrument
    c. Entering participants in a raffle for 1 of 10 annual memberships or membership renewals in the Oncology Nursing Society (worth $92.00)
    d. Sharing results of the study with participating BMT centers
2. Decreasing social costs
    a. Using language that does not subordinate the participant
    b. Enclosing a return envelope
3. Increasing trust
    a. Emphasizing the importance of the study
    b. Identifying the investigator as an oncology and BMT nurse

Dillman maintains that providing a small token of appreciation up front is more effective than offering to send a gift upon completion of a mailed survey. Evans, Peterson, and Demark-Wahnefried (2004), using a six-page mailed survey, found no difference in their study of 1402 prostate cancer survivors. They achieved an overall response rate of 60% with no difference in response rate between the group that received a 30-minute prepaid phone card with the survey, and the group that received the phone card after completing the survey.

Table 11 shows response rates and use of Dillman's (2000) Tailored Design method in nine studies of healthcare providers. The range of response rates was 31 to 90%, with an average response rate of 60%. Only two of the nine studies reported inclusion of a monetary reward with the cover letter, and those two studies had response rates of 49% and 47%, well below the average response rate for the studies. The most consistently used element of Dillman's method was inclusion of a stamped self-addressed return envelope with the mailed survey. Five studies used this element, but response rates among those five ranged from 31 to 82%. No other element was consistently used among the studies.

Number of follow-up contacts ranged from one to "up to five contacts," not further described and over an unspecified period of time (Russell, Injeyan, Verhoef, & Eliasziw, 2004, p. 372) with no apparent increase in response rate associated with increase in number of follow-up contacts. Two studies used prestudy contacts with potential participants, as recommended by Dillman. Gallagher et al. (2007) sent an email notification prior to mailing hard copies of their surveys to participants, and they achieved a 90% response rate. Gutmanis et al. (2007) mailed prestudy letters 1 week before mailing surveys to participants, and they achieved a 47% response rate. Both studies also used follow-up contacts, as shown in Table 10, to increase response rates.

Factors not associated with the Dillman tailored design method (2000) may account for the wide range in response rates. Gallagher et al. (2007) achieved the highest rate with a 90% response. Participants were dental students who were surveyed by their college following their fifth year final exam. Students may have felt vulnerable to perceived pressure to participate.

Table 11. *Response Rates in Studies Using Dillman's Tailored Design Method for Mailed Surveys of Healthcare Providers*

				Elements of Dillman's Tailored Design Method Used (Dillman, 2000)					**N***	**RR^**
Study - Journal	**Subject of Study**	**Participants**	**Sampling Frame**	**SMR[1]**	**SASE[Z]**	**FU[J] Mailings**	**FU[J] Calls**	**Other**		
Vigod & Stewart (2002) - *BMC Women's Health*	**Management of abnormal uterine bleeding**	**Family Physicians**	**622 Ontario Physicians with highest rates of hysterectomy**	**No**	**Yes**	**FU reminder with new copy of survey at 3 weeks and at 8 weeks**	**N/R**	**N/R**	**194**	**31%**
Russell, Injeyan, Verhoef, & Eliasziw (2004) - *Vaccine*	**Beliefs and behaviours of chiropractors about immunization**	**Chiropractic**	**All chiropractors registered to practice in Alberta**	**N/R**	**N/R**	**"up to five contacts" with "the principles described by Dillman"**	**N/R**	**N/R**	**503**	**78%**
Ruggiero (2005) - *Journal of Nursing Administration*	**Health, work variables, and job satisfaction among nurses**	**Critical Care RNs**	**Systematic selection (every 7th) from a random selection of 3500 RNs**	**$2.00**	**Yes**	**FU reminder postcards after 1 week**	**N/R**	**N/R**	**247**	**49%**
Sempowski, Rungi, & Seguin *(2006)-BMC Family Practice*	**Urban Canadian family physicians' minor office procedures**	**Family Physicians**	**All General and Family Practitioners in Kingston, Ontario**	**No**	**Yes**	**One FU mailing**	**N/R**	**N/R**	**89**	**82%**
Silcox, Ashbury, Van DenKerkhof & Milne (2006) - *Anesthesia and Analgesia*	**Attitudes of residents and program directors about research during training**	**Anesthesia Residents and Program Directors**	**All residents and Program Directors at a teaching hospital**	**No**	**Yes**	**One FU email after 2 months; replacement surveys 1 month later**	**N/R**	**N/R**	**283**	**60%**
Baird (2007) - *Professional Psychology: Research and Practice*	**Illinois psychologists' attitudes about prescriptive privileges**	**Clinical Psychology**	**Random selection of Random selection of 25% of licensed psychologists in Illinois**	**No**	**Yes**	**Not reported**	**N/R**	**N/R**	**306**	**37%**

Table 11. (*Continued)*

				Elements of Dillman's Tailored Design Method Used (Dillman. 2000)					*N**	RR[S]
Study - Journal	**Subject of Study**	**Participants**	**Sampling Method**	**SMR[1]**	**SASE"**	**FU[J] Mailings**	**FU' Calls**	**Other**		
Gallagher, Patel, Donaldson, & Wilson (2007) - ***BMC Oral Health***	**Views of final year dental students about their professional career**	**Dental Students**	**All final year dental students**	**N/R**	**N/R**	**FU reminder after 3 weeks; FU letter and new survey in 6 weeks; FU letter in 8 weeks**	**N/R**	**Pre-study email**	**126**	**90%**
Gutmanis, Beynon, Tutty, Wathen, & MacMillan (2007) - ***BMC Public Health***	**Factors influencing identification of and response to intimate partner violence**	**Physicians and Nurses in Women's Care Areas of Practice**	**Random selection of 1000 MDs and 1000 nurses from professional directories**	**$2.00 gift card for coffee shop**	**N/R**	**FU reminder letter with new survey after 3 weeks**	**N/R**	**Pre-study letter**	**931**	**47%**
Skedros, Hunt, & Pitts (2007) - ***BMC Musculoskeletal Disorders***	**Variations in steroid/anesthetic injections for painful shoulder conditions among 4 different specialty groups of physicians**	**Physicians**	**Orthopaedic surgeons and "selected non-surgeon sub-specialists and specialty physicians" in Utah, Idaho and Wyoming**	**No**	**N/R**	**FU mailing after 6 weeks**	**N/R**	**N/R**	**169**	**64%**

Note. 'SMR = small monetary reward enclosed; [2]SASE = self-addressed stamped envelope enclosed; [3]FU = follow-up; [4]*N* = Number; [?]RR = Response Rate; N/R = not reported

Length of the survey is probably a determinant of response rates. The Vigod and Stewart study (2002) used a five-page questionnaire and had a 31% response rate, the lowest response rate of the nine studies.

The nature of the information requested in the survey may also affect participant response rates. Interestingly, Gutmanis et al. (2007) mailed surveys to 1000 nurses and 1000 physicians in practice areas preidentified as specifically including women's care. Their study elicited information about participants' identification of and response to intimate partner violence against women. Of the targeted population, 60% of the nurses and 33% of the physicians responded, for an overall response rate of 47%. This suggests that nurses may be more interested in the study topic than are physicians. However, it could also suggest that physicians and nurses may differ on other characteristics, such as likeliness to respond to surveys or gender.

While evidence suggests the Dillman tailored design method (2000) may improve response rates to surveys, it is also evident that other factors influence potential participants' decisions to participate or not to participate. The publications containing descriptions of the survey instruments and the recruiting methods used in the nine studies in Table 10 did not supply sufficient information to make valid comparisons of all the possible factors contributing to the wide difference in response rates among the nine studies.

Type I Error

Type 1 error (alpha) was set at .05, just as a matter of convention (Hinlke, Wiersma, & Jurs, 1998). Although this was an exploratory study, it was important to set alpha at a generally respected level in order to prevent jumping to an incorrect conclusion that the null hypothesis should be rejected (that is, that associations existed between practice factors and self-reported use of the CDC Pis, when, in consideration of the studied evidence, they did not).

Type II Error

The minimal acceptable power for a study is .80 (Hinkle et al., 1998). A lower power increases the possibility of a Type II error (beta), failing to detect an actual difference (i.e., failing to detect a studied relationship which, in fact, did exist among the studied variables).

Effect Size

The significance of this study is two-fold and is based on the assumed inverse relationship between rates of CLI in BMT patients and levels BMT centers' use of the CDC's 2002 research-based recommendations for prevention of CLI, specifically use of the CDC's PI recommendations. Hence the study sought to (a) highlight variations in practice patterns relative to the CDC Pis and (b) identify factors related to levels of use of the Pis. Therefore, effect size was defined as r, or the correlation between use of the Pis and the practice factors, after controlling for effects of the demographic and organizational factors. Low levels of use of the Pis would provide targets for practice improvement, and significant correlations between low levels of usage and any of the predictor variables would identify potential areas for changes in BMT centers' structure and/or process for prevention of CLI. Such changes could lead to improved outcomes, namely decreased rates of CLI in BMT patients.

Determining the ES that could be detected in this study was a critical process because a significant effect could represent a potential for reducing the rate of CLI in BMT patients through implementation of appropriate practice changes. Detecting a statistically significant effect/correlation could, therefore, be a first step toward a clinically significant outcome.

A Conventional Approach to Estimating Attainable Effect Size

The effect to be considered in this study was an association between self-reported use of the Pis and the predictor variables previously identified as the practice factors (staffing patterns, educational preparation of RNs, use of mid-level providers, use of prophylactic anticoagulants, and availability of BMT center rates of CLI) and the demographic and organizational factors. This effect was measured as the strength of the association (r) between self-reported levels of use of the Pis and the predictors. The null hypothesis is $r = 0$. Using Cohen's conventional definition, a medium effect size would be $r = .30$ (Cohen, 1983, p. 60). Working backward through Cohen's (1983, p. 529) power tables, and imputing intermediate values not included in the tables, yields the ES that could be detected at alpha = .05 and power = .80 for a range of possible survey response rates, shown in Table 12.

Using Table 12, then, we could project, for example, that with a sample size of 40% of the study population, or 76 participants, it would be possible to detect an association on the order of $r = .31$ between the predictor variables and self-reported levels of use of the Pis. Carrying that a step further, the predictor variables would explain approximately 9% (f - .306 x .306) of the variance in level of use of the Pis for a participating BMT center. With a higher response rate, for instance a 70% response, or

Table 12. *Detectable Effect Size (r)for Various Levels of Response Rate with Alpha = .05 (two-tailed) and Power = .80*

Response Rate	Number of Participants	Effect Size
20%	38	.43
30%	57	.36
40%	76	.31
50%	95	.28
60%	113	.26
70%	132	.25
80%	151	.23

132 participants, it would be possible to detect an even smaller effect size - a relationship on the order of *r* = .25, between the predictor variables and self-reported use of the Pis if the effect does, in fact, exist.

A Different Approach to Response Estimation

A different way of determining the minimum response rate needed, which confirms the results shown above, is given by Browner, Newman, Cummings, and Hulley (2001). When the study data will be analyzed with a correlation coefficient, a table prepared by Browner et al. shows that an effect size of r- .45 with a two-tailed a = .05 and p = .20 can be detected with a sample of 36. Reaching a comparative conclusion on minimum response rates by using two different tables from two different sources confirmed that a response rate of 20 to 30% would be adequate to detect a significant effect in this population.

Instrument

Instrument Development

Construction and Initial Review of the Instrument

There is no published instrument to measure or estimate use of the CDC guidelines or use of the Pis in the guidelines. Therefore, an instrument, the BMT LIFE (Bone Marrow Transplant Line Infection Factor Evaluation) was developed for this study. The BMT LIFE was based on a review of the 2002 CDC guidelines and constructed to measure self-reported use of the Pis. Each usage question was based on one of the specific CDC (2002a) recommendations related to the four Pis (educating healthcare workers, using maximal sterile barriers, using 2% chlorhexidine skin prep, and discontinuing catheters as soon as medically indicated), for content validity.

Content validity of the BMT LIFE was defined as the ability of the survey to actually measure the level of self-reported usage by a participating BMT center of each of the individual CDC recommendations addressed in the survey. The BMT LIFE had not been used before, so it was imperative to know that the questions would elicit responses that truly represent the essential behaviors which constitute use of each of the CDC recommendations addressed by the study. If, and only if, the content were valid could appropriate, meaningful, and useful inferences be made from analysis of the collected data (Pedhazur & Schmelkin, 1991).

Survey content. Content areas of the questions in the survey are similar to those in the CDC guidelines, but the questions were organized in sections with slightly different names than the names of the sections in the CDC guidelines. The investigator did not want participants to recognize any exact phrases from the CDC guidelines because this might cause them to alter their responses based on the perceived desirability of answers reflecting the CDC guidelines. (Please see a copy of BMT LIFE, which is provided in Appendix A).

Some additional questions were included in the survey to furnish other information that may be useful. Responses to these questions were analyzed separately using descriptive statistics and correlations. Those responses that were significantly correlated with any of the dependent variables were included in the multiple linear regression analysis of self-reported use of the Pis. The additional questions are questions A.5-13, B.l-2, C.l-3, D.6, E. 1,4-11, and F.l.

Questions A.5-8 ask about use of trained CVC personnel for CVC insertion, CVC maintenance, and supervision of CVC trainees, and about staff levels. Respondents were also asked about adequacy of nursing staff levels to minimize incidence of CLIs.

Questions A.9-11 ask about staffing patterns. Information derived from these questions was used to describe nurse-to-patient ratios in participating BMT centers. Comparisons of staffing patterns were then made between participating BMT centers and with use of the Pis. The CDC does not define the term "appropriate nursing staff levels" (2002a, p. 15) used in the recommendation which addresses staffing.

Questions A. 12 and 13 ask about the educational preparation of RNs and the use of mid-level providers; both staffing levels and RN educational preparation have been shown to affect patient outcomes (Aiken et al., 2003; Aiken, Clarke, & Sloane, 2002; Aiken et al., 2002; Pronovost et al., 2001; Safdar, Kluger, & Maki, 2002; Tourangeau et al., 2007). Use of mid-level providers may also affect patient outcomes (Brooten et al., 2002; Fulton & Baldwin, 2004). Answers to these questions were used to describe patterns in educational preparation of RNs and other staff in participating US BMT centers. Staffing levels, RN educational preparation, and use of mid-level providers may also be associated with levels of self-reported use of the Pis (Wallace, MacKenzie, & Weeks, 2006).

Questions B. 1 and 2 ask for the CLI rate in each BMT center for the calendar year 2005. Question C.l requests aggregate data about the number and kinds of transplants performed. Question D-6 requests data about the length of time central lines are generally in use. Answers to these questions could be used to calculate the rates of CLI per 1000 catheter days for those BMT centers that do not express their CLI rates in that

Questions C.2 and 3 request aggregate data about patient age. That information, along with the aggregate data collected in Question C. 1 about number and kinds of transplants performed, and demographic data supplied on the BMT InfoNet website, was used to control for the effects of the demographic and organizational factors.

Question E.l asks for information about the use of prophylactic anticoagulants. The 2002 CDC guidelines discuss (2002a, p. 9) but do not recommend the use of prophylactic anticoagulants.

Questions E.4-11 ask respondents to identify the frequency with which they use preparations other than 2% chlorhexidine for skin antisepsis. The CDC guidelines list four preparations, including chlorhexidine, which may be used for skin antisepsis, with the expressed preference for use of chlorhexidine (2002a, p. 16).

Question F.1 is open-ended and requests that participants list the most important things they do at their BMT center to prevent CLI. This question was intended to show whether or not BMT center personnel identify the Pis or other CDC recommendations as being most important practices to prevent CLI.

Survey format. BMT LIFE contains rating scale, multiple choice, multiple answer, and open-ended questions regarding CLI prevention practices addressed in the CDC guidelines and other selected practices, not mentioned in the CDC guidelines, which may be associated with levels of use of the 2002 CDC Pis. The survey also includes questions about aggregate patient age groups, number and types of BMT performed, and an open-ended question asking respondents to list the most important things they do at their BMT center to prevent CLI.

The BMT LIFE survey was reviewed by content experts for face validity (Nunnally and Bernstein, 1994, p. 110). The content experts were one bachelor's prepared oncology RN, one master's prepared oncology RN, one BMT physician who is board certified in internal medicine/medical oncology, and one hospital epidemiologist who is board certified in internal medicine.

The two oncology nurses were asked to complete the survey and comment on (a) the amount of time it took, (b) the ease with which they could answer the questions, and (c) any questions that needed to be revised. They returned the completed surveys with written comments. Although they had no difficulty answering the questions, both nurses suggested that the length of the survey would result in a low rate of participant response, and one nurse warned of the probability of incomplete responses by participants who just got tired of answering the questions. The two physicians provided verbal feedback on questions specifically related to labeling and quantifying CLI.

Focused Review of Selected Aspects of the Survey Process by Telephone Contact

To further improve the survey process, a telephone contact was made with eight potential participants to get their reactions to questions regarding survey length, ability and willingness of participants to get and disclose data related to CLI rates, and incentives to be given to participants. A schedule of questions was created as a table with questions listed across the top of the table, names of 11 BMT centers with their contact information listed in the left-hand column and open boxes for answers below the questions.

The investigator selected BMT Info Net as the source for a list of US BMT centers, based on the amount and type of demographic and organizational information available to the public on the BMT InfoNet website (BMT, n.d.). BMT InfoNet is a patient support organization which provides lists of US and Canadian BMT centers and other patient support resources for prospective BMT patients. The website contains a page with contact information and demographic and organizational data for each affiliated BMT center.

The investigator decided to contact 5% of the potential US study participants for feedback on questions about the study. To obtain an unbiased sample, the investigator used the alphabetical list of US BMT centers on the BMT InfoNet Website and stratified the list by patient type - pediatric BMT centers, adult BMT centers, and combined pediatric and adult BMT centers. Approximately 5% (or every 20th) of the 202 potential US study participants were systematically selected for the telephone survey, using the following method. Each number from 1 to 20 was written on a piece of paper. The papers were folded and placed in a bowl, and a paper withdrawn blindly from the bowl contained the number 5. Then, using 5 as the starting number in each of the three stratified lists of BMT centers, the 5th center in each of the three patient-type groups and the succeeding 20th (25th, 45th, 65th, etc.) centers in each group were selected for inclusion in the telephone survey. Eleven centers in all were selected, with the resulting telephone survey group containing 2 of the 35 pediatric centers, 6 of the 107 adult centers, and 3 of the 60 combined pediatric and adult centers. Thus the distribution of participants among the three types of BMT centers approximated the distribution of all 202 BMT centers used for the main study. The investigator wanted a telephone survey group which would reasonably represent the larger group of which it was a part.

Cold calls to the centers were made during the first week in May, 2005. The investigator asked to speak to a BMT coordinator in each center and introduced herself to the coordinator as an oncology nurse doing a study of central line infections in bone marrow transplant patients. It took two or three calls to each BMT center to reach someone who could provide answers to the telephone survey questions.

By the end of the week, individuals (usually BMT coordinators) in eight of the eleven centers - one pediatric, five adult, and two combined pediatric and adult - were reached and queried about survey length, ability and willingness of the informant at each center to provide answers to the questions about rates of CLI, and opinions of informants about the desirability of three different incentives - a $5.00 bill attached to the survey, a drawing for one of five certificates for a 1-year memberships in ONS, and a copy of the study findings. The information obtained from the eight informants was considered adequate to meet the objectives of the telephone survey, so no further attempts were made to contact anyone at the remaining three sites.

All eight of the potential study participants said they would not have time, or would have difficulty finding time, to complete a 12-page survey questionnaire. However, all of them said they were very interested in research on prevention of CLI in BMT patients.

Seven of eight people surveyed thought they could get, or would be willing to try to get, CLI rate data for the survey. The same seven people said they would just need to get approval before giving the rate information. The eighth person said that only one or two transplants had been done at his facility in 2003 and none in 2004 or 2005. He stated that the facility was not currently transplanting but would be starting again that summer (the summer of 2005).

Discussion of incentives was interesting. The first three people the investigator spoke to all said they would not be able to accept cash, such as a $5 bill attached to the survey. They could accept gifts, but cash would have to be given to the hospital. The investigator asked if they would be able to accept a $5 Wal-Mart gift card, and they said they could accept that. For the rest of the calls, the cash incentive was not suggested. A $5 Wal-Mart gift card was suggested instead. Most thought that a $5 Wal-Mart gift card would be acceptable. When asked about being placed in a drawing for a paid ONS membership, everyone agreed that would be a highly desirable incentive. Everyone also expressed interest in receiving a copy of the study results.

The 11 sites used for the telephone interviews were retained in the population for the main study. No BMT LIFE survey data were collected from the eight informants during the telephone survey, but the comments of the informants were used to improve the format and content of the BMT LIFE instrument and the cover letter. Of the eight informants in the telephone survey group, two became participants in the study, five did not complete and return surveys, and one did not participate because that site was no longer performing bone marrow transplants.

Revisions to the Instrument

Originally, BMT LIFE was a 12-page survey containing 76 questions assessing self-reported use of 51 CDC recommendations, 10 questions exploring other factors which may be related to CLI in BMT patients, and additional questions requesting aggregate patient and BMT center data. Following the telephone survey, the BMT LIFE survey was shortened by restricting the usage questions mainly to questions aligned with the four Pis in the CDC guidelines. That cut the survey down from 12 pages to 4 pages. Admittedly, the survey instrument lost the ability to discriminate between use and nonuse of the CDC recommendations that were omitted from the survey, but it may be that self-reported use of the CDC recommendations related to the Pis is representative of overall use and not just use of the four specific areas addressed in the Pis. The trade-off was the potential for an increase in the response rate, versus obtaining more detailed data from only a few respondents. The anticipated increased response rate was seen as a way to increase both the sample size and the power of the study to demonstrate significant relationships between some of the study variables.

The investigator originally planned to attach a new $5.00 bill to each survey, for the main study, and to enter all participants in a drawing for one of five ONS memberships. However, based on the comments about not being able to accept cash, the modest interest in the $5.00 Wal-Mart gift card, and the overwhelming interest in the ONS memberships, the investigator decided to increase the number of ONS memberships in the drawing from five to ten, omit attaching the gift cards to the survey, and send a gift card to only those participants whose names were not drawn for ONS memberships.

Pilot Study

Next a pilot study was conducted to identify potential problems with data collection (Waltz, Strickland, & Lenz, 1991). Additionally, response rates and the quality of the data collected were reviewed.

Selection of Participants

The investigator decided to use the Canadian BMT centers listed on the BMT InfoNet website for the pilot study to preserve all possible US centers for the main study. A cohort of 15 Canadian BMT centers was identified. Only English-speaking Canadian centers were selected. The person completing each survey had to be able to read, write, and speak English. The BMT InfoNet website provides the same kinds of information and data for both US and Canadian BMT centers, and the Canadian centers were deemed to be similar to US BMT centers in terms of being able to answer the survey questions and give helpful feedback.

Dillman's Tailored Design Method for Improving Response Rates

Dillman (2000) describes survey research as constituting a social exchange. His Tailored Design method recommends specific practices to establish trust and increase response rates in survey research. Key concepts for improving the rate of survey return include providing rewards, reducing social costs to participants, and establishing trust.

A modified Dillman (2000) approach was used to encourage potential participants to respond. The Dillman strategies, previously discussed, were used with minor changes.

A Canadian $5.00 bill was attached to the cover letter and BMT LIFE survey sent to each BMT center in the Canadian cohort, as the cohort was small enough to make that incentive affordable, and it was not possible to procure Canadian Wal-Mart gift cards in this country. Surveys were mailed to potential participants on April 20, 2006.

Implementing Dillman's Method

In the implementation phase of survey research, Dillman (2000) describes five needed elements which can increase response rates: (a) a respondent-friendly survey instrument, (b) four contacts by first class mail and an additional contact made by telephone, if feasible, or if needed, (c) using real first-class stamps on return envelopes, (d) personalizing all correspondence, and (e) providing small financial incentives in advance. Modifications to these elements related to recruiting participants internationally.

Prior to mailing the 15 pilot surveys, the investigator streamlined the survey instrument and made it as clear and user-friendly as possible. The oncology nurses who had reviewed the survey found no difficulty in reading, interpreting and answering the questions.

Follow-up contacts for the pilot survey were by email. The investigator provided her email address in the cover letter to the pilot survey recipients. The Canadian participants were asked to email the investigator with any questions.

A self-addressed return envelope was included for ease in returning the completed survey. The envelopes were not stamped because the investigator did not have access to Canadian postage. However, the attached $5 bills provided more than enough cash to reimburse participants for purchasing postage. Interestingly, all of the respondents mailed the surveys using their BMT center mail system, as evidenced by the metered postage on each of the return envelopes, so the respondents bore no personal burden of time or expense for purchasing postage.

The envelopes containing the surveys were personally addressed to the BMT coordinator in each BMT center whose name appeared on the BMT InfoNet website. Likewise, the cover letters were also personally addressed.

The $5 bill attached to each cover letter was for the person completing the survey. It was described as a token of appreciation from the investigator.

Response to the Mailing

As previously stated, the purposes of the pilot study were to identify problems with data collection and the quality of the data collected and to project the probable response rate for the main study. By May 16, 2006, 16 days following mailing of the surveys, three of the surveys had been completed and returned. Two additional surveys came in within the next few days. No follow-up contacts were used to increase the response rate, such as were planned for the main study, because the pilot surveys which had been received by May 20th had adequately met the purposes of the pilot study.

There were no problems with the data collection or the quality of the data collected, and the response rate for the pilot was 33% without extensive follow-up contacts, suggesting the possibility of a higher response rate with additional follow-up contacts.

Following data collection, names of the 5 participants in the pilot study were placed in a bowl, and one name was drawn for the 1-year Oncology Nursing Society membership. The investigator telephoned to inform the participant of the award and to verify the correct mailing address. The membership certificate was mailed to the winner, and no further contact was made with any of the participants. Following completion of the main study, all five Canadian participants were placed on a list to receive copies of the study findings.

Findings of the Pilot Study

Five of the 15 Canadian recipients completed and returned the BMT LIFE survey, for a response rate of 33.33%. Participants answered each question without apparent difficulty, with the exception of the questions asking for rates of CLI. No Canadian participant was able to supply that information. That finding was not unexpected and is significant in terms of use of the CDC guideline (CDC, 2002a) about surveillance of rates of CLI.

No material change was made to the BMT LIFE survey on the basis of the Canadian pilot study. Procedural differences between the pilot study and the main study were as follows:

	Pilot Study	Main Study
Return envelope:	Self-addressed, no stamp affixed	Self-addressed, US postage affixed

Incentive:	Canadian $5.00 bill attached	$5.00 Wal-Mart gift card promised to participants
Contacts:	No follow-up mailings; email contacts provided; no telephone contacts	Follow-up contacts, including post cards, telephone calls, email, and additional surveys

Main Study

Concept Clarification

CDC Guidelines

Theoretical definition. In this study, the term "CDC guidelines" referred to the Guidelines for Prevention of Intravascular Catheter-Related Infections (CDC, 2002a).

Operational definition. Only recommendations in the CDC-defined categories IA and IB are addressed by questions in the BMT LIFE survey instrument. These two categories, as described in Chapter II, are strongly recommended by the CDC because they are supported by research. The other categories of recommendations were excluded from the survey because, by definition, they are not supported by research, and they cannot be considered evidence-based. The CDC guidelines define Category IC recommendations as requirements imposed by regulatory agencies, Category II recommendations as having suggestive clinical, epidemiologic or theoretical support, and Unresolved Issues as having insufficient evidence regarding efficacy (CDC, 2002a, p. 15).

In the 2002 CDC guidelines, the first section contains general recommendations which are applicable to insertion, maintenance and care of all intravascular catheters.

Following the general section are sections specific to (a) peripheral catheters in adult and pediatric patients, (b) central venous catheters (CVCs) in adult and pediatric patients, (c) peripheral arterial catheters and devices for monitoring pressure in adult and pediatric patients, and (d) umbilical catheters. Only the first section of general recommendations and the section with recommendations specifically for CVCs are addressed by questions in the BMT LIFE instrument.

Theoretical definition. The terms "use" and "utilization" and "implementation" have been employed in studies to assess or identify a level of acceptance or adoption of recommended behaviors, such as new practice models (Lindqvist, Torsson, Almqvist, & Bjorgell, 2008) and clinical practice guidelines (Kontos & Poland, 2009), and to assess the outcomes of utilization of new procedures (Hermansen et al., 2008). Use in this study is the extent to which participating US BMT centers perform procedures for prevention of CLI described in select recommendations from the 2002 CDC guidelines for central line insertion, care, and maintenance.

Operational definition. Use in this study is operationally defined as self-reported performance of behaviors recommended in the Pis in the CDC guidelines (2002a), or the level of compliance, self-reported by each participating BMT center, to selected Category IA and Category IB CDC recommendations for practice. Self-reported use was scored as a mean use score for each PI. The use scores for each participant were then summed to create an Overall Mean Use-Total (OMU-T) score for each participant, and then all the participant scores were summed and averaged to create the OMU-T score for the participants as a whole. The specific question(s) in the BMT LIFE instrument, and the corresponding answers, that were employed to calculate the level of self-reported use of each CDC recommendation are identified in Table 13.

Calculating use. Each survey question has points attached to each possible answer. Self-reported use scores were calculated using the points earned for each of the answers related to a recommendation. This method was employed for all four types of questions - rating scale (RS), multiple answer (MA), multiple choice (MC), and open-ended (OE). The RS questions were on a 5-point likert-type scale, but only Always (4 points), Usually (3 points), Sometimes (2 points), and Rarely (1 point) were assigned points. Never was worth 0 points.

The following example illustrates the calculation of self-reported use of a CDC recommendation. The first CDC (2002a) PI is "implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters" (p. 13). CDC general recommendation I - "Health-care worker education and training" (CDC, 2002a, p. 13) has three parts - A, B, and C - which address education and training of healthcare workers. BMT LIFE contains four questions with a total of 10 items which assess use of this performance indicator. The coding for the possible answers to these questions is Always (4 points), Usually (3 points), Sometimes (2 points), Rarely (1 point), and Never (0 points). Participant responses were calculated for each individual item, with a mean calculated for each item and an overall mean calculated for each PI.

The second PI is use of maximal sterile barriers during CVC insertion. This multiple answer question has seven possible answers, with five correct answers required for a maximum of five points. Some BMT centers reported having CVCs inserted in just

Table 13. *Question(s) Used to Calculate Use of Each CDC Recommendation*

CDC Recommendation	BMT LIFE Question(s)	Question Type	Response That Indicates the Highest Level of Self-reported Use of the 2002 CDC Guidelines
I.A. Educate health-care workers about IV catheter use, insertion, maintenance, and infection prevention.	A - 1: a.	RS	Always
	b.	RS	Always
	c.	RS	Always
	d.	RS	Always
	A - 2 : a.	RS	Always
	b.	RS	Always
I. B. Assess knowledge of and use of guidelines.	A - 3 : a.	RS	Always
	b.	RS	Always
	A - 4 : a.	RS	Always
	b.	RS	Always
VI. A.1. Use 2% chlorhexidine for cutaneous antisepsis before catheter insertion and during dressing changes.	E - 2	RS	Always
	E - 3	RS	Always
VIII. B. Promptly remove IV catheters that are no longer essential.	D - 5	OE	Criteria for line removal must include language equivalent to "Promptly remove" when "no longer essential for medical management" (CDC, 2002a, p. 14, 16).
IV. A. Use maximal sterile barrier precautions during catheter insertion.	D - 1	MA	a, b, d, e, and g
	D - 2	MA	a, b, d, e, and g
	D - 3	MA	a, b, d, e, and g
	D - 4	MA	a, b, d, e, and g

Note: General = Refers to general recommendations for use with all intravascular catheters; CVC = Refers to recommendations to be used specifically with central venous catheters; Category IA or IB = Refers to CDC guidelines categories of recommendations

Table 13. *(Continued)*

(CDC, 2002a), where Category IA recommendations are strongly supported by research, and Category IB recommendations are supported by some research and "a strong theoretical rationale"; RS = rating scale; MA = multiple answer; OE = open-ended; Always = The response Always indicates that the participant always does the specific behavior mentioned in the survey question. Always = 4 points; Usually = 3 points; Sometimes = 2 points; Rarely = 1 point; Never = 0 points.

one setting in the BMT facility, while other BMT centers used more than one setting. To make the scores equivalent for all centers, scores for each setting were added together and divided by the number of settings. This resulted in an overall mean usage score across all settings for each BMT center.

The third PI is use of 2% chlorhexidine for skin antisepsis before CVC insertion and during dressing changes. Most participants answered the question about use during dressing changes, but some could not answer the question about use prior to CVC insertion. Therefore, the answers were summed and then divided by the number of questions answered, similar to the scoring described for the second PI.

The fourth PI is prompt discontinuation of CVCs no longer medically necessary. This open-ended question was scored from zero to three points, based on specific required language.

Central Line Infection

Theoretical definition. There are several terms and definitions which fit under the umbrella term "central line infection." The terms used in the BMT LIFE survey include exit site infection, tunnel infection, catheter-associated BSI, catheter-related BSI, pocket infection, and clinical sepsis. Each of these terms is defined precisely in the CDC guidelines (2002a), and the CDC definitions are described in the survey.

Operational definition. For the purposes of this study, a central line infection is defined by the CDC (2002a) recommended definitions for each of the CLI terms listed above.

Description and Operationalization of Practice Factors

Staffing Patterns

Staffing patterns refers to the nurse-to-patient ratio, to ensuring appropriate nursing staff levels, and to designating trained CVC personnel for specific CVC-related procedures. Nurse-to-patient ratio was operationalized as the number of patients per RN, LPN, or NA on a typical day shift for each participating BMT center and was collected in that format from the survey. The day shift was used, rather than other shifts, to be consistent with previous studies of the outcomes of nurse staffing levels (Aiken, Clarke, & Sloane, 2002; Pronovost et a1, 2001). Ensuring appropriate nursing staff levels and designating trained CVC personnel were measured on a 5-point likert-type scale and operationalized as a score of 0, 1, 2, 3, or 4, reflecting the frequency of having appropriate nursing staff levels (ranging from never [0] to always [4]). All of the staffing pattern items are ordinal level data.

Educational Preparation of RNs

Educational preparation of RNs was operationalized as the percentage of RNs holding a bachelor's degree. It was obtained in that format from the BMT LIFE survey. The level of these data is ratio.

Use of Mid-level Providers

Use of mid-level providers was operationalized as either No (0 points) or Yes (1 point). In addition, three dummy variables for use of clinical nurse specialists (CNSs), nurse practitioners (NPs), and physicians' assistants (PAs) were created to assess use of specific mid-level providers. This data level is categorical.

Use of Prophylactic Anticoagulants

Use of prophylactic anticoagulants was measured using a 5-point likert-type scale with Always = 4 and Never = 0. This is interval level data. Participants were also asked to list the anticoagulant if one were used.

Access to BMT Center Rates of CLI

Access to BMT center rates or numbers of CLI is dichotomous and was operationalized as the ability (or lack of ability) of a participant to obtain and report CLI rate or number data on the BMT LIFE survey. Participants who supplied CLI data in any format were deemed to have access to BMT center rates or numbers of CLI. Those who checked the box indicating that their institution does not provide CLI data specifically for their BMT centers were deemed not to have access to BMT center rates or numbers of CLI. This variable was dummy-coded as 0 (No) or 1 (Yes) and is categorical.

Most Important Practices to Help Prevent CLI

The variable most important practices to help prevent CLI was operationalized as self-reported most important practices to help prevent CLI listed by participants in answer to question one in Section F - Practices Which Help to Prevent Central Line Infections. Responses to this question were not analyzed. Such analysis was beyond the scope of this study and may be the subject of future research.

Description and Operationalization of the Demographic and Organizational Factors

All of the information for the demographic and organizational factors was obtained from the BMT InfoNet website.

Type of Transplant Unit

Type of transplant unit was operationalized as either adult, pediatric, or combined adult and pediatric. This is a categorical variable.

Type(s) of Transplants Performed

Type(s) of transplants performed is a categorical variable and was operationalized as either autologous only or autologous and allogeneic. BMT centers performing only autologous transplants were coded 0, and centers performing both autologous and allogeneic transplants were coded 1.

Years in Practice

Years in practice was derived from the year listed as the year the transplant unit opened. It is ratio level data.

Number of Transplants Performed

Number of transplants performed was operationalized as the number of transplants listed for each BMT center to 2005. The data is ratio level.

Measures of Validity

Instrument Validity

Content validity. Questions in the BMT LIFE were designed to assess self-reported use of concrete behaviors recommended by the 2002 CDC guidelines, or to assess variations in practice patterns of participating BMT centers. Table 14 shows the alignment of survey questions with the individual CDC recommendations and with the

Table 14. *Alignment of Survey Questions with Specific CDC Recommendations and the Performance Indicators*

BMT LIFE Content Areas and Question Numbers	CDC Recommendations	Performance Indicators
Section A - Healthcare Workers		
1 - 2	General - I-A. Educate health-care workers	Educating healthcare workers
3 - 4	General - I-B. Knowledge assessment	Educating healthcare workers
5 - 6	General - XIII. IV-therapy personnel	Educating healthcare workers
7	CVC - II-D. Designate trained personnel to supervise training for line insertion	Educating healthcare workers
8	General - I-C. Nursing staff levels	NPI
9 - 13[1]	N/A	N/A
Section B - Surveillance		
1 - 2	CVC - I-A. Surveillance to determine CRBSI rates and trends	NPI
1 - 2	CVC - I-B. Method of expressing CRBSI rates	NPI
1.b.[2]	N/A	N/A
Section C - BMT Center Demographics		
1 - 3[2 and 3]	N/A	N/A
Section D - Catheter Insertion, Removal, and Days in Place		
1 - 4	CVC - IV-A. Use of aseptic technique during catheter insertion	Using maximal sterile barriers
5 - 6	General - VIII-B. Prompt removal of catheters	Discontinuing catheters
6[2]	N/A	N/A
Section E - Catheter and Catheter Site Care		
1[1]	N/A	N/A
2 - 9	General - VI-A-1. Cutaneous antisepsis using 2% chlorhexidine	Using 2% chlorhexidine
10 - 11	General - VI-A-3. Allowing the antiseptic to air dry	Using 2% chlorhexidine
Section F - Practice Patterns and Changes		
1[4]	N/A	N/A

Table 14. (*Continued)*

Note: General = Refers to the CDC category of general recommendations for use with all intravascular catheters; CVC = Refers to the CDC category of recommendations to be used specifically with central venous catheters; NPI = No performance indicator associated with these questions/recommendations; N/A = Not addressed in the CDC guidelines; [1] These questions are intended to elicit information related to other potential risk factors for CLI not addressed in the CDC guidelines. [2] These questions are intended to provide information needed to calculate rates of CLI in each BMT center. [3] These questions seek information to be used, in connection with data analysis, to control for interaction effects. [4] This question is intended to identify (a) BMT center beliefs about what helps to prevent CLI and (b) other CLI prevention strategies not captured by the survey.

Pis. Opinions, attitudes, and subjective or evaluative responses were not solicited, except for the final open-ended question, which asked respondents to list the most important things they did to prevent CLIs.

Criterion-related Validity

The outcome of interest, and the criterion of this study, is the dependent variable (DV), use of the Pis in the 2002 CDC guidelines among participating US BMT centers. The introduction to the CDC guidelines states that they contain "specific recommendations to reduce the incidence of intravascular catheter-related bloodstream infections" (p. 2). Based on that statement and the considerable research support of the guidelines, use of the guidelines may be associated with CLI rates in BMT patients.

Construct Validity

Abstract characteristics, such as use, cannot be measured directly, but are indirectly measured using carefully selected indicators. Assuring the validity of the indicators leads to meaningful results (Carmines & Zeller, 1979). The indicators chosen for this study were the behaviors specified in the CDC guidelines. Level of self- reported use of the CDC guidelines was calculated using both the number, and the frequency of performance, of the specified indicator behaviors.

Because the construct of usage is abstract, only observable aspects of usage were measured by self-report. As has been described, the CDC guidelines refer to concrete behaviors which can be observed and reported objectively. Therefore, use of the Pis was measured by comparing the self-reported behaviors to the behaviors recommended in the 2002 CDC guidelines.

Limitations to Instrument Validity

Responses to self-report surveys or inventories may be biased by the participants' concerns about giving the "right" answer, or the socially desirably answer. Attempts have been made to counter such response bias by the use of triangulation, or converging operations (Nunnally & Bernstein, 1994, p. 37). For example, survey question 8 in Section A states "We ensure appropriate nursing staff levels to minimize the incidence of catheter-related bloodstream infections." Participants were asked to indicate how often that statement describes the way things are usually done in their BMT center. The most socially desirable answer would, of course, be "Always." The question was formatted in this way to facilitate statistical comparisons. However, five follow-up questions request objective information about nurse-to-patient ratios and levels of educational preparation of the staff. These demographic data provide a different way of assessing "appropriate nursing staff levels" and may seem less evaluative to participants.

A similar approach was taken to assessing use of some of the other CDC recommendations. Straightforward multiple-answer and open-ended questions were used to assess the self-reported criteria for deciding when to remove central lines and rates of CLI in each BMT center. Aggregate demographic data about usual length of dwell time of the central line for each type of transplant were collected to provide comparable data across all the BMT centers. Other aggregate data were collected to provide the raw numbers needed to calculate rates of CLI for each BMT center. In addition to controlling for the effects of social desirability, these methods were employed to hedge against mono-operation bias (Burns & Grove, 1997, pp. 232-3).

A limitation in measuring use of the Pis is that, in a self-reported survey, it is only possible to measure the presence or absence of some behaviors and not the quality of the behaviors. For instance, education of healthcare workers cannot be evaluated as to its comprehensiveness or the quality of the education programs. The behavior of using maximal sterile barriers is measured by use or non-use of specific items without measurement or evaluation of the significant component of sterile technique. In spite of the inability of the investigator to observe such aspects of use of the Pis, it must be assumed that most healthcare workers want to use the appropriate techniques in order to provide the best care for their patients.

Terms related to use of performance indicators are not used in the survey, and the CDC guidelines are not mentioned in the survey. This was done intentionally to minimize evaluation apprehension, a threat to construct validity (Burns & Grove, 1997, p. 233). One of the stated aims of the study was to describe self-reported practice patterns surrounding the use and care of central lines. Therefore, the questions asked participants to select specific behaviors they use or to mark on a rating scale the symbol which indicates how well a statement describes usual practice in their BMT center in regard to specific aspects of central line insertion and care. The intent was to eliminate or decrease subjective or evaluative responses, to elicit objective responses to the questions, and to facilitate a mathematical calculation of self-reported behaviors that either do or do not adhere to CDC guidelines.

Internal Consistency Reliability

Ten BMT LIFE survey items relate to PI 1, educating healthcare workers. The other three Pis are measured by only one-three items each. Item analyses were conducted on the 10 items proposed to measure use of PI 1. Cronbach's alpha for the items was .737. Whereas alpha > .80 is considered adequate for a well-developed instrument, an alpha coefficient of at least .70 is considered adequate for a newly developed instrument, (Ferketich, 1990). As determined by Cronbach's Alpha if item deleted (SPSS, 2005), assessing knowledge of CVC guidelines and assessing use of CVC guidelines for persons who insert CVCs were better items; educating healthcare workers about proper procedures for CVC insertion, educating healthcare workers about proper procedures for CVC maintenance, and using hands-on teaching methods were worse items.

Procedure

Distributing and Collecting the BMT LIFE Survey Instrument

Following the pilot study and the implementation of minimal changes related to the pilot BMT centers being outside the US and the study centers being inside the US, the BMT LIFE was mailed to all US BMT centers listed on the BMT InfoNet (n.d.) website as of lune, 2006. A cover letter and self-addressed, stamped return envelope were included with the survey. The cover letter requested that an RN, preferably a BMT coordinator, clinical nurse specialist (CNS), or nurse practitioner (NP), complete the survey and return it in the provided envelope. It was presumed that a BMT coordinator or CNS or NP would be more acquainted than the medical director with the details of routine care of central lines in each facility.

The cover letter included a summary of the study aims, listing the potential benefits to each participating transplant center. The letter also included a statement guaranteeing confidentiality and protection of privacy. No BMT center and no person completing the survey was identified, either by name or by location, to any other participant or in any report of study results. The letter stated each participating center would receive a copy of the study results.

Finally, the letter stated that the informant (the person in each BMT center who completed and returned the survey) would be entered into a raffle for one of ten annual memberships in the Oncology Nursing Society (ONS), to be awarded to the informant in each of 10 different participating BMT centers. Participants whose names were not drawn in the raffle for the ONS memberships would be sent a $5.00 Wal-Mart gift card. The memberships and gift cards would be awarded as soon as data collection was completed. A copy of the cover letter is provided in Appendix B.

Completion of the survey was estimated to take approximately 5-10 minutes. However, collection of the data requested in the survey would require additional time and effort on the part of informants in BMT centers where CLI data are not routinely collected and reported.

Since there is usually more than one BMT coordinator, and there may be other persons qualified to complete the survey in each selected BMT center, the informant in each center was asked to write her or his name and contact information on a brief form on the last page of the survey. The informant was asked for permission to be contacted by the investigator, if needed, to clarify or complete any answers to survey questions. The informant was asked to return the survey in the provided envelope. The contact information was also used to contact and send complimentary membership certificates to the 10 winners in the drawing for the ONS annual memberships. Only one informant provided survey answers and contact information in each site.

Follow-up contacts varied somewhat from Dillman's (2000) Tailored Design method which recommends four first class mailings with an additional telephone contact, if needed. Departure from the Dillman method was necessary because some names and addresses on the BMT InfoNet website were found to be outdated when the mailed surveys were returned for inaccurate recipient names or addresses. The investigator contacted 57 potential participating BMT centers by telephone to obtain corrected names and addresses of appropriate survey recipients. Therefore, the investigator decided to contact all nonrespondents by telephone and to mail new surveys only to verified recipients at verified addresses. Once telephone contact had been made, additional follow-up by telephone was faster, more efficient, and much less expensive than repeated mailings of the survey. Mailings and calls were made over approximately 314 months, with the first mailing on July 20, 2006 and the last phone calls on November 6, 2006.

Three weeks following the mailing of the surveys, a follow-up post card was mailed, on August 8, 2006, to BMT centers that had not returned the completed survey (Dillman, 2000). Two weeks following the post card mailing, beginning August 23, 2006, phone calls were made to nonresponders. The following general format was used for the calls. The investigator:

1. Asked to speak with the BMT coordinator listed on the BMT InfoNet website, specifically, the person to whom the survey had been addressed.
2. Introduced herself as an oncology and BMT nurse doing a study of central line infections in bone marrow transplant patients.
3. Asked if the BMT coordinator had received the BMT LIFE survey which had been mailed to her or him in a large white envelope.

   a. If not, the investigator explained that she was collecting data on infection prevention strategies used in US BMT centers, stated she would like to send a copy of the study survey to the BMT coordinator, and asked for the current mailing address of the BMT center.
   b. If the BMT coordinator had received the survey, the investigator said she hoped the BMT coordinator would be able to participate in the study.
   c. If the BMT coordinator had received the survey but no longer had it, the investigator said she would be happy to mail another copy of the survey to the BMT Coordinator.
4. Stated that all participants would be entered in a drawing for a certificate for a one-year ONS membership and that those who did not win a membership would receive a $5.00 WalMart gift card. In addition, all participants would receive a copy of the study results.
5. Stated that the BMT center's data would be kept confidential and that the BMT center's participation was very important to the outcomes of the study.

In some cases, BMT coordinators listed on the BMT InfoNet website were no longer working at the BMT center, and the surveys addressed to them had been misplaced or discarded. The investigator got the names of the new BMT coordinators, and new surveys were addressed and mailed to the new BMT coordinators.

If the BMT coordinator did not answer the call but had an answering device, the investigator left a message briefly stating that she was an oncology and BMT nurse doing a study of central line infections in BMT patients, saying that she hoped the BMT center would be able to participate in the study, asking the coordinator to return her call, and giving the toll-free number. Alternately, the coordinator could email the investigator, and the email address was given.

Prior to mailing out the surveys, the investigator had set up a toll-free telephone line on which she could be reached in person or a message could be left. The answering message on the toll-free number identified it as the site for the BMT LIFE study and asked callers to leave a message which would be answered as soon as possible. Each BMT LIFE survey had a small box at the top of the first page giving the investigator's name, toll-free number, and email address for informants who had questions about the survey. Both the toll-free number and the email address were used by informants and were important in establishing 24-hour access for informants.

The investigator kept a log of all telephone and email follow-up contacts for each BMT center. The list of BMT centers was alphabetical, and the investigator went all through the list making follow-up calls. As soon as the investigator concluded the first round of calls, she started over at the first of the list and began a second round of calls. This was repeated for five rounds of calls. Collection of surveys and all follow-up calls were concluded when all BMT centers had either returned their completed surveys, or stated that they did not wish to participate, or when repeated calls and voicemail messages had failed to yield any new participants. Calls were made August 23, 2006 through November 27, 2006.

Response to Mailings, Emails and Telephone Calls

Initially, 202 surveys were mailed on July 18, 2006, and 15 participants responded by August 7. On August 8, reminder postcards were mailed to the remaining 187 BMT centers, with a response of nine more surveys by August 31. From August 23 to September 6, the first round of follow-up calls was made, with a response of 10 more surveys by September 17. From September 12 to October 3, second round follow-up calls were made, and 12 more surveys came in by October 10. Between October 4 and October 9, third round calls were made, and six more surveys came in by October 16. The fourth and fifth rounds of calls were made from October 13 to October 24 and from October 27 to November 6, respectively, with six more surveys received by November 21. On February 5, 2007, 1 participant called to see if the investigator still wanted her survey, to which the reply was a definite yes. She sent in her survey, which was received February 9, 2007. Very unexpectedly, one last survey was received May 7, 2007, for a total of 60 surveys completed and returned. Table 15 depicts the response rates of participants through each mailing and each round of follow-up contacts.

In all, 580 follow-up calls and email contacts were made to 179 BMT centers between August 23 and November 6; 99 additional surveys, most with corrected addresses, were mailed to centers that had not received or had lost the original surveys. Eleven BMT centers were eliminated from the study when calls revealed that they were no longer active transplant centers, and two additional BMT centers were excluded because no, or insufficient, data were available on the BMT InfoNet website. Of the remaining 189 viable BMT centers, 60 completed and returned surveys, for a 32% response rate.

Table 15. *Response Rate of Participants Following Mailings and Follow-up Contacts*

Type of Contact Made	Date(s) of Contact	Number of Surveys Received	Dates Surveys Received.
Surveys mailed to 202 BMT Centers; 99 additional surveys mailed to 95 BMT centers	July 18, 2006 Throughout study	15	July 26 - August 7, 2006
Follow-up postcards mailed to 187 BMT centers	August 8, 2006	9	August 12 - August 31, 2006
1st round of phone calls and emails: 203 calls and emails to 170 BMT centers	August 23 - September 6, 2006	10	September 1 - September 17, 2006
2nd round of phone calls and emails: 165 calls and emails to 124 BMT centers	September 12 - October 3, 2006	12	September 22 - October 10, 2006
3rd round of phone calls and emails: 115 calls and emails to 91 BMT centers	October 4 - October 9, 2006	6	October 13 - October 16, 2006
4th round of phone calls and emails: 49 calls and emails to 35 BMT centers	October 13 - October 24, 2006	4	October 19 - October 30, 2006
5' round of phone calls and emails: 48 calls and emails to 33 BMT centers	October 27 - November 6, 2007	4	November 6, 2006 May 7, 2007
Total phone calls and emails: 580 calls and emails to 179 BMT centers	August 8 - November 6, 2007	60	July 26, 2006 - May 7, 2007

Data Management

Each BMT center was assigned a unique identification (ID) number. The survey sent to each BMT center bore the unique ID number of that BMT center. Completed and returned surveys were checked for completion and stored in a locked cabinet accessible only to the investigator and to one research assistant in the investigator's office at her home. A list of each BMT center and its unique ID number was kept in an Excel file on a removable disk which was kept in the locked cabinet, also accessible only to the investigator and one research assistant. The list of BMT centers and their ID numbers was used by the investigator only for the purposes of identifying which BMT centers had and had not responded so that appropriate follow-up could be made, and to identify BMT centers for any needed telephone calls to clarify answers or fill in missing data. All files were kept and used only in the investigator's personal home office, and the confidentiality of the participants was strictly maintained. The surveys and the electronic list of participating BMT centers will be destroyed following completion of the study and mailing of the study results to participants.

Survey data were analyzed using the Statistical Package for the Social Sciences (SPSS 14.0 [2005]). Participating BMT centers were not identified in the data analysis, and all survey data were entered and analyzed using only the unique ID number of each of the participating centers.

Data Editing and Verification

The investigator assured accuracy of the survey data by using a double entry method. The investigator entered all survey data twice, first into sheet 1 of an Excel file and then into sheet 2 of the same Excel file. Next the data in each cell of sheet 1 were subtracted from the data in each corresponding cell in sheet 2. The results were displayed in sheet 3 where zeros occupied each cell for which the entries in sheets 1 and 2 were identical. A value other than zero indicated an error on either sheet 1 or sheet 2. In all, 8484 pieces of data were entered on sheet 1 and again on sheet 2, for a total of 16,968 data points on the two sheets. Twelve discrepancies were shown as values greater than zero on sheet 3. All 12 errors were then checked against the surveys and corrected so that the data were known to be accurate. Finally, the survey data were imported from the corrected Excel file into SPSS.

Prior to analysis, the data were screened for missing data. Where possible, missing data were obtained; however, sample size differs in some of the analyses due to missing and unobtainable data. Frequencies were run, using SPSS, to double check for outliers, missing data, and data entry errors. Descriptive statistics were used to screen for normality, linearity, and homoscedasticity. Specifically, the various use measures and each of the independent variables were tested for normal distribution by looking at histograms for the shape of the distribution and by using the Kolmogorov-Smirnov one-sample test. Scatterplots were analyzed for outliers and for linearity and homoscedasticity. Consideration was given to transformation of the data when warranted by the absence of normality, linearity, and homoscedasticity (Tabachnick & Fidell, 2001) and to the use of nonparametric statistics.

Data Analysis

The five individual CDC recommendations related to the Pis are all category IA recommendations. The level of self-reported use of the five recommendations related to the four Pis was assessed as shown in Table 13. As previously discussed, the BMT LIFE survey contains 11 questions which measure self-reported use of the five individual CDC recommendations.

Descriptive statistics were computed on responses to each of the 11 survey questions related to the four Pis. The four questions about PI 1- Educating Healthcare Workers (EHW) each had multiple parts, with a total of 10 parts. Some participants did not answer all 10 parts in PI 1, usually due to lack of knowledge. To retain as many surveys as possible in the analysis, surveys were included if participants answered at least 7 of the 10 parts. For each participant, a mean score of self-reported use of PI 1 (API 1) was computed for all responses related to PI 1. Possible mean scores for API 1 - EHW were from 0 to 4, with 0 meaning that participants self-reported that they never used (or adhered to) the CDC-recommended behaviors, and 4 meaning that participants self-reported that they always used the CDC-recommended behaviors. A higher score equals a higher level of self-reported use of PI 1, and a lower score equals a lower level of self-reported use of PI 1.

The same procedures were used to compute mean scores for each of the other three Pis. Possible mean scores for API 2, API 3, and API 4, respectively, were 0 to 5, 0 to 4, and 0 to 3. The mean scores related to each of the four Pis were summed for each participant, to produce the overall mean use scores for participants. Possible overall mean use scores were from 0 to 16. Table 16 shows the scores to be calculated as levels of use.

The BMT LIFE survey contains 25 additional questions, as delineated on pages 58-60, which are not related to the Pis. These additional questions are about staffing

Table 16. *Use Scores to be Calculated from the Data Collected in the BMT LIFE Survey*

Use Scores	Interpretation of the Scores
UPI 1 - EHW	Use of the 2 CDC recommendations related to Educating Healthcare Workers
UPI 2 - MSB	Use of the 1 CDC recommendation related to using Maximal Sterile Barriers
UPI 3 - 2%C	Use of the 1 CDC recommendation related to using 2% Chlorhexidine
UPI 4 - DC	Use of the 1 CDC recommendation related to Discontinuing Catheters
OMU-T	Overall Mean Use-Total to all 5 CDC recommendations related to the 4 Pis

patterns (4), educational preparation of the nurses (4), use of mid-level providers (1), use of prophylactic anticoagulants (1), access to BMT center rates of CLI (2), aggregate BMT center and patient demographics (4), skin antisepsis (8), and important practices for prevention of CLIs (1).

The last section in the survey contains one open-ended question asking survey respondents to list the most important things they do to prevent CLI. This last question was intended to explore the question of whether or not participants identify any of the Pis or the other CDC recommendations as being among the six most important ways of preventing CLI. Content analysis of participants' responses was beyond the scope of this study and was not done.

Planned Analysis

Research Question One: What Are the Self-reported Practices for Prevention of CLI in Participating US BMT Centers?

The BMT LIFE survey contains questions about various practices for prevention of CLI in BMT patients. Descriptive statistics, including frequencies, means, standard deviations, and ranges, were used to summarize responses to survey questions about each of the practices. Findings are presented for each surveyed practice.

Research Question Two: What Are the Self-reported Levels of Use of the Pis in the 2002 CDC Guidelines in Participating US BMT Centers?

Five different use scores were calculated for each participating BMT center, as shown in Table 16. Use of each aspect of the CDC recommendations related to each PI was evaluated and scored as a level of self-reported use of that PI, in the following manner:

1. Mean self-reported use levels were computed from the responses to the question or questions related to each PI:
    a. API 1 - EHW - Questions A. 1-4: four rating scale questions with a total of 10 separate items; each item rated on a 0-4 point scale for frequency of use of a CDC-specified healthcare worker education behavior; with 0 = never and 4 = always
    b. API 2 - MSB - Questions C. 1-4: four multiple answer questions with five correct responses and two distracters; with each selection of a

    CDC-specified sterile barrier used by the participant = 1 point; no points deducted for selection of distracters

    c. API 3 - 2%C - Questions E.2 and 3: two rating scale questions with one item each; each item rated on a 0-4 point scale for frequency of use of the CDC-preferred preparation for skin antisepsis; with 0 = never and 4 = always
    d. API 4 - DC - Question D.5: one open-ended question asking for criteria for CVC removal; with mention of one, two or three CDC-specified criteria = 1, 2, or 3 points
    e. APIs 2 and 3 had multiple parts. Use levels were calculated for the separate parts, with an overall mean usage level calculated for each of the two Pis, as follows: OMU-PI 2 and OMU-PI 3

2. The means of the four PI scores were then summed, with a total of 16 points possible.
3. Next a mean of the summed scores was calculated for the total overall mean use (OMU-T) level.
4. Descriptive statistics were computed on the five outcome variables, APIs 1-4 and OMU-T.

Research Question Three: Which Practice Factors Are Associated with Self-reported Levels of Use of the Pis in the 2002 CDC Guidelines in Participating US BMT Centers?

The factors in this study that could be associated with self-reported levels of use included staffing patterns, educational preparation of the RNs, use of mid-level providers, use of prophylactic anticoagulants, access to BMT center rates of CLI, type of transplant unit, type(s) of transplants performed, years in practice, and total transplants performed to 2005.

Variables analyzed included the five outcome variables (levels of use of the Pis); the five practice factors (staffing patterns, educational preparation of the RNs, use of mid-level providers, use of prophylactic anticoagulants, and access to BMT center rates of CLI); and the four demographic and organizational factors (type of transplant unit, type(s) of transplants performed, years in practice, and total transplants performed to 2005).

The analytic plan for research question three included computing a correlation matrix for the independent variables and use of the Pis, to screen the data for multicollinearity and to eliminate redundant variables. Multiple regression analyses were conducted, using the dependent variables and the remaining independent variables (both the practice factors and the demographic and organizational factors).

Consideration was given to using a Bonferroni correction of the Pearson correlation p-values because of the multiple comparisons. However, due to the exploratory nature of the present study, a Bonferroni correction was thought to be too conservative. Instead, the planned analyses were performed without adjustment, and then a modified Bonferroni procedure, the Bonferroni-Holm procedure, was calculated to show the differences in p values without and with adjustment.

The Bonferroni-Holm method of adjustment uses a sequentially rejective procedure, as follows. First, raw p-values are ranked from smallest to greatest. Next, the first (or smallest) p value is multiplied by n, the number of comparisons. Then each succeeding *p* value is multiplied by a sequentially smaller number, with the greatest *p* value being multiplied by 1. Tests of significance are continued until one association has been rejected. Once a variable has been rejected, all succeeding variables are rejected. With this method, it is possible for a given *p* value to be smaller than the one preceding it. Since this would not be logical, any such smaller *p* value is assigned the same *p* value as the comparison immediately preceding it (Ludbrook, 1998).

The Bonferroni-Holm procedure has several advantages over the Bonferroni approach. The a-level can be maintained at 0.05, while the power level is increased (Sankoh, Huque, & Dubey, 1997). The procedure is applicable whenever multiple simultaneous comparisons are being made, including multiple correlation and regression analysis (Gordi & Khamis, 2004). The Bonferroni-Holm procedure is relatively simple and requires nothing more than a simple calculator (Gordi & Khamis; Ludbrook, 1998).

Research Question Four: What Are the Self-reported Rates of CLI in Participating US BMT Centers?

For centers that track rates of CLI according to the CDC guidelines, the answers for each participating US BMT center were found in survey questions B. l.a, which asks for the rates of CLI in the center for the calendar year 2005, and B.2.a-g, which ask for the rate and the number of specific kinds of CLIs which occurred in the transplant center in 2005 (or for whatever data the BMT center had on number or rate of CLIs for the study year). For centers that do not track rates of CLI, the answer was intended to be calculated using the answers to survey questions B.1.b and/or B.2.a-g; question C.1, which asks for the number of each kind of transplant performed in the center during the study year; and question D.6, which asks for the number of days the central line is generally in place in patients who have each of the different kinds of transplants performed in the center during the study year. The formula for the calculation is:

$$\frac{\text{Number of central line-associated BSI}}{\text{Number of central line-days}} \times 1000 = \text{Central line-associated BSI per 1000 catheter days}$$

Descriptive statistics were run on the reported rates and numbers of CLI for all the participating BMT centers that provided CLI rates and/or numbers. The resulting data were used to describe the current rates and numbers of self-reported CLI in BMT patients among those US BMT centers. Centers which did not report CLI rates also did not supply the necessary data to calculate those rates, so no calculations were made for those BMT centers. These were left missing.

Note Pertaining to the Overall Plan for Data Analysis

It was not possible to anticipate the method which BMT centers would use to report their rates of CLI. The literature review suggested that it could be very inconsistent. Therefore, a conservative approach was taken with regard to planning statistical analysis of that data. The novelty of the BMT LIFE survey instrument in both its development and its use supported this approach, as did the absence of other published studies or instruments designed to reflect and evaluate the current state of clinical practice related to the prevention of CLI specifically in BMT patients.

Controlling for Threats to Internal Validity

Demographic and Organizational Factors

The BMT Infonet website provided demographic and organizational data about the BMT centers in this study regarding the age categories of their patients (pediatric, adult, or combined pediatric and adult), the type(s) of transplants they perform (autologous alone or autologous and allogeneic), their years in practice, and the numbers of transplants they performed to 2005. Most of this information was confirmed by participants' responses to questions throughout the BMT LIFE survey instrument.

Although these demographic and organizational factors were not the main focus of the study they were factors of interest, and they were considered to be potential mediators of the effects of the predictor variables on the outcome variables. For example, centers that perform greater numbers of BMTs may implement different standards of care than centers that perform only a few BMTs each year. Centers that perform only autologous BMTs would be expected to have lower CLI rates than centers that perform allogeneic BMTs due to the less aggressive immunosuppression for autologous patients who are not usually at risk of rejecting their own collected and reinfused bone marrow or stem cells. BMT centers with different patient and transplant mixes may differ in their use of the 2002 CDC Pis. Finally, differences in treatment regimens for adult versus pediatric patients could also affect BMT centers' levels of use of the CDC Pis.

The effects of the demographic and organizational factors on the outcome variables were investigated using linear regression analyses. The analyses were carried out in two stages.

First, bivariate correlations were run on all the variables to check for collinearity and to identify predictor variables significantly related to the outcome variables. Collinearity was defined if a predictor variable was highly related (Spearman $r > .85$) to another predictor variable (Schroeder, 1990). Predictor variables that were highly correlated with other predictor variables, and redundant variables were excluded. Six predictor variables that were significantly related to one or more of the outcome variables ($p < .05$) were identified. They were (a) typefs] of transplants performed, (b) years in practice, (c) ensuring appropriate nursing staff levels, designating trained CVC personnel to maintain CVCs, (d) designating trained CVC personnel to supervise CVC insertion trainees, and (e) using mid-level providers who were PAs.

Next, using SPSS 14.0, a series of regression analyses was conducted. The stepwise method of entry was used for the predictor variables. Because this study was exploratory cut points for entry and removal of variables were set somewhat liberally at p <.10 for entry into the model and p >.20 for removal. Listwise deletion of cases with missing data resulted in an n = 54 for the regression analyses. A ratio of 10 observations per predictor is generally recommended for "a stable prediction equation" (Nunnally & Bernstein, 1994, p. 201). However, given the exploratory nature of this study, a more liberal approach was taken, and all six of the predictors that were significantly correlated with one or more of the five outcome variables were entered into the regression analyses.

The stepwise method of entering predictor variables was carried out in the manner described by the following steps:

1. The predictor variable that had the highest correlation with the outcome variable was entered into the regression model first.
2. Next, the predictor variable that produced the biggest increase in the R" of the model was entered, and so on until each variable was assessed.
3. As each variable was entered, the contribution of that variable and of each variable previously entered was assessed to be sure that its contribution was still significant. A predictor variable already entered was removed if its

contribution was no longer statistically significant (i.e., removal cut point, $p > .20$), in the new combination of predictor variables.

4. The steps were completed when no more variables met the cut points for entry into or removal from the model.

The most parsimonious model for each outcome variable was identified. Model fit was determined using analysis of variance to identify the model that produced the smallest residual sum of squares.

The effect of each of the predictor variables was assessed by looking at the standardized coefficients (Beta). Given the exploratory nature of the study, standardized coefficients with p values less than .10 were considered significant. The predictor with the largest effect was determined by the largest magnitude (absolute value) of the standardized coefficient.

History

Participants were all asked to report their rates of CLI for the calendar year 2005. This was intended to help control for events or changes in transplant protocols that would result in widespread changes in CLI rates. No attempt was made to control for local changes and their effects on local CLI rates. Rates were simply described as they were reported. Data collection began in July of 2006, which should have provided ample time for BMT centers to summarize their data for transplants performed in 2005.

Controlling for Threats to External Validity

Selection

Aggregate patient data and BMT center data were used to determine the representativeness of the participating BMT centers. Descriptive statistics were used to facilitate a comparison of the demographics of participating and nonparticipating BMT centers. Demographics used in this comparison were solely those available from the BMT InfoNet website, so that the data being compared would be equivalent. Significant differences between participating and nonparticipating BMT centers would have limited the generalizability of the study findings.

CHAPTER IV

RESULTS

Population and Sample Descriptions

The population consisted of 189 BMT centers that met inclusion criteria. The sample (hereafter called the participants) consisted of 60 BMT centers that returned completed surveys to the investigator. There were 129 nonparticipants. The overall response rate was 32%.

Data collected from the website for all 189 BMT centers included the following categories listed on the website:

1. Location of and contact information for the BMT center;
2. Background Data, including type of transplant unit (pediatric, adult, or combined), FACT (The Foundation for the Accreditation of Cellular Therapy) status, NMDP (National Marrow Donor Program) status, year transplant unit opened, number of autologous and allogeneic transplants performed through December 31, 2005;
3. Number of Transplants Performed in each of seven transplant types, for the years 2003, 2004, and 2005;
4. Minimum Donor Match Criteria;
5. Support Groups Available;
6. Research Interests; and

7. Date Last Updated.

For this study, location (by time zone regions) and background data were used to identify comparable characteristics of the participants and the nonparticipants. The website data for number of transplants performed in each of seven transplant types for the years 2003, 2004, and 2005 were incomplete for many BMT centers, so they were not used for any statistical comparisons. Minimum donor match criteria, support groups available and research interests were not considered useful terms for statistical comparisons, and no statistical tests were run on those data.

Two separate analyses were conducted to compare the participants and nonparticipants according to location and background BMT characteristics obtained from the BMT InfoNet website. Independent t-tests were conducted for continuous variables, and Chi Square analyses were conducted for nominal-level variables. Results of both analyses are shown in Table 17.

Only one statistically significant difference between participants and nonparticipants was found. In the Chi Square analyses (Table 17), the proportion of BMT centers' FACT approval status was significantly different from its nonparticipant counterpart. Seventy-three (57%) nonparticipant BMT centers reported being FACT approved for both autologous and allogeneic BMTs, while only 22 (37%) participant BMT centers reported FACT approval for both autologous and allogeneic BMTs, Pearson X^2 (2, N = 189) = 7.43, p = .024. During the data collection time period, many nonparticipants stated that their BMT centers were busy completing the necessary procedures for FACT accreditation and, therefore, unable to participate in the BMT LIFE

Table 17. *Analyses Comparing Participants and Nonparticipants According to Demographic and Organizational Characteristics of the Bone Marrow Transplant Centers*

	Participant (M=60) **Mean *(SD)***	**Nonparticipant *(N=129)*** **Mean *(SD)***	**P Value**
Years in Practice	**17.95 (5.77)**	**16.71(6.91)**	**0.23**
Autologous Transplants Performed to 2005	**543.68(830.19)**	**617.40(711.41)**	**0.18**
Allogeneic Transplants Performed to 2005	**375.87(1035.51)**	**381.14(574.64)**	**0.97**
Total Transplants Performed to 2005	**919.55 (1507.04)**	**998.53(1227.24)**	**0.32**

		N (%)		
		Participant	**Non-participant**	**Total**
Region	**Pacific and Mountain**	**13 (21.7)**	**24 (18.6)**	**37(19.6)**
	Central	**19(31.7)**	**38 (29.5)**	**57 (30.2)**
	Eastern	**28 (46.7)**	**67 (51.9)**	**95 (50.3)**
Type of BMT Unit	**Pediatric**	**11 (18.3)**	**22 (17.1)**	**33 (17.5)**
	Adult	**30 (50.0)**	**66 (51.2)**	**96 (50.8)**
	Combined Pediatric and Adult	**19(31.7)**	**41 (31.8)**	**60 (31.8)**
FACT Approval Status*	**Autologous - No; Allogeneic - No**	**23 (38.3)**	**39 (30.2)**	**62 (32.8)**
	Autologous - Yes; Allogeneic - No	**15(25.0)**	**17 (13.2)**	**32 (16.9)**
	Autologous - Yes; Allogeneic - Yes	**22 (36.7)**	**73 (56.6)**	**95 (50.3)**
NMDP Center Status	**No**	**26 (43.3)**	**38 (29.5)**	**64 (33.9)**
	Yes	**34 (56.7)**	**91 (70.5)**	**125 (66.1)**
Type(s) of BMT Performed	**Autologous Only**	**13 (21.7)**	**21 (16.3)**	**34 (18.0)**
	Autologous and Allogeneic	**47 (78.3)**	**108 (83.7)**	**155 (82.0)**

*$p < 0.05$

Abbreviations: FACT = The Foundation for the Accreditation of Cellular Therapy;
NMDP = National Marrow Donor Program

study, which may account for the significant difference in that characteristic between participants and nonparticipants.

Analysis of Survey Data

Participant responses to the BMT LIFE survey are organized by the four aims of the study and summarized in tables and figures. The independent variables are grouped as demographic and organizational factors (characteristics of the BMT centers) and practice factors (practices related to prevention of CLI). The dependent variables are levels of use of each of the four Pis in the 2002 CDC guidelines. The four Pis, as described in the CDC guidelines, are:

1. "implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters [PI 1 - EHW];
2. use of maximal sterile barrier precautions during catheter placement [PI 2 - MSB];
3. use of chlorhexidine for skin antisepsis [PI 3 - 2%C]; and
4. rates of catheter discontinuation when the catheter is no longer essential for medical management [PI 4 - DC]."

The analytic approach for this study was driven by the specific aims of the study. The Pis in the 2002 CDC guidelines and the independent variables identified in this study as practice factors are linked directly to both the aims and to the analytical approach. These relationships are shown in Table 18.

Table 18. *Relationships Between the Aims of the Study, the Practice Factors (IVs) and the Performance Indicators (Pis) in the 2002 CDC Guidelines for Prevention of Intravascular Catheter-Related Infection, and the Analytic Approach for this Study.*

Aims of the Study	Practice Factors (IVs), Pis, and Rates of Central Line Infection (CLI	Analytic Approach
Describe self-reported practice patterns for prevention of CLI in participating US BMT centers.	Practice factors (IVs): Practices used to prevent incidence of CLI	Compute descriptive statistics for self-reported practices to prevent CLI in participating US BMT centers; identify patterns in practice
Determine the level of self-reported use of the Pis in the 2002 CDC guidelines among participating US BMT centers.	Pis: • Educating Healthcare Workers (EHW) • Using Maximal Sterile Barrier Precautions (MSB) • Using 2% Chlorhexidine (2%C) • Discontinuing Catheters as soon as possible (DC).	Calculate levels of self-reported use of each PI and overall mean use of all 4 Pis.
Determine which of the practice factors (IVs) are associated with the dependent variables (DVs), self-reported levels of use of the Pis in the 2002 CDC guidelines.	Practice factors: • Staffing Patterns • Educational Preparation of RNs • Use of Mid-level Providers • Use of Prophylactic Anticoagulants • Availability of BMT Center CLI incidence rates.	Compute bivariate correlations and multiple linear regression of IVs on the DVs, controlling for effects of demographic and organizational factors: • Type of transplant unit • Type(s) of transplants performed in 2005 • Years in practice • Number of transplants performed to 2005.

Table 18. *(Continued*

Aims of the Study	Practice Factors (IVs), Pis, and Rates of Central Line Infection (CLI	Analytic Approach
Describe self-reported incidence rates and number of CLI in participating BMT centers.	Rates and numbers of CLI: • CLIs per 1000 catheter days • Number of CLIs in 2005.	Compute descriptive statistics for self-reported incidence rates and numbers of CLI in participating BMT centers.

Aim One: Describe Self-reported Practice Patterns for Prevention of CLI

Self-reported practices are presented by sections of the BMT LIFE survey.

Section A - Healthcare Workers

Education of healthcare workers. On a likert-type scale, with never equal to 0 and always equal to 4, most participants, 95-100%, said they usually or always taught healthcare workers the indications for central venous catheters (CVCs), the proper procedures for maintaining CVCs, and the strategies for preventing CVC-related infections. Only 67% of participants said they usually or always taught proper CVC insertion procedures.

Most participants, 82%, said they usually or always used lecture. Nearly all participants, 98%, said they usually or always included hands-on teaching methods.

Most participants (92%) reported that they usually or always assess knowledge of CVC guidelines for persons who maintain CVCs, but much fewer (54%) reported that they usually or always assess knowledge of CVC guidelines for persons who insert CVCs. Similarly, 81% of the participants reported that they assess use of CVC guidelines by persons who maintain the CVCs, but only 51% said they usually or always assess use of CVC guidelines by insertion personnel.

Designation of trained personnel. Most participants reported that trained personnel were usually or always designated for insertion of CVCs, 88.7%, and for maintenance of CVCs, 95%; 75% of participants reported that trainees who perform CVC insertion were usually or always supervised by trained personnel.

Appropriate nurse staffing levels, patient-to-nurse ratios, and RN educational preparation. Participants reported the following:

1. Most (95%) reported that they usually or always ensure nursing staff levels to minimize incidence of CLI.
2. The mean patient-to-RN ratio on the day shift was 3.1 patients per RN.
3. One hundred percent of responding BMT centers employed RNs to perform direct patient care.
4. Only 4 BMT centers employed LPNs.
5. Just over half of BMT centers, 57%, employed NAs; the mean patient-to-NA ratio on the day shift was 8.4 patients per NA.
6. The percent of RNs who were bachelor's-prepared ranged from 0 - 100%, with a mean of 62%.

Use of mid-level providers. Most participants, 84.7%, reported using mid-level providers in their BMT centers. Of those who use mid-level providers, 57.6% use clinical nurse specialists, 55.9% use nurse practitioners, and 28.8% use physicians' assistants.

Section B - Surveillance

Questions in Section B relate to the methods used to measure rates of CLI and to the types of CLI reported by participating BMT centers. Eight participants left this section blank. Of the 52 who responded to the questions:

1. Twenty-four participants reported either rates or numbers of CLI for 2005.
    a. Five reported zero CLI in 2005.
    b. Nine reported CLI in 2005 as CLIs per 1000 catheter days.

    c. Ten reported CLI in 2005 as the number of CLIs diagnosed.

2. Twenty-eight reported that CLI rates for 2005 were not available.
3. Most CLIs reported were either catheter associated bloodstream infections (CABSI) or catheter related bloodstream infections (CRBSI) (19 participants); the remainder were exit site infections (2 participants), and unspecified CLI (5 participants).

Section C - BMT Center Demographics

Questions in Section C refer to a breakdown of types of transplants and ages of patients and not to practice patterns among the participants.

Section D - Catheter Insertion, Removal, and Days in Place

Catheter insertion. Participants reported that CVC insertion occurred, in their facilities, in radiology (46 participants), in the operating room (39 participants), at the bedside (23 participants) and in settings external to the BMT facility (1 participant). Participants were asked to select, from a list of protective barriers, those items used at their BMT facilities during CVC insertion. Of the five CDC-recommended protective barriers included in the list, on average participants reported use of 95% for CVC insertion in the operating room, 92% for CVC insertion in radiology, and 83% for CVC insertion at the bedside.

Catheter removal criteria. Data were not collected as to the number of CVCs inserted per patient or per transplant, but it is reasonable to estimate that each transplant represents one patient with at least one CVC. The total number of transplants performed by the 60 participants in the year 2005 was 3,817.

Participants were asked to list the criteria they used in deciding when to remove CVCs. Forty-nine of the 60 participants (82%) listed criteria they use for CVC removal; 11 (18%) did not. The participants who listed criteria for CVC removal performed 76% of the total transplants performed by participants in the study in 2005. Twenty-nine participants (59%) cited infections and/or positive blood cultures; 19 (39%) cited infections nonresponsive to antibiotics; 14 (29%) cited end of treatment; 10 (20%) cited platelet engraftment, and 8 (16%) cited transfusion independence as criteria for CVC removal. These data suggest a trend for looking at CVC removal as a reactive response to infection rather than a proactive planned step in the treatment trajectory.

Catheter dwell time. Participants were asked to report the average number of days the CVC remains in place for seven types of BMT. Most reported ranges rather than average numbers of days. Ranges of catheter dwell time reported for the different BMT types were from 14 to 365 days.

Section E - Catheter Site and Catheter Care

Use of prophylactic anticoagulants. Thirty-four participants reported using prophylactic anticoagulants, but only 14 (23%) reported that they usually or always use them. The anticoagulants most frequently reported were Coumadin and heparin.

Use of preparations for skin antisepsis. The survey listed four different products for skin antisepsis with a 5-point likert-type scale for frequency of use during CVC insertion and CVC dressing changes. Eighty-four percent of participants reported usually or always using chlorhexidine during CVC insertion, and 95% reported usually or always using chlorhexidine during dressing changes. Only 7 - 27% of participants reported usually or always using tincture of iodine, iodophor, or 70% alcohol during these procedures.

Ninety- eight percent of participants reported that they usually or always allow the antiseptic to air dry before inserting the catheter or applying the dressing. Of those who use an iodophor for skin antisepsis, 68.8% reported that they allow the iodophor to remain on the skin for at least 2 minutes or longer if needed to dry.

Section F - Practices Which Help to Prevent Central Line Infections

This section contained only one question, an open-ended question asking participants to list the six most important things they do to prevent CLI. Participants' responses to this question were not analyzed. A content analysis of these data was beyond the scope of this study but is a subject for future research.

Self-reported Practice Patterns for Prevention of CLI

Participants' responses to BMT LIFE survey questions varied. Six practice patterns emerged.

Healthcare worker education was focused more on CVC maintenance than on CVC insertion; more emphasis was placed on providing education about, and assessing knowledge of, CVC guidelines than on assessing use of CVC guidelines.

Participants reported, generally, that their nursing staff levels were appropriate to prevent CLI. RNs were used much more than LPNs or NAs, but only two-thirds of the RNs were bachelor's prepared. Most participants reported using mid-level providers, with NPs and CNSs more prevalent than PAs.

The high percentage of participant involvement in education programs to prevent CLI in BMT patients is in stark contrast to the lack of participants' knowledge of the rates of CLI in their BMT facilities. While about half of the participants reported that CLI rates or numbers were not available for their BMT unit, only 15% of the participants reported actual rates of CLI per 1000 catheter days.

Use of recommended barrier precautions during insertion of CVCs was higher in the operating room and in radiology and lower during insertion at the bedside. Criteria reported most frequently by participants for removal of CVCs were line infection or malfunction, as opposed to protocols for planned prompt removal.

About half of the participants reported that they routinely use Coumadin and/or heparin to prevent catheter-associated thrombosis.

Most participants reported using 2% chlorhexidine for skin antisepsis, with about 14% more using it for CVC dressing changes than for CVC insertion.

Aim Two: Determine the Level of Self-reported Use of the Pis in the 2002 CDC Guidelines Among Participating US BMT Centers

Level of use of each PI was calculated. The means of the four PI scores were then summed to create an Overall Mean Use-Total (OMU-T) level for each participant and for the participants as a whole, and the standard deviation for OMU-T was calculated.

PI 1 - Educating Healthcare Workers (API I - EHW)

The first CDC (2002a) PI recommends, "...implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters" (p. 14). Two separate CDC recommendations address this PI and specify content, methods, and assessments to be included in educational programs.

Four BMT LIFE survey questions relate to PI 1. Each of the four questions has multiple items, with a total of 10 items, asking participants to report the frequency with which they included specific content, didactic methods, and assessments in the educational programs used in their BMT centers. Possible answers on these rating-scale questions ranged from Never (0 points) to Always (4 points). All participants' responses are summarized in Table 19. Participants' responses were included in the computation of OMU-T only if they responded to at least 7 of the 10 items. Mean use of PI 1 was 3.36 (Sd = .587), on a 4-point scale, indicating that participants self-reported using most of the staff education guidelines recommended by the CDC for prevention of CLI.

PI 2- Maximal Sterile Barriers (API 2 - MSB)

For PI 2, the CDC (2002a) recommends "...use of maximal sterile barrier precautions during catheter placement" (p. 14). Specifically, the CDC lists "...the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet..." (p. 20) in the guidelines for insertion of CVCs.

Four questions in the BMT LIFE survey deal with the use of maximal sterile barriers during line insertion. The questions use a multiple answer response format with five correct responses and two distracters. Each question pertains to a different setting in which CVCs may be inserted - at the bedside, in the operating room, in radiology, and other. Only 2 participants identified other settings, so no statistics were computed on other settings. Because some participants identified only one setting and other

Table 19. *Participant Responses to BMT LIFE Survey Questions About Performance Indicator I - Education of Healthcare Workers*

BMT LIFE Survey Questions A. 1-4		Statistics			
1. We educate healthcare workers about:		Minimum	Maximum	Mean	Std. Deviation
a.	Indications for central vascular catheters (CVCs) (n = 60)	0	4	3.65	.755
b.	Proper CVC insertion (n = 57)	0	4	2.88	1.465
c.	Proper CVC maintenance (n = 60)	3	4	3.95	.220
d.	Prevention of central line infections (n = 60)	2	4	3.87	.389
2. Our education of healthcare workers includes:					
a.	Didactic (lecture) instruction (n = 60)	0	4	3.45	.928
b.	Interactive (hands-on) teaching (n = 60)	2	4	3.73	.482
3. We periodically (at regularly scheduled times) assess knowledge of CVC guidelines:					
a.	For all persons who insert CVCs (n = 52)	0	4	2.38	1.586
	For all persons who maintain CVCs (n = 60	0	4	3.52	.873
4. We periodically assess usage to CVC guidelines:					
a.	For all persons who insert CVCs (n = 51)	0	4	2.35	1.683
b.	For all persons who maintain CVCs (n = 59)	0	4	3.32	1.121

participants identified multiple settings in which they insert CVCs, scores for all settings identified were averaged for each BMT center. Possible scores were from 0 (no CDC-specified sterile barriers selected from a list) to 5 (all five CDC-specified sterile barriers selected from a list). All participants' responses are summarized in Table 20. Only the CDC-specified sterile barriers were included in the computation of scores and in Table 20. Participants' responses were included in the computation of OMU-PI 2 and OMU-T only if they responded to at least one of the four questions. On a 5-point scale, mean use of PI 2 was 4.54 (Sd = .618), indicating participants self-reported they used a majority of the CDC-recommended sterile barrier precautions during CVC insertion. Mean use was highest when CVCs were inserted in the operating room (4.75, Sd = .495), next highest for insertions performed in radiology (4.58, Sd = .698), and lowest for insertions performed at the bedside (4.17, Sd = 1.029). Figure 4 shows the percent of participants who self-reported use of each of the 5 CDC-recommended sterile barrier items when line insertions were performed in each of the 3 settings.

PI 3 - 2% Chlorhexidine for Skin Antisepsis (API 3 - 2%C)

The third CDC (2002a) PI simply reads, "...use of chlorhexidine for skin antisepsis..." (p. 14). The recommendation pertaining to skin antisepsis more specifically states that skin is to be disinfected prior to catheter insertion and during dressing changes and that "a 2% chlorhexidine-based preparation is preferred..." (p. 16).

Two rating scale questions in the BMT LIFE survey ask participants to report the frequency with which they used a ***2%*** chlorhexidine-based preparation for skin antisepsis. Possible scores ranged from 0 points (Never) to 4 points (Always). The questions refer to skin antisepsis (a) prior to catheter insertion and (b) during dressing changes.

Table 20. *Participant Responses to BMT LIFE Survey Questions About Performance Indicator 2 - Use of Maximal Sterile Barriers*

BMT LIFE Survey Questions D. 1-3

	Cap	Mask	Sterile Gown	Sterile Gloves	Large Sterile Sheet
1. During insertion of CVCs at the *bedside* (n = 23), we use aseptic technique, including the use of a:					
No	8 (35%)	1 (4%)	2 (9%)	0	8 (35%)
Yes	15 (65%)	22 (96%)	21 (91%)	23 (100%)	15 (65%)
2. During insertion of CVCs in the *radiology* (n = 43), we use aseptic technique, including the use of a:					
No	3 (7%)	3 (7%)	1 (2%)	2 (5%)	9 (21%)
Yes	40 (93%)	40 (93%)	42 (98%)	41 (95%)	34 (79%)
3 During insertion of CVCs in *operating room* (n = 37), we use aseptic technique, including the use of a:					
No	1 (3%)	0	0	0	8 (22%)
Yes	36 (97%)	37 (100%)	37 (100%)	37 (100%)	29 (78%)

Note: Only the five CDC-specified sterile barriers were included in the analysis shown in this table.
Abbreviation: CVC = central vascular catheter

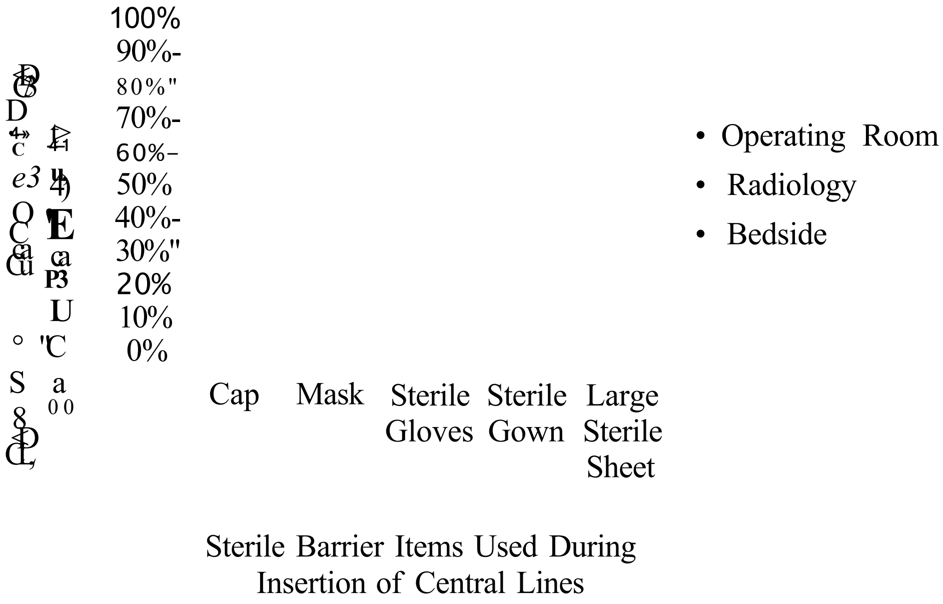


Figure 4. Percent of participants who self-reported use of each of the five CDC-recommended sterile barrier items when line insertions were performed in the operating room, in radiology, and at the patient's bedside.

Participants' responses were included in the calculation of overall mean usage (OMU-PI 3 and OMU-T) only if they responded to at least one of the two questions. Mean use of PI 3 was 3.61 (Sd = .864) out of a possible 4 points, indicating that, on the whole, participants self-reported a relatively high level of use of the CDC's recommendation to use 2% chlorhexidine for skin antisepsis. The level of mean use of chlorhexidine was higher for use during dressing changes (3.75, Sd = .795) than for use before catheter insertion (3.39, Sd = 1.201). A one-sample *t* test was conducted to evaluate whether the two means were significantly different from the total mean usage (3.61) for PI 3. The test showed no significant difference between OMU-PI 3 (3.61) and either chlorhexidine use during dressing changes (3.75, p = .178) or chlorhexidine use before catheter insertion (3.39, p = .201). However, significant differences in means were found when t tests were conducted comparing chlorhexidine use before insertion to chlorhexidine use during dressing change (?[50] = -2.127,/? = .038), and then comparing chlorhexidine use during dressing change to chlorhexidine use before insertion (?[59] = 3.509, p = .001).

PI 4 - Discontinuing Catheters (API 4 - DC)

This CDC (2002a) PI specifies "...rates of catheter discontinuation when the catheter is no longer essential for medical management" (p. 14). The CDC recommendation addressing catheter discontinuation states, "Promptly remove any intravascular catheter that is no longer essential" (p. 16).

One open-ended BMT LIFE survey question addressed PI 4 and asked participants to report the criteria they use in deciding when to remove a CVC. Three full-page lines were provided for answer(s). Points were given as follows:

1. 1 point for answers including reference to one essential use of a CVC, evidence that the line is no longer needed, or reference to a schedule for CVC removal
2. 2 points for answers including references to two or more of the above concepts
3. 3 points (total) for answers including both the concept of essential uses of a CVC and the concept of early or prompt removal of the CVC.

Essential uses of a CVC were defined as frequent infusions (blood products, antibiotics, parenteral nutrition, IV fluids, chemotherapy, etc.), and frequent lab draws. Evidence of no longer needing the CVC included platelet engraftment, white blood cell count recovery, clinical stability of patient, minimal use of the line, etc. Reference to a schedule for CVC removal included end of treatment, number of days since insertion, etc. In all, 34 (57%) participants listed essential uses of a CVC, evidence of not needing the line, or reference to a schedule for CVC removal. Prompt or timely removal of the CVC was indicated by inclusion of terms such as early, prompt, timely, as soon as possible,

Participant responses to this open-ended question demonstrated a lower level of use of PI 4 than participant responses indicated to any of the other Pis. Forty-nine participants listed criteria for line removal; 11 gave no response. Of the 49 who responded, 14 listed criteria which were not related to either a need for the line or to prompt removal of the line. Most of these participants listed reasons related to line infection or malfunction. Scores ranged from 0 to 3, with a mean of 1.06 (*SD* = .827), suggesting that, in making decisions about when to remove CVCs, less than half of the participants reported that they considered the two CDC-recommended criteria, essential use and prompt removal of CVCs.

Overall Mean Use-Total

An Overall Mean Use-Total (OMU-T) level was computed, as previously described. OMU-T levels ranged from 8.6 to 15.10 with a mean of 12.62 *(SD* = 1.493) out of 16 points possible. These data indicate that the majority of participants reported use of some or all of the CDC recommendations related to the four Pis in the CDC guidelines.

Aim Three: Determine Which Factors Are Associated With Self-reported Use of the Pis

To investigate issues of multicollinearity, correlation tests were conducted between all the independent variables (including the demographic and organizational factors as well as the practice factors). Spearman correlations were used because the sample was not random, the sample size was small, and the data were not normally distributed. For each bivariate correlation test, pairwise deletion of variables with missing data was used.

Demographic and organizational factors were:

1. Type of transplant unit (pediatric, adult, or combined pediatric and adult)
2. Type(s) of transplants performed (autologous only or autologous and allogeneic)
3. Years in practice
4. Total transplants performed to 2005

Type(s) of transplant was dummy-coded into three variables. Pediatric BMT centers were dummy-coded as 0 for no and 1 for yes. Adult BMT centers and combined BMT centers were similarly coded.

Type(s) of transplants performed was also dummy-coded as 0 for BMT centers performing autologous transplants only and 1 for BMT centers performing both autologous and allogeneic transplants.

Practice factors were:

1. Ensuring appropriate nursing staff levels to minimize incidence of CLIs
2. Designation of trained personnel to insert CVCs
3. Designation of trained personnel to maintain CVCs

4. Designation of trained personnel to supervise CVC insertion trainees
5. Use of routine prophylactic anticoagulants
6. Number of patients per RN during the day shift
7. Percent of RNs who are bachelor's prepared
8. Use of midlevel providers - CNS
9. Use of midlevel providers - NP
10. Use of midlevel providers - PA
11. Availability of CLI data for the BMT unit

Practice factors 1-5 were each scored on a 5-point likert-type scale (0 = never; 4 = always). Practice factors 6-7 were continuous variables. Practice factors 8-11 were each dummy-coded as 0 for no and 1 for yes.

Three demographic and organizational factors were significantly correlated with each other. Years in practice and total transplants performed to 2005 were significantly correlated ($r = .636$, $p < .01$). In addition, both years in practice and total transplants performed were significantly correlated with type(s) of transplants performed ($r = .596$, $p < 0.01$, and $r = .555$, $p < 0.01$, respectively).

Several practice factors were also significantly correlated with each other but no factors were correlated highly enough to pose a threat of multicollinearity (see Table 21). Multicollinearity is diagnosed when correlations between variables are >0.85 (Munro, 1997).

Next, to identify factors associated with the dependent variables, Spearman correlation tests were conducted between the independent and dependent variables (Table 22). Because of the high number of statistical comparisons consideration was given to

Table 21. *Speannan Correlations Among All the Factors (Independent Variables)*

DEMOGRAPHIC AND ORGANIZATIONAL FACTORS									10		12	13	14	15	16	17	18
1. TYPE OF BMT UNIT: PEDIATRIC	1.000																	
2. TYPE OF BMT UNIT: ADULT	.474**	1.000																
3. TYPE OF BMT UNIT: COMBINED PEDIATRIC AND ACULT	-.323*	,681**	1.000															
4. YEARS IN PRACTICE	.211	-.279*	.124	1.000														
5. TYPE(S) OF TRANSPLANTS PERFORMED: AUTOLOGOUS ONLY OR AUTOLOGOUS AND ALLOGENEIC	.249	,526**	.358**	.596**	1.000													
6. TOTAL TRANSPLANTS	-.088	-.239	.330*	.636**	,555**	1.000												
PRACTICE FACTORS																		
7. ENSURE APPROPRIATE STAFF LEVELS	.006	.081	-.092	.097	.047	.101	1.000											
8. RNS	-.073	.122	-.070	-.114	-.224	-.247	-.148	1.000										
9. TRAINED PERSONS INSERT CVCS	-.122	.088	.012	.294*	.129	.135	-.005	-.055	1.000									
10. TRAINED PERSONS MAINTAIN CVCS	-.025	.015	.005	.010	-.136	-.094	.278*	.112	.060	1.000								
11. TRAINED PERSONS SUPERVISE	-.104	-.139	.238	.385**	.308*	.275*	.142	-.060	.379**	.232	1.000							
12. % BSN PREPARED RNS	.134	-.269	.181	.273	.352*	.319*	.050	-.047	.137	.333*	.138	1.000						
13. MID-LEVEL PROVIDERS - NO/YES	.203	.337**	.192	.209	343**	.321*	.-.049	.080	-.142	.066	-.032	.325*	1.000					
14. CNS EMPLOYED IN UNIT	.058	-.117	.077	.171	.123	.010	.036	.321*	.054	.111	.155	.150	495**	1.000				
15. NP EMPLOYED IN UNIT	-.013	-.288*	.319*	-.023	.187	.313*	-.146	-.029	.042	-.023	-.159	.287*	.478**	.068	1.000			
16. PA EMPLOYED IN UNIT	-.208	-.027	.202	.200	.248	.347**	-.023	-.186	.123	-.052	.247	.175	.270*	1.091	.112	1.000		
17. ROUTINE ANTICOAGULANTS USED	.220	-.248	.082	.062	.134	.126	-.294*	-.052	-.118	-.204.	-.025	.042	.153	.008	.066	-.074	1.000	
18. CLI DATA AVAILABLE TO UNIT	.033	.350*	-.399**	-.157	-.317*	-.402**	.036	-.074	.076	.048	-.203	-.023	-.087	.125	-.181	-.283*	-.211	1.000

* $p < 0.05$; ** $p < 0.01$; Note: Numbers on the top line of the table correspond to the numbers of the factors listed in the first column.

Table 22. *Spearman Correlations Between the Independent Variables (Demographic and Organizational Factors and Practice Factors) and the Dependent Variables (Use of the Four Performance Indicators and Overall Mean Use-Total)*

	USE OF PERFORMANCE INDICATOR 1	USE OF PERFORMANCE INDICATOR 2	USE OF PERFORMANCE INDICATOR 3	USE OF PERFORMANCE INDICATOR 4	USE OF ALL FOUR PERFORMANCE INDICATORS
	EDUCATING HEALTHCARE WORKERS	USE OF MAXIMAL STERILE BARRIERS	USE OF 2% CHLORHEXIDINE FOR SKIN ANTISEPSIS	CRITERIA FOR DISCONTINUEG CATHETERS	OVERALL MEAN USAGE-TOTAL
INDEPENDENT VARIABLES: DEMOGRAPHIC AND ORGANIZATIONAL FACTORS					
TYPE OF UNIT - PEDIATRIC	.210	-.009	-.091	-.004	.080
TYPE OF UNIT - ADULT	-.099	.078	.207	-.042	-.025
TYPE OF UNIT - COMBINED	-.069	-.075	-.146	.046	-.039
TYPE(S) OF TRANSPLANTS PERFORMED: AUTOLOGOUS ONLY OR AUTOLOGOUS AND ALLOGENEIC	.281*	-.008	-.090	.004	.229
YEARS IN PRACTICE	.280*	.315*	.174	-.075	.365**
TOTAL TRANSPLANTS IN 2005	.033	.048	-.051	.062	.089
INDEPENDENT VARIABLES: PRACTICE FACTORS					
ENSURE APPROPRIATE STAFF LEVELS	.356**	-.029	.121	.057	.247
NUMBER OF PATIENTS PER RNS	-.071	-.030	.223	-.129	.007
TRAINED PERSONS INSERT CVCS	.187	-.030	-.049	-.160	.030
TRAINED PERSONS MAINTAIN CVCS	.263*	-.198	.340**	-.166	.106
TRAINED PERSONS SUPERVISE	.369**	-.188	.181	-.081	.219
% BSN PREPARED RNS	.170	-.069	.094	.040	.211
USE OF MID-LEVEL PROVIDERS	-.014	.097	.004	-.032	.089
CNS EMPLOYED IN UNIT	.208	.065	.138	-.092	.212
NP EMPLOYED IN UNIT	-.118	-.060	-.138	.079	-.082
PA EMPLOYED IN UNIT	-.327*	-.031	-.167	.198	-.121
ROUTINE ANTICOAGULANTS USED	-.155	-.149	-.172	.046	-.142
CLI DATA AVAILABLE TO UNIT	.134	.165	.040	.107	.162

* $p < 0.05$; ** $p<0.01$

correcting the significance level by using a Bonferroni approach. However, given the exploratory nature of this study, the decision was made to report the results without correction and to acknowledge the multiple comparisons as a possible risk for making a Type I error.

Dependent variables were:

1. Use of PI 1 - Educating Healthcare Workers (API 1 - EHW)
2. Use of PI 2 - Use of Maximal Sterile Barriers (API 2 - MSB)
3. Use of PI 3 - Use of 2% Chlorhexidine (API 3 - *2%C)*
4. Use of PI 4 - Discontinuing Catheters (API 4 - DC)
5. Overall Mean Usage-Total to the Pis - (OMU-T)

Two demographic and organizational factors (years in practice and type[s] of transplants performed) and four practice factors (ensuring appropriate nursing staff levels, designating trained personnel to maintain CVCs, designating trained CVC personnel to supervise CVC insertion trainees, and using mid-level providers - PAs) were significantly associated with one or more of the dependent variables.

Separate linear regression analyses were conducted to predict the level of use of each of the five dependent variables and to evaluate the contribution of each of the six factors identified above as factors associated with use of one or more of the Pis. Because the study was exploratory, the investigator did not know which variables would result in the best model, so the stepwise method of variable entry was used. Criteria for stepwise entry and removal of IVs in all regression analyses in this study were set at p 0.15 and p 0.20, respectively. Listwise deletion of cases with missing data was used in all regression analyses. Results of the regression analyses are described below and shown in Table 23.

Table 23. *Multiple Linear Regression of the Significantly Related Independent Variables on the Four CDC Performance Indicators (Pis) and Overall Mean Use-Total (OMU-T)*

Performance Indicators and Variables	**P**	SE	**SO)**	R^2	*F*
USE OF PI 1 - EDUCATING HEALTHCARE WORKERS					
Designating Trained CVC Personnel to Perform CVC Maintenance	.203	.062	.335	.170	10.652**
Type(s) of Transplants Performed	.435	.140	.329	.310	11.473***
Using Mid-Level Providers - PA	-.456	.021	-.391	.409	11.524***
Designating trained CVC Personnel to Supervise CVC Insertion Trainees	.106	.037	.299	.488	11.677***
Ensuring Appropriate Staffing Levels	.160	.068	.237	.541	11.306***
USE OF PI 2 - MAXIMAL STERILE BARRIERS					
Years in Practice	.032	.014	.322	.104	5.776*
USE OF PI 3 - 2% CHLORHEXIDINE					
Designating Trained CVC Personnel to Perform CVC Maintenance	.273	.132	.268	.075	4.224*
Years in Practice	.041	.020	.267	.146	4.367*
OVERALL MEAN USE-TOTAL					
Years in Practice	.035	.010	.408	.172	10.769**
Designating Trained CVC Personnel to Perform CVC Maintenance	.161	.070	.279	.249	8.462*

$^*p < 0.05$; $^{**} p < 0.01$; $^{***} p < 0.001$

(3 = Unstandardized Coefficients; SE = Standard Error; S (|3) = Standardized Coefficients; R^2 = R Square; *F* = *F* Test

Use of PI 1 - Educating Healthcare Workers

Multiple linear regression analysis was conducted to identify associations of IVs with use of PI 1. The six factors (type[s] of transplants performed, years in practice, ensuring appropriate nurse staffing levels, designating trained CVC personnel to maintain CVCs, designating trained CVC personnel to supervise CVC insertion trainees, and using mid-level providers who are PAs) were entered simultaneously.

The fifth stepwise iteration in this analysis produced the most parsimonious model (Table 23) and retained five factors/IVs that were significantly associated with the DV. One demographic and organizational factor, type(s) of transplants performed, accounted for 14.0% ($p < 0.01$) of the variance in level of use of PI 1. Four practice factors accounted for a combined 40.1% of the variance in level of use of PI 1, over and above the strength of the association of the demographic and organizational factor with use of PI 1.

Contributions of individual variables were (a) designating trained CVC personnel for maintenance of CVCs - 17.0% ($p < 0.01$), (b) type(s) of transplants performed - 14.0% ($p < 0.01$), (c) use of mid-level providers who are PAs - 9.9% ($p < 0.01$), (d) designating trained CVC personnel to supervise CVC insertion trainees - 7.9% ($p < 0.01$), and (e) ensuring appropriate nurse staffing levels to minimize incidence of CLIs - 5.3% ($p < 0.05$). Participants who reported higher levels of use of PI 1 were more likely to (a) designate trained CVC personnel for CVC maintenance, (b) designate trained CVC personnel for supervision of CVC insertion trainees, (c) ensure appropriate nursing staff levels, and (d) perform allogeneic as well as autologous transplants. Participants who reported lower levels of use of PI 1were more likely to report use of mid-level providers who were PAs.

Use of PI 2 - Use of Maximal Sterile Barriers During Insertion of CVCs

Multiple linear regression analysis was conducted to identify factors associated with use of PI 2. The same six factors used in the regression analysis for PI 1 were again entered simultaneously.

Years in practice was the only factor significantly correlated with use of PI 2 ($r = .322, p = .010$). Years in practice was associated with a 10.4% variance in use of PI 2 ($p < 0.05$). Participants who reported higher levels of use of PI 2 had more years in practice. (See Table 23.)

Use of PI 3 - Use of Chlorhexadine for Skin Antisepsis

A third multiple linear regression analysis was conducted to identify associations of IVs with use of PI 3. The six factors were again entered simultaneously.

Designating trained CVC personnel for maintenance of CVCs was significantly correlated with use of PI 3 ($r = .274, p = 0.022$). Years in practice was also significantly correlated with level of use of PI 3 ($r = .272, p = 0.023$). Together the two factors were associated with only 14.6% of the variance in use of PI 3 ($p < 0.05$).

Participants who reported higher levels of use of PI 3 also reported higher frequencies of designating trained CVC personnel for CVC maintenance and had more years in practice. (See Table 23.)

Use of PI 4 - Discontinuing CVCs When the CVC is No Longer Essential for Medical Management

A fourth multiple linear regression analysis was conducted to identify associations of IVs with use of PI 4. The six factors were again entered simultaneously. No factors were significantly correlated with PI 4.

Overall Mean Usage-Total

A final multiple linear regression analysis was conducted to identify IVs associated with Overall Mean Usage-Total (OMU-T). The six factors used in the first four analyses were again entered simultaneously.

Years in practice, or number of years performing BMTs, was significantly correlated with OMU-T (r = .414, $p < 0.001$). Years in practice was associated with 17.2% of the variance in OMU-T ($p < 0.01$). Over and above the strength of the association with years in practice, designating trained CVC personnel for CVC maintenance was associated with 7.8% of the variance in OMU-T ($r = .085, p < 0.05$).

Participants who reported higher levels of OMU-T had more years in practice and more frequently reported designating trained CVC personnel for CVC maintenance. (See Table 23.)

As previously described, following analysis of these data, p-values derived from the correlation tests between the IVs and the DVs used in the regression analyses were adjusted using the Bonferroni-Holm procedure for the effects of multiple comparisons. Table 24 shows the results.

Table 24. *Comparison of Raw p-Values and p-Values Adjusted by the Bonferroni-Holm Procedure for n = 6 Associations Between Performance Indicators and the Independent Variables*

Performance Indicators (Pis) and Independent Variables	p-Values	
	Raw	Using Bonferroni-Holm Procedure
Use of PI 1 - Educating Healthcare Workers		
Designating Trained CVC Personnel - Maintenance	0.001	**0.006**
Designating Trained CVC Personnel - Supervise Trainees	**0.004**	**0.020**
Ensuring Appropriate Nursing Staff Levels	**0.006**	**0.024**
Type(s) of Transplants Performed	**0.010**	**0.030**
Years in Practice	**0.018**	**0.036**
Using Mid-Level Providers - Physician Assistants	**0.020**	**0.036"**
Use of PI 2 - Maximal Sterile Barriers		
Years in Practice	**0.010**	0.060
Ensuring Appropriate Nursing Staff Levels	0.110	0.550
Designating Trained CVC Personnel - Supervise Trainees	**0.208**	0.832
Designating Trained CVC Personnel - Maintenance	0.353	>0.999
Type(s) of Transplants Performed	0.362	>0.999[a]
Using Mid-Level Providers - Physician Assistants	0.473	>0.999[a]
Use of PI 3 - 2% Chlorhexidine		
Designating Trained CVC Personnel - Maintenance	**0.022**	0.132
Years in Practice	**0.023**	0.132[a]
Designating Trained CVC Personnel - Supervise Trainees	0.058	0.232
Type(s) of Transplants Performed	0.116	0.348
Using Mid-Level Providers - Physician Assistants	0.430	0.860
Ensuring Appropriate Nursing Staff Levels	0.481	0.860[a]
Use of PI 4 - Discontinuing Catheters		
No Significant Associations		
Overall mean Use - Total		
Years in Practice	0.001	**0.006**
Designating Trained CVC Personnel - Maintenance	**0.018**	0.090
Type(s) of Transplants Performed	**0.022**	0.090[a]
Ensuring Appropriate Nursing Staff Levels	**0.036**	0.108
Designating Trained CVC Personnel - Supervise Trainees	**0.038**	0.108[a]
Using Mid-Level Providers - Physician Assistants	0.241	0.241

CVC = Central Vascular Catheter; bolded p-values are statistically significant

[a] - Note that this *p-v*alue is given the same value as the one just preceding it to maintain the rule of sequentially rejective levels of decreasing or identical significance explained by Ludbrook (1998).

Aim Four: Describe Self-Reported Incidence Rates of CLI in Participating US BMT Centers

Only 14 BMT centers reported CLIs per 1000 catheter days, with the rate in five of those centers being 0.0. The other nine BMT center rates of CLI for 2005 ranged from 1.0 to 12.5 CLI per 1000 catheter days. CLI rates in the participating BMT centers fall within the ranges of CLI rates reported in the NNIS studies discussed in the literature review (CDC, 2001b; CDC, 2002b; CDC, 2003).

The BMT LIFE survey contained questions about numbers of CLIs during 2005, numbers and types of transplants performed during 2005 and average catheter dwell time for the different types of transplants performed during 2005. The intent was to collect data that would enable the PI to calculate rates of CLI for those who did not report their rates. However the reported catheter dwell times were mostly ranges rather than average times, so the data were imprecise, and no reliable rates could be calculated.

Descriptive statistics were computed on CLIs per 1000 catheter days, as reported by 14 participants. Results are shown in Figure 5. Thirty-eight participants reported that CLIs per 1000 catheter days were not available in their BMT centers; 8 participants left the question blank.

Summary of Results

Findings of the study indicate that practice patterns vary among participating BMT centers and that most participants have high levels of use of CDC-recommended guidelines for educating healthcare workers, using 2% chlorhexidine for skin antisepsis, and using maximal sterile barrier precautions during CVC insertions. On the other hand, most participants scored quite low on prompt removal of CVCs that are no longer essential.

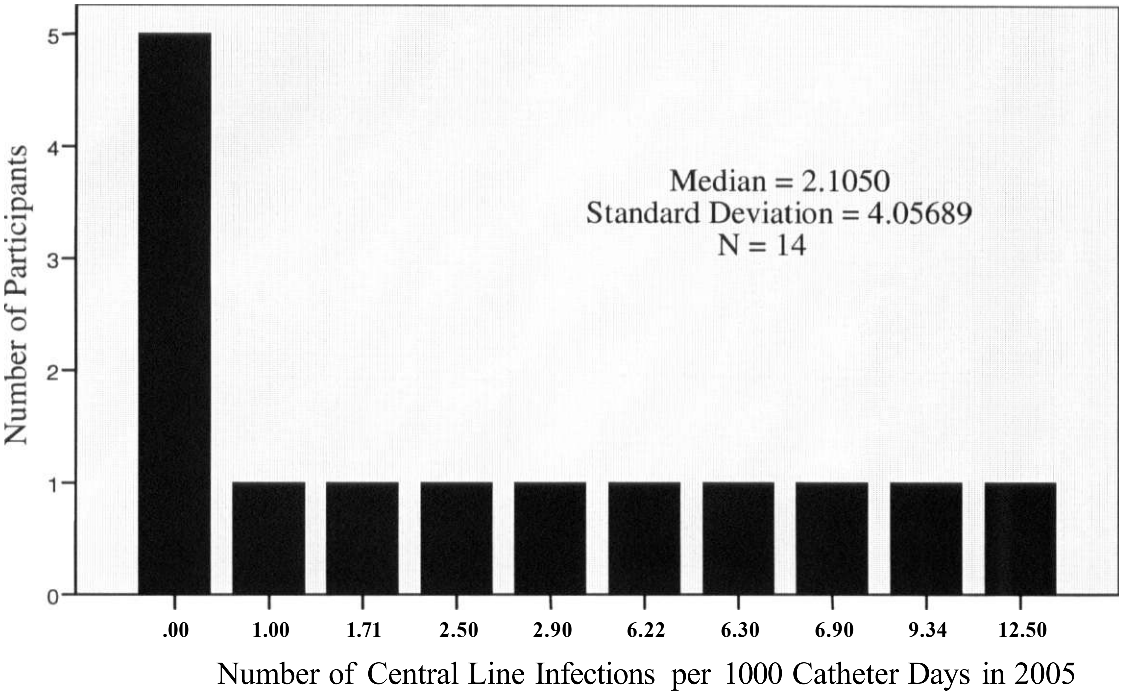


Figure 5. Bar chart showing frequencies of central line infections (CLIs) per 1000 catheter days reported for the year 2005 by 14 participants.

CHAPTER V

DISCUSSION

Study Findings

No published study has examined use of the four performance indicators in the CDC guidelines for prevention of CLI (2002a) in patients having a BMT. The present study is the first such report and indicates (a) that practice patterns for CLI prevention vary among participating BMT centers, (b) that overall self-reported levels of use of three out of four of the CDC Pis is generally high, (c) that factors associated with levels of use of the Pis included designating trained CVC personnel to supervise CVC insertion by trainees and to perform CVC maintenance, using mid-level providers who are PAs, ensuring appropriate nursing staff levels, types of transplants performed at a BMT center, and number of years in practice of a BMT center, and (d) that most participants could not or would not report CLI incidence rates for their BMT centers.

Study findings of interest, in the four areas listed above, are introduced briefly and then discussed in relation to the a priori conceptual model of infection prevention depicted in Figure 2. Emphasis is on the structures, processes and outcomes identified under Primary Prevention (Breaking the Chain of Transmission) and Secondary Prevention (Education and Early Detection).

Variations in Practice Patterns

Identifying variations in practice patterns is informative and helpful in two particular ways. First, practice variations suggest differences in healthcare workers' (a) knowledge of organizational policies and procedures, (b) familiarity with current evidence-based practice guidelines, and (c) perceptions of the severity of the benefits and risks to patients when policies and guidelines are followed or not followed. Second, variations in practice patterns for CLI prevention provide (a) indicators of the quality of patient care in BMT centers and (b) targets for performance improvement (Davis, Localio, Stafford, Helfaer, & Durbin, 2005; Link et al., 2001; Solberg, Kottke, & Brekke, 2001).

In the present study, three notable variations in practice patterns emerged from the data. They relate to nursing staff education, CVC insertion, and skin antisepsis. The CDC guidelines provide a significant and readily available resource, as part of the external structure for preventing CLI, and they give explicit directions for processes dealing with each of the following practice variations identified in this study.

First, by far the majority of participants reported they usually or always perform nursing staff education using the methods and topics recommended by the CDC. However, about one-tenth of participants reported they rarely or never teach proper insertion procedures and they rarely or never assess usage to CVC guidelines for those who insert and those who maintain CVCs.

Second, participants reported that almost all of the time CVC insertion personnel use four of the five CDC-recommended sterile barrier precautions for CVC insertions in the operating room and in radiology and only three of five for insertions at the bedside.

This finding is surprising because one would expect that use of precautions would be standardized across insertion settings. Differences in sterile barriers used in the three settings may simply reflect differences in sterile supplies stocked in those settings.

Third, when answering the survey questions about the skin antisepsis products used at their BMT centers, most participants reported usually or always using chlorhexidine. Yet, nearly 20% also reported usually or always using one, two, or three other skin antisepsis products, as well as chlorhexidine. The practice of using multiple antisepsis products when performing dressing changes could potentially cause skin irritation and breakdown, putting the patient at greater risk for an exit site infection.

Levels of Use of the Pis

The preparers of the CDC guidelines (2002a) suggested that use of the Pis could be evaluated as a way of determining the impact of the guidelines. Some studies have demonstrated the effectiveness of instituting use of two of the four Pis - maximal sterile barrier precautions and chlorhexidine for skin antisepsis during CVC insertion - with impressive resultant decreases in CLI incidence rates (Berenholtz et al., 2004; Young, Commiskey, & Wilson, 2006). However, there are no comparative data in the literature on levels of use of all four Pis among BMT centers or in other populations. Using the BMT LIFE scale created for this study was an exploratory attempt to measure use of all four of the Pis in a vulnerable population.

Although usage scores for Pis 1-3 (educating and assessing staff knowledge and use of CVC guidelines, use of maximal sterile barrier precautions, and use of chlorhexidine) were quite high, scores for PI 4 (prompt removal of CVCs) were low, indicating that neither the Pis nor the CDC guidelines, as a whole, have been adopted by participating BMT centers.

Factors Associated with Use of the Pis

Two interesting and significant relationships emerged in response to this part of the study. They are as follows.

First, the investigator expected that both years in practice and total transplants performed to 2005 would be associated with use of the Pis because they are two different dimensions of the same latent construct - experience. However, experience over time had a stronger relationship with use levels than did experience with more patients. This suggests that it takes time for programs to assimilate evidence and translate it into practice and that healthcare workers become more likely to adopt and use guidelines as they receive more training and education over time.

Second, the significant negative association between use of PI 1 (Educating Healthcare Workers) and use of mid-level providers that are PAs was surprising. In general, PAs are seen and used primarily as physician extenders; they perform medical procedures. Roles of PAs, from the beginning, have been based on a medical model of provision of patient procedures and services, and more recently as substitutes for diminishing numbers of medical residents in teaching hospitals (Bowen, Torres, & Small, 2007; Druss, Marcus, Olfson, Tanielian, & Pincus, 2003; Riportella-Muller, Libby, & Kindig, 1995). While NPs and CNSs are also being used as substitutes for house staff in some settings, their additional and more traditional roles also include patient and staff education as well as monitoring use of clinical guidelines (Hoffman, Happ, Scharfenberg, DiVirgilio-Thomas, & Tasota, 2004; Hoffman, Tasota, Zullo, Scharfenberg, & Donahoe, 2005; Smith & Hall, 2003). A possible explanation for the negative association of PAs and PI 1 is that PAs may be used more often in BMT centers that are more aligned with a medical model of patient care, and CNSs and NPs may be used more often in BMT centers that place equal emphasis on medical and nursing care, including patient and staff education. A more credible explanation, however, may be that this is simply a spurious finding due to multiple statistical comparisons.

Use of multiple comparisons introduces the risk of making a Type I error. Table 24 shows a comparison of unadjusted versus adjusted p-values for associations between the six independent variables (IVs) and the Pis. Although using the Bonferroni-Holm procedure eliminated any statistically significant relationships between the six IVs and Pis 2 and 3, the six IVs still had statistically significant associations with PI 1, and one IV (years in practice) was still significantly associated with OMU. Therefore, it is reasonable to report a statistically significant association between the six IVs and PI 1 and between one IV (years in practice) and OMU. In addition, there may be other associations tending toward statistical significance.

The Bonferroni-Holm procedure has been reported in two previous studies using an analytic approach similar to the present study. In both of those studies, Pearson correlation p-values were adjusted using the sequentially rejective Bonferroni test, or Holm step-down adjustment procedure (Gordi, & Khamis, 2004; Ludbrook, 1998; Sankoh, Huque, & Dubey, 1997), to decrease the risk of making a Type I error. This procedure was followed by multiple linear regression analysis to control for the influence of demographic variables on the outcome variables, as in the present study (Baune et al. 2008; DiMonaco, DiMonaco, Manca, & Cavanna, 2002).

CLI Incidence Data

A truly significant and disappointing finding of this study was the report by the majority of participants that CLI data were not available for their BMT centers. Of course it is possible that some participants just did not want to report their CLI data.

Implications of the Study Findings

These findings suggest at least three distinct organizational problems - failure of healthcare worker education programs to produce change, low or inconsistent inter-disciplinary care coordination, and lack of availability of CLI incidence rates. These problems cannot be resolved at the bedside or within the BMT department alone; they require broader organizational attention.

Looking again at Figure 2, the conceptual model of infection prevention, the pathway to the desired outcome begins broadly in the external structures. In their study of performance measurement in a public health system, Handler, Issel, and Turnock (2001) widened the scope of Donabedian's model (1980) of structures, processes, and outcomes to begin, first, with the macro context (the social, economic, and political environment), then the organizational mission and purposes, and then the structures, processes, and outcomes. In addition, Mendez (1999) points out that when organizations try to introduce change beginning at the process level, they often fail. At the very least, then, changes must begin with a look at the organizational mission.

Fortunately, even in a depressed economic environment, the purposes of healthcare organizations generally reflect a mission to support and improve the health of the population they serve. Still, changes which reduce operating costs may be more favorably considered than changes which increase operating costs. The CDC's estimate of 250,000 cases of CLI annually in the U.S. at a cost to the health care system of $25,000 per episode results in a $6.25 billion annual price tag for CLIs (2002a). What could be more persuasive to a healthcare organization than a strategic plan to reduce or eliminate a health care facility's share of that cost! Within that context, what are the implications for internal structure and processes in BMT centers? What is the ultimate outcome of interest?

Education

Within the organizational structure, the education department and the BMT nurse educators must work together to strengthen the program of nursing staff education about prevention of CLI, by using effective teaching methods. Young, Commiskey, and Wilson (2006) found that mandatory education programs emphasizing barrier precautions and chlorhexidine did not result in exclusive use of those products at a large teaching hospital. It took removing CVC kits with small sterile sheets and povidone-iodine skin prep from the shelves and supplying only CVC kits with large sterile sheets and chlorhexidine skin prep to achieve the desired change in behavior. The result was a dramatic drop in the CVC-associated BSI rate from 11.3 to 3.7 BSI per 1000 catheter days.

Facilitating change is essential. Healthcare workers are generally willing to make changes that will improve outcomes of their patients, but changes that require additional time in gathering supplies are less likely to succeed. The process of education must be accompanied by appropriate structural changes that support new policies and procedures with easy access to recommended supplies. This process should include not only presentations of information but also assessment of staff knowledge of, and usage to, evidence-based CVC guidelines.

Performance Improvement

The present study's findings suggest there is a disconnect between education of staff and assessment of staff usage to CVC guidelines, demonstrating the need for improvement in practice. Numerous studies have shown that feedback is a significant factor in performance improvement. Two studies dealt with feedback to reduce CLI incidence rates. Berenholtz et al. (2004) reported eliminating CLI in an ICU in a large hospital. Over a 5-year study period they consistently used a checklist to monitor CVC insertion and to give feedback about breaks in sterile technique during the procedures. The checklist approach has the advantage of being less intimidating when giving face-to-face feedback because it is perceived as being less subjective. Young, Commiskey, and Wilson (2006) cited the benefits of using education and feedback to improve infection rates, but when they removed old CVC insertion kits from the shelves and only stocked kits which contained large drapes and chlorhexidine their CLI incidence rate dropped from 11.3 to 3.7 per 1000 catheter days.

In studies of other areas of performance improvement several kinds of feedback have been used. These include posting performance reports and rates of compliance internally (Rosenthal et al., 2003; Wallin et al., 2006); using competency-based on-the-job observations (Arco & duToit, 2006) and competency-based face-to-face feedback (Kalb et al., 2006); providing feedback based upon numbers of appropriate lab tests ordered (Larsen, Cannon, & Towner, 2003); and giving feedback in terms of decreasing numbers of UTI following education about handwashing prior to urinary catheter care (Rosenthal, Guzman, & Safdar, 2004).

Two studies (Schumacher, Stock, & Richards, 2003; & Wallin et al., 2006) found feedback to be a crucial part of implementing evidence-based practice, especially when it is linked to specific performance indicators or benchmarks. Swain et al. (2004), demonstrated improvement in organizational culture and employee morale, as well as work performance following institution of 360 degree feedback in a local health department. Feedback was given by managers, peers, and employees, rather than being limited to just the traditional top-down form of feedback. Use of 360 degree feedback tends to occur more as part of a developmental process than as a tool for performance appraisal.

In each of these studies, feedback added to educational instruction proved more effective in creating performance improvement than educational instruction without feedback. An integrated program of both formative (instructive) and summative (evaluative) performance feedback should include the use of performance indicators determined by the interdisciplinary BMT care team. Its success should be measured by periodic internal reports of CLI incidence rates for the BMT patients.

Interdisciplinary Team Coordination

Structurally, the BMT health care team should be interdisciplinary. The Agency for Healthcare Research and Quality (AHRQ, n.d.) recommends that team members should have specific responsibilities and that they should each know their teammates' responsibilities as well as they know their own. AHRQ further reports that teams, when they have been trained together and understand their responsibilities, make fewer errors than individuals do.

Processes and responsibilities of care team members should include finding and sharing evidence for effective methods of CLI prevention, advocating for prompt removal of catheters no longer essential for medical treatment, participating in staff education sessions regarding CLI prevention, overseeing coordination of care with regard to such things as standardizing use of recommended products for skin antisepsis and ensuring use of CVC insertion kits containing all five sterile barrier precautions recommended by the CDC, and reporting back to the whole team on individual areas of accountability.

In the present study, there was some difference between rates of chlorhexidine use during CVC insertion and during CVC dressing changes. Although the difference was small, it suggests a lack of communication and coordination among members of the interdisciplinary care team. Skin antisepsis in both procedures is a vital part of breaking the chain of transmission and preventing CLI. Protocols for prevention of CLI should be evidence based and consistent throughout the BMT facility and among all members of the care team. Trust among team members is essential to effective processes, and it can best be achieved when team members are accountable to each other and when they communicate effectively (Chou, Yano, McCoy, Willis, & Doebbeling, 2008).

For a care team to function optimally, all members must have specific roles to perform and accountability for performance of those roles. The prospective ICU cohort study described by Young et al. (2006), implemented five interventions to prevent CLI in CVCs inserted percutaneously over a 5-year period. One of the interventions included having a nurse complete a checklist during each catheter insertion to ensure usage to a standardized list of guidelines. This intervention created an expected dialogue between members of the care team regarding aseptic technique use during each CVC insertion. Nurses were charged to stop the procedure if guidelines were not followed and aseptic technique was broken. In the start-up phase of use of the check list, physicians were compliant 62% of the time, but that improved throughout the study, and CLIs were eliminated entirely. The on-going rate of violations of usage after completion of the study was reported to be 15-25%, but there were no catheter-related BSIs in over 9 months of follow-up. The key to that success was the consistent dialogue and double-checking between members of the care team with regard to their areas of responsibility and accountability (Berenholtz et al., 2004). Similarly, each member of a BMT care team should be charged to carry out and report back on specific duties known to reduce or eliminate CLI.

CLI Incidence Rates

The structure needed to track CLI rates in the BMT center resides in the infection control (IC) department. With today's computerization of records, it should not be difficult to create or modify a process that separates CLI data and tracks it by units in the healthcare facility. When a CLI is diagnosed, there could be a mechanism for reporting it automatically to IC where it would be tagged by a patient/unit identification so that it could be sorted by unit for statistical purposes.

Outcomes

Quality improvement (QI), in terms of improving patient safety, is a high priority in medical care today. The Agency for Healthcare Research and Quality (AHRQ) has developed patient safety indicators (PSIs) to be used to track outcomes of care, one of which is adoption of CLI prevention practice (Lacey, Smith, & Cox, n.d.). Lacey et al. identified characteristics of effective indicators, and the Pis in the present study possess those characteristics. They are scalable; they can be applied across all types of BMT units. They are feasible; staff would not be unduly burdened by data collection procedures. They are valid and reliable; their accuracy and consistency hold up over time. The Pis in this study also meet additional recommended qualifications of being inexpensive and free from subjective bias (Rivard, Rosen, & Carroll, 2006).

Weiner, Alexander, Baker, Shortell, and Becker (2006) found that support and participation of management, including the CEO and board, is essential to successful adoption of QI indicators, and that Ql operates best at the process level. Prospective processes of systemic education and implementation are more effective than retrospective correction of individuals.

The structures and processes related to education, to care teams, and to CLI incidence rates have a common outcome - to decrease CLI incidence rates. The processes recommended in the CDC Pis have been shown to be effective in improving patient outcomes by decreasing the incidence of CLI.

One major implication of the study findings relates to the make-up of the CDC Pis. At the end of the paragraph listing the Pis, the CDC publication stated, "The impact these recommendations will have on individual institutions should be evaluated using specific performance indicators" (p. 14). That would be true if the Pis included the recommendation to track rates and monitor trends of CLI. As the present study shows, measuring use of the Pis does not provide information about the effectiveness of the Pis. Tracking CLI rates should be PI 1.

Motivation for Change

The theory of planned behavior (TPB) has been used in attempts to motivate health care workers to adopt new patient care behaviors. In two studies physician, nurse, nursing assistant and other health care worker usage to hand hygiene guidelines ranged from 30 to 57% among participants (Pittet, Mourouga, & Perneger, 1999; Pittet et al., 2004). O'Boyle, Henly, and Larson (2001) reported 70% usage to hand hygiene recommendations, using a TPB-based model. Participating nurses completed a form indicating their level of motivation, their intent to follow guidelines, and a self report of their level of usage. Participant motivation levels predicted intention which, in turn, predicted self-reported usage. However, in their study, intent to handwash was not related to observed handwashing behavior. The investigators concluded that intensity of work, due to busy times of the shift and/or short staffing, predicted behavior more reliably than did internal motivation or intent.

Even the best motivation fails to bring about change when healthcare workers are short-staffed. Facilitating change requires providing appropriate resources including appropriate levels of nurse staffing. Tracking usage should include an on-going dialogue with healthcare workers about what hinders and what facilitates change and usage to new policies and not just an annual skills pass-off day.

External and internal structures for breaking the chain of transmission are in place by mandate of regulatory agencies, such as the Joint Commission on Accreditation of Healthcare Organizations. Implementing processes for assessing, assuring, and facilitating usage to policies and procedures specifically for decreasing rates of CLI in BMT patients is vital.

Research Implications

The conceptual model of infection prevention was used to guide this study. The question can certainly be asked, Do healthcare workers think about breaking the chain of transmission as a method of primary prevention when they are performing CVC care? A companion question might be, Are healthcare workers thinking about secondary prevention when they teach or attend staff education sessions or when they draw blood cultures from a patient with a high temperature and send them to the lab?

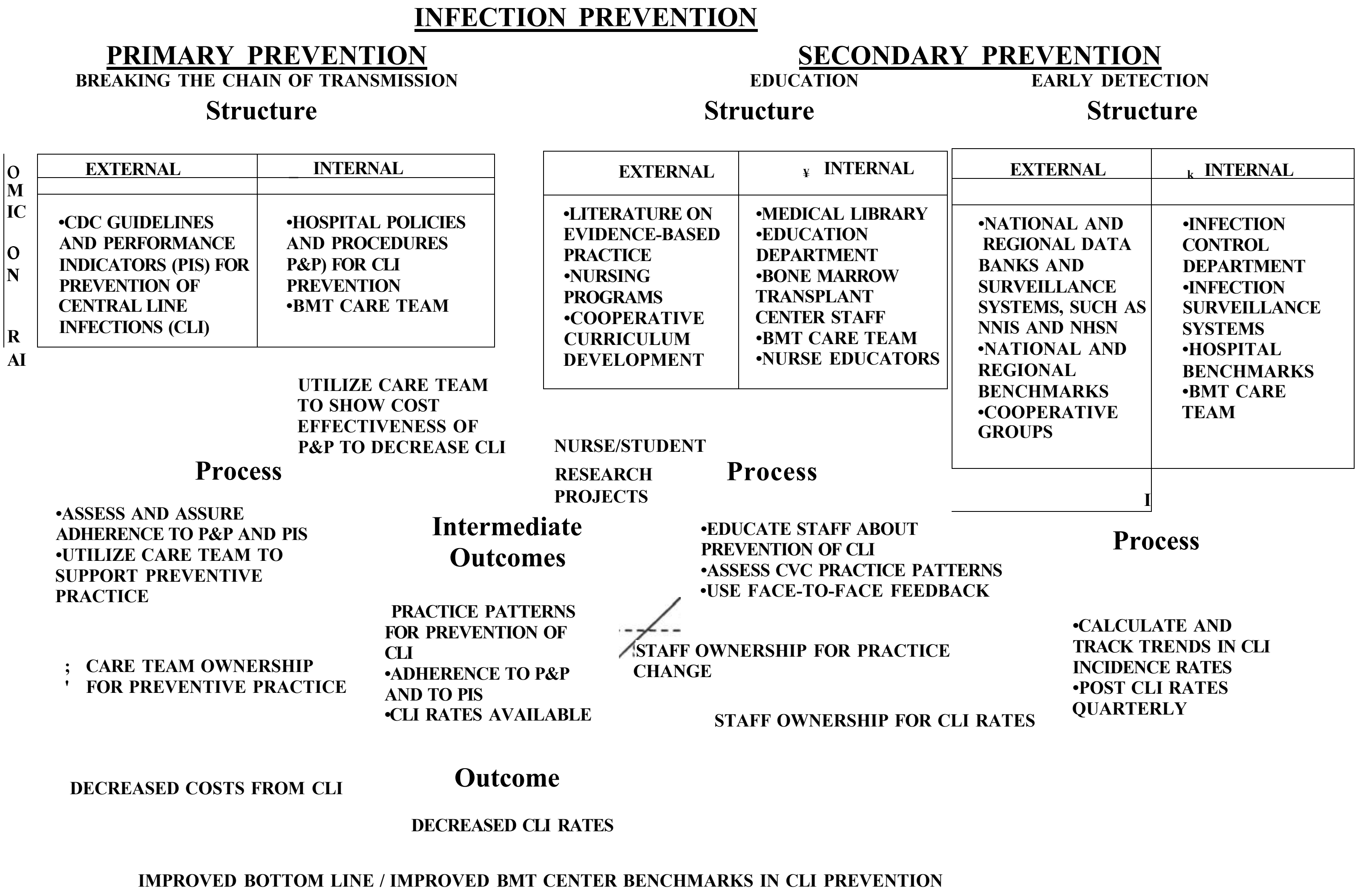
One of the questions in the BMT LIFE survey asked participants to list the six most important things they do to prevent CLI. This question produced some interesting data related to the things nurses believe to be helpful in CLI prevention. The Health Belief Model (HBM) would provide an appropriate conceptual model for a follow-up study to examine the relationship between practices the participants listed as important for prevention of CLI and their use of the CDC guidelines, specifically of the CDC Pis. A study using the HBM could examine effects of (a) healthcare workers' perceptions of patients' susceptibility to CLI, (b) their perceptions of the severity of the problem of CLI, (c) their perceptions of the benefits and costs of following guidelines for prevention of CLI, (d) their motivation to follow guidelines, and (e) factors that enable use of, or modify barriers to use of, guidelines (Becker, et al., 1978).

Studies using the HBM have typically examined issues of patient/consumer compliance with preventive or treatment regimens (Becker, et al., 1978; Marienga, 1995; Martinez, Gratton, Coggin, Rene, & Waller, 2004; Nahcivan & Secginli, 2007).

However, studies have also employed the HBM in examining effects of healthcare workers' beliefs on their use of preventive regimens in their provision of patient care (Brevidelli, & Cianciarullo, 2001; Canbulat, & Uzun, 2008; Tan, Goh, & Lee, 2006), but more studies are needed. There is some controversy about whether attitudes or knowledge of healthcare workers have more effect on their usage to standards of care (Hysong, Best, Pugh & Moor, 2005; Larme, & Pugh, 1998). A study of care providers' attitudes and beliefs about their roles in preventing CLI, relative to the CDC guidelines, could help identify ways of achieving increased use of the guidelines. Such research could inform QI interventions.

Moving to a broader focus, it is clear that research produces evidence-based healthcare practice guidelines more rapidly than those guidelines are adopted. It is estimated that only about half of patients in the US receive the healthcare that is recommended and supported by consensus guidelines (Krein et al., 2005). The problem lies not just at the point of care, but all through the structure and processes of the healthcare system. Figure 6 identifies points for research and practice improvement throughout the conceptual model of infection prevention used for the present study.

Future research related to translation of evidence-based guidelines into practice could focus on adoption of evidence-based preventive practices. A study of seven cases found components of Rogers's diffusion of innovation model in the studied cases (Peterson, Rogers, Cunningham-Sabo, and Davis, 2007). This model identifies five stages of diffusion leading to adoption of new interventions. Davis, Peterson, Helfrich, and Cunningham-Sabo (2007) cited use of Roger's model in a less studied area, diffusion



INFECTION PREVENTION

PRIMARY PREVENTION

BREAKING THE CHAIN OF TRANSMISSION

Structure

O
M
IC
O
N
R
AI

EXTERNAL	INTERNAL
•CDC GUIDELINES AND PERFORMANCE INDICATORS (PIS) FOR PREVENTION OF CENTRAL LINE INFECTIONS (CLI)	•HOSPITAL POLICIES AND PROCEDURES P&P) FOR CLI PREVENTION •BMT CARE TEAM

UTILIZE CARE TEAM TO SHOW COST EFFECTIVENESS OF P&P TO DECREASE CLI

Process

- ASSESS AND ASSURE ADHERENCE TO P&P AND PIS
- UTILIZE CARE TEAM TO SUPPORT PREVENTIVE PRACTICE

CARE TEAM OWNERSHIP FOR PREVENTIVE PRACTICE

DECREASED COSTS FROM CLI

SECONDARY PREVENTION

EDUCATION

Structure

EXTERNAL	INTERNAL
•LITERATURE ON EVIDENCE-BASED PRACTICE •NURSING PROGRAMS •COOPERATIVE CURRICULUM DEVELOPMENT	•MEDICAL LIBRARY •EDUCATION DEPARTMENT •BONE MARROW TRANSPLANT CENTER STAFF •BMT CARE TEAM •NURSE EDUCATORS

NURSE/STUDENT RESEARCH PROJECTS

Process

- EDUCATE STAFF ABOUT PREVENTION OF CLI
- ASSESS CVC PRACTICE PATTERNS
- USE FACE-TO-FACE FEEDBACK

STAFF OWNERSHIP FOR PRACTICE CHANGE

STAFF OWNERSHIP FOR CLI RATES

EARLY DETECTION

Structure

EXTERNAL	INTERNAL
•NATIONAL AND REGIONAL DATA BANKS AND SURVEILLANCE SYSTEMS, SUCH AS NNIS AND NHSN •NATIONAL AND REGIONAL BENCHMARKS •COOPERATIVE GROUPS	•INFECTION CONTROL DEPARTMENT •INFECTION SURVEILLANCE SYSTEMS •HOSPITAL BENCHMARKS •BMT CARE TEAM

Process

- CALCULATE AND TRACK TRENDS IN CLI INCIDENCE RATES
- POST CLI RATES QUARTERLY

Intermediate Outcomes

PRACTICE PATTERNS FOR PREVENTION OF CLI

- ADHERENCE TO P&P AND TO PIS
- CLI RATES AVAILABLE

Outcome

DECREASED CLI RATES

IMPROVED BOTTOM LINE / IMPROVED BMT CENTER BENCHMARKS IN CLI PREVENTION

Figure 6. Points for research and practice improvement throughout the conceptual model of infection prevention used for the present study.

Figure 6. (Continued)

Note: Bolded insets and bolded bullet points demonstrate practice and research implications of this study.

Abbreviations: CDC = Centers for Disease Control and Prevention; NNIS = National Nosocomial Infection Surveillance System; NHSN = National Healthcare Safety Network; CVC = Central venous catheter of policy innovation. This would be particularly applicable to research in adoption of CDC guidelines for prevention of CLI.

Other applicable models describe knowledge translation (Sudsawad, 2007). These models describe an iterative process between researchers and research users and systems to support research utilization. In particular, the Canadian Institutes of Health Research (CIHR) use a model of knowledge translation and publish their research in "plain language and accessible formats" (2005), which makes it less intimidating for practitioners and healthcare consumers to read. This has great appeal in healthcare settings, where studies are more likely to be read by busy nurses and other healthcare workers if the terminology is plain. Such a model could help to move evidence-based preventive practices from the research arena to the bedside.

Limitations

Self-Report

Collecting data by self-report introduces the potential bias of social desirability. In the present study, participants who wanted their BMT centers to be seen as "good" healthcare facilities, may have tended to overreport the frequency of behaviors they interpreted as being more desirable or correct (Nunnally & Bernstein, 1994; Toh, Lee, & Hu, 2006). Without observation of the target behaviors, it is difficult to assess the extent of the gap between reported practice and actual practice. However, observation also tends to change behavior for the same reason - most healthcare providers want to be observed performing procedures in the way they perceive to be correct.

Responses to the likert-type questions in the BMT LIFE survey were more likely to have been influenced by social desirability bias than were the multiple answer, open-ended or short answer questions. On likert-type scales with questions phrased as positive statements of the frequency of behaviors, higher frequency of behaviors could easily be seen as more desirable.

Social desirability bias may be more pronounced in reports of sensitive information, such as rates or numbers of CLI. Fewer is obviously better in this case. Rates of CLI expressed as CRBSIs per 1000 catheter days were not likely to have been understated because the calculation would have been performed in the infection control department using objective data. Actual numbers of CLI given in response to the question about numbers of infections during 2005 were more likely to have been estimates and to have been underreported. Interestingly, 1 participant reported the actual number of CLI as 1 and also reported the CLI incidence rate as 1 per 1000 catheter days. Apparently this participant did not understand the calculation of a CLI incidence rate and just made an uninformed estimate. In fact, 1 CLI per 1000 catheter days would only be the incidence rate in the unlikely case that the total number of catheter days in that BMT center was 1000 days in 2005.

Inserting a brief, reliable social desirability scale into a survey questionnaire has been recommended as a means of helping to determine the validity of the questionnaire (DeVellis, 2003). It should be noted, however, that there has been considerable debate over the nature and the cause of the systematic variance attributed to social desirability bias. Although this bias is known, in psychological studies, to be a major factor in self-descriptions of "normal individuals," the variance in other studies using self-report can also be attributed to the level of self-knowledge (organizational knowledge in this case) or the level of frankness of the individual or participant (Nunnally & Bernstein, 1994). Assuring confidentiality of responses in the present study was intended to overcome tendencies of participants to misrepresent or withhold sensitive or negative responses and/or data. The fact that 9 participants did report CLIs/1000 catheter days ranging from 1 to 12.5, with a mean of 5.5 suggests that at least some participants were not concerned about social desirability.

A final note about social desirability refers to the data-collecting phase of this study. During telephone follow-up conversations numerous individuals assured the investigator that they would return the completed survey, some stating that they would do it on that very day, and then failing to do so. Social desirability undoubtedly influenced those communications, as potential participants wanted to appear helpful even though their intent to fulfill their verbal commitments did not last long after the telephone conversation had ended. The contexts of face-to-face or telephone conversations are more socially compelling more likely to be affected by social desirability bias than anonymous or confidential mailed surveys (Pedhauzer & Schmelkin, 1991).

Survey Instrument

Problematic Questions

The novelty of the BMT LIFE survey led to difficulties in data collection that were not detected during the pilot study. Two questions were particularly problematic.

The open-ended question asking participants to list criteria they used in deciding when to remove CVCs may have been misconstrued due to contextual effects (Pedhauzer & Schmelkin, 1991). Most participants listed more criteria related to infection or malfunction of the CVC than criteria related to a plan for timely removal of the CVC. The context within which the question was asked - a study of CLI in BMT patients - may have influenced participants to frame their answers as responses to a CLI, rather than as means of preventing a CLI. Providing a list of criteria for line removal and having participants either select the criteria most important to them or prioritize the criteria would probably have resulted in more useful responses to that question.

The questions requesting rates and numbers of CLI required most participants to seek information from another person, usually someone outside of the BMT department. This additional time and effort, and the fact that CLI information was not available for many BMT centers, discouraged numerous potential participants from completing and returning the survey.

Multiple Styles of Questions

The BMT LIFE survey contained multiple question styles. Participants had to stop and read the directions for questions each time the question style changed. This required a little more time, which may have discouraged some potential participants. Answering four pages of questions of the same style would undoubtedly have been faster and easier.

On the other hand, if all survey items are formatted using the same response metric, participants may tend to choose a moderate level of response (for example, usually, as opposed to always or sometimes), resulting in a "halo effect" (Nunnally & Bernstein, 1994). This effect occurs when someone who is rating a person (or a healthcare agency) has a generally positive impression of the subject and applies that impression to all aspects of the subject being evaluated.

Short answer questions require more precise responses and do not allow such effects as the halo effect. However they have the inherent risk of confusion, as already addressed in reference to the open-ended question about criteria for line removal.

Multiple choice questions present participants with both appropriate and inappropriate response options, and they invite guessing as to which answer is most appropriate. Multiple answer questions, which were used instead in the BMT LIFE survey required participants to select the sterile barrier precautions used in their BMT centers during CVC insertion. These questions also provided appropriate and inappropriate responses and invited some guessing. In this case, however, participants were instructed to select the items their BMT centers used, and no specific number of responses was suggested. The effect of guessing may have been moderated by the knowledge that several, perhaps most or even all, of the response were appropriate.

Overall, measurement error was a possibility in all parts of the BMT LIFE survey (Nunnally & Bernstein, 1994). However, the use of multiple question styles may have caused participants to slow down and think more critically about each section of questions. In addition, multiple question styles decreased both guessing and the halo effect in some parts of the survey.

Study Design

A retrospective cross-sectional study using a newly-developed instrument lacks the capacity to compare results over time. Both the study design and the relatively small response rate limit the generalizability of the study findings. However, this study represents an initial step in investigating application of the CDC Pis for prevention of CLI in a unique and vulnerable population. More studies are needed to determine both the use and the effectiveness of the CDC Pis among BMT patients. A cross-sectional study is one glimpse in time and may or may not represent the population in general over a period of time. A prospective study, with repeated observations over time to validate the self-report of practices described in the Pis, would be appropriate. Although the response rate was only 31%, revision of the problematic questions in the survey and possibly providing an email or telephone option for completing the survey, could increase the response rate substantially.

Conclusion

Three significant findings emerged from this study. First, there were variations in practice patterns related to CLI prevention. Second, although reported use of the CDC performance indicators (Pis) was generally high, 75% of participants reported they did not know the incidence rates of CLI in their BMT centers. And third, there was a trend toward higher use of the Pis in BMT centers that had more years of experience, that performed both autologous and allogeneic BMTs, that reported designating trained CVC personnel for CVC insertion and maintenance, and that reported usually or always being appropriately staffed.

Improving patient outcomes by decreasing incidence rates of CLI can be achieved. It will require (a) strengthening the healthcare worker education program by focusing on implementing evidence-based preventive practices based on the most current CDC recommendations or other evidence-based guidelines for prevention of CLI, then following up with assessment and feedback on both knowledge of and use of those practices, (b) defining roles and establishing coordination and accountability among members of the BMT care team, and (c) instituting the policy and practice of tracking rates and trends in CLI.

Research studies are needed to establish benchmarks for CLI in BMT patients and best practice for decreasing incidence rates of CLI. Studies based on the Health Belief

Model could identify healthcare workers' perceptions of the problem of CLI and their roles in preventing CLI, thus providing significant topics for healthcare worker education regarding CLI in BMT patients. There are currently no published studies on either of these topics. Future research studies should consider employing a moderately conservative correction procedure, such as the Bonferroni-Holm procedure, to hedge against making a Type I error when using multiple comparisons in the data analysis.

CLI in BMT patients is preventable. The monetary cost of CLI in BMT patients is high, but the human cost is inestimable. BMT centers must assume accountability for providing best practice in prevention of CLI in the BMT patients.

APPENDIX A

BMT LIFE SURVEY

BMT LIFE

A survey to facilitate Line Infection Factor Evaluation
In
Bone Marrow Transplant Patients

Please answer each question in the way that most accurately reflects usual practice in your BMT center.
After you have completed the survey, please place it in the enclosed stamped envelope, and put it in the mail. Thank you.
Do not use or adapt this survey without permission.

SECTION A - HEALTHCARE WORKERS

Please check the box which indicates how well the following statements describe actual practice (the way things are usually done) in your BMT center.

	Never	Rarely	[illegible]	[illegible]	Always
1. In our BMT center, we educate healthcare workers about:					
a. Indications for central venous catheter (CVC) use.........	●	●	●	●	●
b. Proper procedures for insertion of CVCs	●	●	●	●	●
c. Proper procedures for maintenance of CVCs...............	●	●	●	●	●
d. Strategies to prevent CVC-related infections...............	●	●	●	●	●
2. Our education of healthcare workers includes:					
a. Didactic instruction (lecture)..................................	●	●	●	●	●
b. Interactive teaching (hands-on experience).................	n	●	●	●	●
3. We periodically (at regularly scheduled times) assess knowledge of CVC guidelines for:					
a. All persons who insert CVCs	●	●	●	●	●
b. All persons who maintain CVCs..............................	●	●	●	●	●
4. We periodically assess usage to CVC guidelines for:					
a. All persons who insert CVCs	●	●	●	●	●
b. All persons who maintain CVCs..............................	●	●	●	●	●
5. We designate trained personnel for the *insertion* of CVCs.........	●	●	●	●	●
6. We designate trained personnel for the *maintenance* of CVCs. ..	●	●	●	●	●
7. We designate trained personnel who exhibit competency in CVC insertion to *supervise* trainees who perform CVC insertion......	●	●	●	●	●
8. We ensure appropriate nursing staff levels to minimize the incidence of catheter-related bloodstream infections................	●	●	●	●	●

For the next 4 questions, please either fill in the appropriate number or check the square box.

9. What is your usual ratio of RNs to patients on the day shift? **1 RN to______patients**
• Not applicable; we don't use RNs.

10. What is your usual ratio of LPNs to patients on the day shift? **I LPN to______patients**
• Not applicable; we don't use LPNs.

11. What is your usual ratio of nursing assistants (NAs) to patients on the day shift? **1 NA to______patients**
• Not applicable; we don't use NAs.

12. What percent of your RNs are bachelor's-prepared?______________________________%
• Not applicable; we don't use RNs.

#

Please continue on the back of this page

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13. Which of the following do you employ at your BMT center? (*Please circle ALL THAT APPLY, and tell HOW MANY are scheduled on the DA Y SHIFT.)*

- **a. Master's-prepared clinical nurse specialists (CNS) - How many?**
- **b. Master's-prepared nurse practitioners (NP) - How many?**
- **c. Physician's assistants (PA) - How many?**

SECTION B - SURVEILLANCE

1. The rate or number of CLIs in our BMT center for the calendar year 2005 was (*Please describe in the format you use.):*

a.____________CLIs per 1,000 catheter days

b.____________(actual number o0 CLIs in 2005

c. Other *(please describe):*

d. Our institution does not provide these data specifically for our BMT center.
(Please check the following box if this is true for your center.) •

2. The specific types of CLIs diagnosed in our BMT center during the calendar year 2005 were:

	Type of Central Line Infection	CLIs per 1000 Catheter Days	Actual Number of CLIs	Data not Provided for Our Center (Check box.)
a.	Exit Site Infection (redness or swelling within 2 cm of the catheter exit site without bloodstream infection (BSI) and without purulence			
b.	Tunnel Infection (tenderness, redness, or swelling >2 cm from the catheter site along the tract of a tunneled catheter, without BSI			•
c.	Catheter-Associated BSI (bloodstream infection which develops while the line is in place or within 48 hours of line use)			•
d.	Catheter-Related BSI (Patient with [a] at least one positive blood culture (peripheral); and [b] fever, chills, and/or hypotension; and [c]no other apparent source for the BSI; and one of the following: • A positive semiquantitative or quantitative culture where the same organism is isolated from the catheter segment and peripheral blood • Simultaneous quantitative blood cultures with > 5:1 ratio of CVC versus peripheral • Differential period >2 hours for CVC versus peripheral blood culture positivity			•
e.	Pocket Infection (Purulent fluid in the pocket surrounding a totally implanted intravascular catheter, without an accompanying BSI			•
f.	Clinical Sepsis (Patient with either fever >100.4° F [>38° C], or systolic blood pressure <90 mm Hg, or oliguria (<20 mL/hr), and no or negative blood culture and no other apparent site of infection)			
g.	Other *(Please describe.)* ____________________			•

Please continue on to the next page.

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SECTION C - BMT CENTER DEMOGRAPHICS

	Type of Transplant	# Performed
1. How many transplants were performed in your BMT center, between January 1 and December 31, 2005, in each of the following categories?	a. Autologous stem cell and/or bone marrow	
	b. Allogeneic matched related donor	
	c. Allogeneic mis-matched related donor	
	d. Allogeneic matched unrelated donor	
	e. Allogeneic mis-matched unrelated donor	
	f. Cord blood	
	g. Nonmyeloablative	
	h. Other *{Please describe.):* ____________	

2. The age range of BMT patients at our center between January 1 and December 31, 2005 was:
   a. Youngest patient__________________years old
   b. Oldest patient____________________years old

Min Age Max Age

3. The acceptable age range for patients in our BMT center is:________________- _______

SECTION D - CATHETER INSERTION, REMOVAL, AND DAYS IN PLACE

1. During insertion of CVCs at the *bedside,* we use aseptic technique, including the use of a *(Please circle ONLY those that apply.):*
   a. cap
   b. mask
   c. clean gloves
   d. sterile gown
   e. sterile gloves
   f. small sterile sheet
   g. large sterile sheet
   h. Not applicable; we don't insert CVCs at the bedside.

3. During insertion of CVCs in *radiology,* we use aseptic technique, including the use of a *(Please circle ONLY those that apply.):*
   a. cap
   b. mask
   c. clean gloves
   d. sterile gown
   e. sterile gloves
   f. small sterile sheet
   g. large sterile sheet
   h. Not applicable; we don't insert CVCs in radiology.

2. During insertion of CVCs in the *operating room* (OR), we use aseptic technique, including the use of a (*Please circle ONLY those that apply.):*
   a. cap
   b. mask
   c. clean gloves
   d. sterile gown
   e. sterile gloves
   f. small sterile sheet
   g. large sterile sheet
   h. Not applicable; we don't insert CVCs in the operating room.

4. If you do not insert CVCs at the bedside, in the OR, or in radiology, please describe the setting in which CVCs are inserted in your BMT center and indicate which equipment you use.
   Setting ___________________________
   (Please circle ONLY those that apply.)
   a. cap
   b. mask
   c. clean gloves
   d. sterile gown
   e. sterile gloves
   f. small sterile sheet
   g. large sterile sheet
   h. Not applicable

5. We use the following criteria in deciding when to remove the CVC? (*Please describe.)*

Please continue on the back of this page.

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6. For patients with the following donors, the CVC remains in place an average (mean) of:

		# of Days
a.	Autologous donors (self)	______days
b.	Allogeneic matched related donors	______days
c.	Allogeneic MIS-matched related donors	______days
d.	Allogeneic matched UNrelated donors	______days
e.	Allogeneic MIS-matched UNrelated donors	______days
f.	Cord blood transplants	______days
g.	Nonmyeloablative pre-transplant therapy	______days
h.	Other *(Please describe.)*:	______days

9. SECTION E - CATHETER SITE AND CATHETER CARE

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1. We administer prophylactic anticoagulants to prevent CVC-associated thrombosis... If you do, please describe:______________________	●	●	●	●	●
2. We use *2% chlorhexidine*-based preparation to disinfect clean skin before catheter insertion..	●	●	●	●	●
3. We use 2% *chlorhexidine-based* preparation to disinfect clean skin during dressing changes..	●	●	●	●	●
4. We use *tincture of iodine* to disinfect clean skin before catheter insertion..	●	●	●	●	●
5. We use *tincture of iodine* to disinfect clean skin during dressing Changes..	●	●	●	●	●
6. We use an *iodophor* (such as povidone iodine) to disinfect clean skin before catheter insertion...	●	●	●	●	●
7. We use an *iodophor* to disinfect clean skin during dressing changes...	●	●	●	●	●
8. We use *70% alcohol* to disinfect clean skin before catheter insertion..	●	●	●	●	●
9. We use *70% alcohol* to disinfect clean skin during dressing changes..	●	●	●	●	●
10. We allow the antiseptic to air dry before catheter insertion or dressing..	●	●	●	●	●
11. If an iodophor is used, we allow it to remain on the skin for at least 2 minutes or longer if needed to dry......................................	●	●	●	●	●

SECTION F - PRACTICES WHICH HELP TO PREVENT CENTRAL LINE INFECTIONS

1. What, for your BMT center, are the 6 most important things you do to prevent central line infections?

a.______________________ d.______________________

b.______________________ e.______________________

c.______________________ f.______________________

May we have your permission to contact you to clarify any answers? (*Please circle one.)* *YES* *NO*
Please provide your name and contact information below.

Name *(Pleaseprint.)* Title Credentials

Signature Telephone Number Email

Thank you very much. Please return the completed survey in the enclosed stamped envelope to:
BMT LIFE Study, 2291 N 1430 E, Provo, Utah 84604

APPENDIX B

COVER LETTER

July 18, 2007

Bone Marrow Transplant Coordinator
Address

Dear____________:

I am writing to ask for your help as a participant in an important research project. I am an oncology and bone marrow transplant (BMT) nurse, and I am currently studying central line infections (CLI) in BMT patients for my doctoral research at the University of Utah. Participating in the study means completing the enclosed survey, "BMT LIFE," and returning the survey to me in the enclosed, stamped, self-addressed envelope.

There is a wide range in the rates of CLI among BMT patients in transplant centers. There is also variation in practices used in BMT centers to prevent infections. The purpose of this study is to describe variations in practice regarding central line care in BMT patients.

There are no right or wrong answers to the survey questions. The intent of the survey is to obtain a picture of current practice in BMT centers in the United States.

You and your institution were selected because your transplant center is listed on the BMT InfoNet website. Completion of the survey should take approximately 5-10 minutes. However, more time will be required to retrieve some of the information called for in the survey. Names of individuals completing surveys, and names of their institutions, will be kept strictly confidential during and after the study. Published results of the study will not identify any individuals who completed surveys or any participating BMT centers.

It would be most helpful to have an RN, preferably a BMT coordinator or a clinical nurse specialist (CNS) or nurse practitioner (NP) in the BMT center, complete the survey because they would likely be the individuals most able to answer all of the questions. The name, credentials, and contact information (work telephone number and email address) of the person completing the survey should be filled in on the form at the end of the survey. This information will be kept in a locked file in the investigator's office and will be destroyed following completion of the study. During the study, the information will be available only to me and to one research assistant. It will enable me to follow up and clarify any questions I may have about responses to the survey questions.

When you complete and return the enclosed survey, your name will be placed in a drawing for one of ten one-year memberships/renewals in the Oncology Nursing Society. If you do not win one of the ONS memberships, you will be sent a $5.00 Wal-Mart gift card. All participants will receive a copy of the study results.

Please return the completed survey as soon as possible. Completion and return of the completed survey will be considered consent to participate in the study. If you have any questions, please feel free to call me toll free at 1-877-345-1916, or email me (leecarolyn@mstarmetro.net).

If you have questions regarding your rights as a research participant, or if problems arise which you do not feel you can discuss with the Investigator, please contact the Institutional Review Board Office at (801) 581-3655.

Thank you for your participation. Study results will be used to help decrease rates of CLI BMT patients.

Sincerely,

Carolyn Sutherland Bearnson, MS, RN
Principal Investigator
BMT LIFE Study

APPENDIX C

CDC GUIDELINES

Guidelines for the Prevention of Intravascular Catheter-Related Infections

Prepared by
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The material in this report was prepared for publication by the National Center for Infectious Diseases, James M. Hughes, M.D., Director; Division of Healthcare Quality Promotion, Steven L. Solomon, M.D., Acting Director.

Summary

These guidelines have been developed for practitioners who insert catheters and for persons responsible for surveillance and control of infections in hospital, outpatient, and home health-care settings. This report was prepared by a working group comprising members from professional organizations representing the disciplines of critical care medicine, infectious diseases, health-care infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatric medicine, and *nursing. The working group was led by the Society of Critical Care Medicine (SCCM), in collaboration with the Infectious Disease Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American College of Chest Physicians (ACCP), American Thoracic Society (ATS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Infusion Nurses Society (INS), Oncology Nursing Society (ONS), Society of Cardiovascular and Interventional Radiology (SCVIR), American Academy of Pediatrics (AAP), and the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC) and is intended to replace the Guideline for Prevention of Intravascular Device-Related Infections published in 1996. These guidelines are intended to provide evidence-based recommendations for preventing catheter-related infections. Major areas of emphasis include 1) educating and training health-care providers who insert and maintain catheters; 2) using maximal sterile barrier precautions during central venous catheter insertion; 3) using a 2% chlorhexidine preparation for skin antisepsis; 4) avoiding routine replacement of central venous catheters as a strategy to prevent infection; and 5) using antiseptic/antibiotic impregnated short-term central venous catheters if the rate of infection is high despite usage to other strategies (i.e., education and training, maximal sterile barrier precautions, and 2% chlorhexidine for skin antisepsis). These guidelines also identify performance indicators that can be used locally by health-care institutions or organizations to monitor their success in implementing these evidence-based recommendations.*

Introduction

This report provides health-care practitioners with background information and specific recommendations to reduce the incidence of intravascular catheter-related bloodstream infections (CRBSI). These guidelines replace the *Guideline for Prevention of Intravascular Device-Related Infections,* which was published in 1996 *(1).*

The *Guidelines for the Prevention of Intravascular Catheter-Related Infections* have been developed for practitioners who insert catheters and for persons who are responsible for surveillance and control of infections in hospital, outpatient, and home health-care settings. This report was prepared by a working group composed of professionals representing the disciplines of critical care medicine, infectious diseases, health-care infection control, surgery, anesthesiology, interventional radiology, pulmonary medicine, pediatrics, and nursing. The working group was led by the Society of Critical Care Medicine (SCCM), in collaboration with Infectious Disease Society of America (IDSA), Society for Healthcare Epidemiology of America (SHEA), Surgical Infection Society (SIS), American College of Chest Physicians (ACCP), American Thoracic Society (ATS), American Society of Critical Care Anesthesiologists (ASCCA), Association for Professionals in Infection Control and Epidemiology (APIC), Infusion Nurses Society (INS), Oncology Nursing Society (ONS), Society of Cardiovascular and Interventional Radiology (SCVIR), American Academy of Pediatrics (AAP), and the Healthcare Infection Control Practices Advisory

Committee (HICPAC) of the Centers for Disease Control and Prevention (CDC). The recommendations presented in this report reflect consensus of HICPAC and other professional organizations.

Intravascular Catheter-Related Infections in Adult and Pediatric Patients: An Overview

Background

Intravascular catheters are indispensable in modern-day medical practice, particularly in intensive care units (ICUs). Although such catheters provide necessary vascular access, their use puts patients at risk for local and systemic infectious complications, including local site infection, CRBSI, septic thrombophlebitis, endocarditis, and other metastatic infections (e.g., lung abscess, brain abscess, osteomyelitis, and endophthalmitis).

Health-care institutions purchase millions of intravascular catheters each year. The incidence of CRBSI varies considerably by type of catheter, frequency of catheter manipulation, and patient-related factors (e.g., underlying disease and acuity of illness). Peripheral venous catheters are the devices most frequently used for vascular access. Although the incidence of local or bloodstream infections (BSIs) associated with peripheral venous catheters is usually low, serious infectious complications produce considerable annual morbidity because of the frequency with which such catheters are used. However, the majority of serious catheter-related infections are associated with central venous catheters (CVCs), especially those that are placed in patients in ICUs. In the ICU setting, the incidence of infection is often higher than in the less acute in-patient or ambulatory setting. In the ICU, central venous access might be needed for extended periods of time; patients can be colonized with hospital-acquired organisms; and the catheter can be manipulated multiple times per day for the administration of fluids, drugs, and blood products. Moreover, some catheters can be inserted in urgent situations, during which optimal attention to aseptic technique might not be feasible. Certain catheters (e.g., pulmonary artery catheters and peripheral arterial catheters) can be accessed multiple times per day for hemodynamic measurements or to obtain samples for laboratory analysis, augmenting the potential for contamination and subsequent clinical infection.

The magnitude of the potential for CVCs to cause morbidity and mortality resulting from infectious complications has been estimated in several studies (2). In the United States, 15 million CVC days (i.e., the total number of days of exposure to CVCs by all patients in the selected population during the selected time period) occur in ICUs each year (2). If the average rate of CVC-associated BSIs is 5.3 per 1,000 catheter days in the ICU (J), approximately 80,000 CVC-associated BSIs occur in ICUs each year in the United States. The attributable mortality for these BSIs has ranged from no increase in mortality in studies that controlled for severity of illness *(4-6),* to 35% increase in mortality in prospective studies that did not use this control (7,8). Thus, the attributable mortality remains unclear. The attributable cost per infection is an estimated $34,508—

$56,000 (5,9), and the annual cost of caring for patients with CVC-associated BSIs ranges from $296 million to $2.3 billion (70).

A total of 250,000 cases of CVC-associated BSIs have been estimated to occur annually if entire hospitals are assessed rather than ICUs exclusively *(11).* In this case, attributable mortality is an estimated 12%-25% for each infection, and the marginal cost to the health-care system is $25,000 per episode *(11).*

Therefore, by several analyses, the cost of CVC-associated BSI is substantial, both in terms of morbidity and in terms of financial resources expended. To improve patient outcome and reduce health-care costs, strategies should be implemented to reduce the incidence of these infections. This effort should be multidisciplinary, involving health-care professionals who insert and maintain intravascular catheters, health-care managers who allocate resources, and patients who are capable of assisting in the care of their catheters. Although several individual strategies have been studied and shown to be effective in reducing CRBSI, studies using multiple strategies have not been conducted. Thus, it is not known whether implementing multiple strategies will have an additive effect in reducing CRBSI, but it is logical to use multiple strategies concomitantly.

Terminology and Estimates of Risk

The terminology used to identify different types of catheters is confusing, because many clinicians and researchers use different aspects of the catheter for informal reference. A catheter can be designated by the type of vessel it occupies (e.g., peripheral venous, central venous, or arterial); its intended life span (e.g., temporary or short-term versus permanent or long-term); its site of insertion (e.g., subclavian, femoral, internal jugular, peripheral, and peripherally inserted central catheter [PICC]); its pathway from skin to vessel (e.g., tunneled versus nontunneled); its physical length (e.g., long versus short); or some special characteristic of the catheter (e.g., presence or absence of a cuff, impregnation with heparin, antibiotics or antiseptics, and the number of lumens). To accurately define a specific type of catheter, all of these aspects should be described (Table 1).

The rate of all catheter-related infections (including local infections and systemic infections) is difficult to determine. Although CRBSI is an ideal parameter because it represents the most serious form of catheter-related infection, the rate of such infection depends on how CRBSI is defined.

Health-care professionals should recognize the difference between surveillance definitions and clinical definitions. The surveillance definitions for catheter-associated BSI includes all BSIs that occur in patients with CVCs, when other sites of infection have been excluded (Appendix A). That is, the surveillance definition overestimates the true incidence of CRBSI because not all BSIs originate from a catheter. Some bacteremias are secondary BSIs from undocumented sources (e.g., postoperative surgical sites, intra-abdominal infections, and hospital-associated pneumonia or urinary tract infections). Thus, surveillance definitions are really definitions for catheter-associated BSIs. A more rigorous definition might include only those BSIs for which other sources were excluded by careful examination of the patient record, and where a culture of the catheter tip demonstrated substantial colonies of an organism identical to those found in the bloodstream. Such a clinical definition would focus on catheter-related BSIs. Therefore, to accurately compare a health-care facility's infection rate to published data, comparable definitions also should be used.

CDC and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) recommend that the rate of catheter-associated BSIs be expressed as the number of catheter associated BSIs per 1,000 CVC days *(12,13).* This parameter is more useful than the rate expressed as the number of catheter-associated infections per 100 catheters (or percentage of catheters studied), because it accounts for BSIs over time and therefore adjusts risk for the number of days the catheter is in use.

Epidemiology and Microbiology

Since 1970, CDC's National Nosocomial Infection Surveillance System (NNIS) has been collecting data on the incidence and etiologies of hospital-acquired infections, including CVC-associated BSIs in a group of nearly 300 U.S. hospitals. The majority of hospital-acquired BSIs are associated with the use of a CVC, with BSI rates being substantially higher among patients with CVCs than among those without CVCs. Rates of CVC-associated BSI vary considerably by hospital size, hospital service/unit, and type of CVC. During 1992-2001, NNIS hospitals reported ICU rates of CVC-associated BSI ranging from 2.9 (in a cardiothoracic ICU) to 11.3 (in a neonatal nursery for infants weighing <1,000 g) BSIs per 1,000 CVC days (Table 2) *(14).*

The relative risk of catheter-associated BSI also has been assessed in a meta-analysis of 223 prospective studies of adult patients (11). Relative risk of infection was best determined by analyzing rates of infection both by BSIs per 100 catheters and BSIs per 1,000 catheter days. These rates, and the NNIS-derived data, can be used as benchmarks by individual hospitals to estimate how their rates compare with other institutions. Rates are influenced by patient-related parameters, such as severity of illness and type of illness (e.g., third-degree burns versus postcardiac surgery), and by catheter-related parameters, such as the condition under which the catheter was placed (e.g., elective versus urgent) and catheter type (e.g., tunneled versus nontunneled or subclavian versus jugular).

Types of organisms that most commonly cause hospital-acquired BSIs change over time. During 1986—1989, coagulase-negative staphylococci, followed by *Staphylococcus aureus,* were the most frequently reported causes of BSIs, accounting for 27% and 16% of BSIs, respectively (Table 3) *(15).* Pooled data from 1992 through 1999 indicate that coagulase-negative staphylococci, followed by enterococci, are now the most frequently isolated causes of hospital-acquired BSIs (72). Coagulase-negative staphylococci account for 37% *(12)* and *S. aureus* account for 12.6% of reported hospital-acquired BSIs *(12).* Also notable was the susceptibility pattern of *S. aureus* isolates. In 1999, for the first time since NNIS has been reporting susceptibilities, >50% of all *S. aureus* isolates from ICUs were resistant to oxacillin (72).

In 1999, enterococci accounted for 13.5% of BSIs, an increase from 8% reported to NNIS during 1986-1989. The percentage of enterococcal ICU isolates resistant to vancomycin also is increasing, escalating from 0.5% in 1989 to 25.9% in 1999 (72).

Candida spp. caused 8% of hospital-acquired BSIs reported to NNIS during 1986-1989 (75,76), and during 1992-1999 *(12,17,18).* Resistance of *Candida* spp. to commonly used antifungal agents is increasing. Although NNIS has not reported the percentage of BSIs caused by nonalbicans species or fluconazole susceptibility data, other epidemiologic and clinical data document that fluconazole resistance is an increasingly relevant consideration when designing empiric therapeutic regimens for CRBSIs caused by yeast. Data from the Surveillance and Control of Pathogens of Epidemiologic Importance (SCOPE) Program documented that 10% of C. *albicans* bloodstream isolates from hospitalized patients were resistant to fluconazole (77). Additionally, 48% of *Candida* BSIs were caused by nonalbicans species, including C. *glabrata* and C. *krusei,* which are more likely than C. *albicans* to demonstrate resistance to fluconazole and itraconazole *(18,19).*

Gram-negative bacilli accounted for 19% of catheter-associated BSIs during 1986—1989 (75) compared with 14% of catheter-associated BSIs during 1992-1999 (72). An increasing percentage of ICU-related isolates are caused by *Enterobacteriaceae* that produce extended-spectrum B-lactamases (ESBLs), particularly *Klebsiella pneumoniae (20).* Such organisms not only are resistant to extended-spectrum cephalosporins, but also to frequently used, broad spectrum antimicrobial agents.

Pathogenesis

Migration of skin organisms at the insertion site into the cutaneous catheter tract with colonization of the catheter tip is the most common route of infection for peripherally inserted, short-term catheters (27,22). Contamination of the catheter hub contributes substantially to intraluminal colonization of long-term catheters (25-25). Occasionally, catheters might become hematogenously seeded from another focus of infection. Rarely, infusate contamination leads to CRBSI (26).

Important pathogenic determinants of catheter-related infection are 1) the material of which the device is made and 2) the intrinsic virulence factors of the infecting organism. In vitro studies demonstrate that catheters made of polyvinyl chloride or polyethylene are likely less resistant to the usage of microorganisms than are catheters made of Teflon®, silicone elastomer, or polyurethane *(27, 28).* Therefore, the majority of catheters sold in the United States are no longer made of polyvinyl chloride or polyethylene. Some catheter materials also have surface irregularities that enhance the microbial usage of certain species (e.g., coagulase-negative staphylococci, *Acinetobacter calcoaceticus,* and *Pseudomonas aeruginosa) (29--31)* catheters made of these materials are especially vulnerable to microbial colonization and subsequent infection. Additionally, certain catheter materials are more thrombogenic than others, a characteristic that also might predispose to catheter colonization and catheter-related infection *(31,32).* This association has led to emphasis on preventing catheter-related thrombus as an additional mechanism for reducing CRBSI.

The usage properties of a given microorganism also are important in the pathogenesis of catheter-related infection. For example, *S. aureus* can adhere to host proteins (e.g., fibronectin) commonly present on catheters *(33,34).* Also, coagulase-negative staphylococci adhere to polymer surfaces more readily than do other pathogens (e.g., *Escherichia coli* or *S. aureus).* Additionally, certain strains of coagulase-negative staphylococci produce an extracellular polysaccharide often referred to as "slime" *(35,36).* In the presence of catheters, this slime potentiates the pathogenicity of coagulase-negative staphylococci by allowing them to withstand host defense mechanisms (e.g., acting as a barrier to engulfment and killing by polymorphonuclear leukocytes) or by making them less susceptible to antimicrobial agents (e.g., forming a matrix that binds antimicrobials before their contact with the organism cell wall) *(37).* Certain *Candida* spp., in the presence of glucose-containing fluids, might produce slime similar to that of their bacterial counterparts, potentially explaining the increased proportion of BSIs caused by fungal pathogens among patients receiving parenteral nutrition fluids *(38).*

Strategies for Prevention of Catheter-Related Infections in Adult and Pediatric Patients

Quality Assurance and Continuing Education

Measures to minimize the risk for infection associated with intravascular therapy should strike a balance between patient safety and cost effectiveness. As knowledge, technology, and health-care settings change, infection control and prevention measures also should change. Well-organized programs that enable health-care providers to provide, monitor, and evaluate care and to become educated are critical to the success of this effort. Reports spanning the past two decades have consistently demonstrated that risk for infection declines following standardization of aseptic care *(39-43),* and that insertion and maintenance of intravascular catheters by inexperienced staff might increase the risk for catheter colonization and CRBSI *(43,44).* Specialized "IV teams" have shown unequivocal effectiveness in reducing the incidence of catheter-related infections and associated complications and costs *(45-47).* Additionally, infection risk increases with nursing staff reductions below a critical level *(48).*

Site of Catheter Insertion

The site at which a catheter is placed influences the subsequent risk for catheter-related infection and phlebitis. The influence of site on the risk for catheter infections is related in part to the risk for thrombophlebitis and density of local skin flora.

Phlebitis has long been recognized as a risk for infection. For adults, lower extremity insertion sites are associated with a higher risk for infection than are upper extremity sites *{49-51)*. In addition, hand veins have a lower risk for phlebitis than do veins on the wrist or upper arm (52).

The density of skin flora at the catheter insertion site is a major risk factor for CRBSI. Authorities recommend that CVCs be placed in a subclavian site instead of a jugular or femoral site to reduce the risk for infection. No randomized trial satisfactorily has compared infection rates for catheters placed in jugular, subclavian, and femoral sites. Catheters inserted into an internal jugular vein have been associated with higher risk for infection than those inserted into a subclavian or femoral vein *(22,53,54)*.

Femoral catheters have been demonstrated to have relatively high colonization rates when used in adults (55). Femoral catheters should be avoided, when possible, because they are associated with a higher risk for deep venous thrombosis than are internal jugular or subclavian catheters *(56-60)* and because of a presumption that such catheters are more likely to become infected. However, studies in pediatric patients have demonstrated that femoral catheters have a low incidence of mechanical complications and might have an equivalent infection rate to that of nonfemoral catheters *(61—63)*. Thus, in adult patients, a subclavian site is preferred for infection control purposes, although other factors (e.g., the potential for mechanical complications, risk for subclavian vein stenosis, and catheter-operator skill) should be considered when deciding where to place the catheter. In a meta-analysis of eight studies, the use of bedside ultrasound for the placement of CVCs substantially reduced mechanical complications compared with the standard landmark placement technique (relative risk [RR] = 0.22; 95% confidence interval [CI] = 0.10-0.45) *(64)*. Consideration of comfort, security, and maintenance of asepsis as well as patient-specific factors (e.g., preexisting catheters, anatomic deformity, and bleeding diathesis), relative risk of mechanical complications (e.g., bleeding and pneumothorax), the availability of bedside ultrasound, and the risk for infection should guide site selection.

Type of Catheter Material

Teflon® or polyurethane catheters have been associated with fewer infectious complications than catheters made of polyvinyl chloride or polyethylene *(27,65,66)*. Steel needles used as an alternative to catheters for peripheral venous access have the same rate of infectious complications as do Teflon® catheters *(67,68)*. However, the use of steel needles frequently is complicated by infiltration of intravenous (IV) fluids into the subcutaneous tissues, a potentially serious complication if the infused fluid is a vesicant *(68)*.

Hand Hygiene and Aseptic Technique

For short peripheral catheters, good hand hygiene before catheter insertion or maintenance, combined with proper aseptic technique during catheter manipulation, provides protection against infection. Good hand hygiene can be achieved through the use of either a waterless, alcohol-based product *(69)* or an antibacterial soap and water with adequate rinsing *(70)*. Appropriate aseptic technique does not necessarily require sterile gloves; a new pair of disposable nonsterile gloves can be used in conjunction with a "no-touch" technique for the insertion of peripheral venous catheters. However, gloves are required by the Occupational Safety and Health Administration as standard precautions for the prevention of bloodborne pathogen exposure.

Compared with peripheral venous catheters, CVCs carry a substantially greater risk for infection; therefore, the level of barrier precautions needed to prevent infection during insertion of CVCs should be more stringent. Maximal sterile barrier precautions (e.g., cap, mask, sterile gown, sterile gloves, and large sterile drape) during the insertion of CVCs substantially reduces the incidence of CRBSI compared with standard precautions (e.g., sterile gloves and small drapes) *(22,71)*. Although the efficacy of such precautions for insertion of PICCs and midline catheters has not been studied, the use of maximal barrier precautions also is probably applicable to PICCs.

Skin Antisepsis

In the United States, povidone iodine has been the most widely used antiseptic for cleansing arterial catheter and CVC- insertion sites (72). However, in one study, preparation of central venous and arterial sites with a 2% aqueous chlorhexidine gluconate lowered BSI rates compared with site preparation with 10% povidone-iodine or 70% alcohol *(73)*. Commercially available products containing chlorhexidine have not been available until recently; in July 2000, the U.S. Food and Drug Administration (FDA) approved a 2% tincture of chlorhexidine preparation for skin antisepsis. Other preparations of chlorhexidine might not be as effective. Tincture of chlorhexidine gluconate 0.5% is no more effective in preventing CRBSI or CVC colonization than 10% povidone iodine, as demonstrated by a prospective, randomized study of adults *(74)*. However, in a study involving neonates, 0.5% chlorhexidine reduced peripheral IV colonization compared with povidone iodine (20/418 versus 38/408 catheters; $p = 0.01$) (75). This study, which did not include CVCs, had an insufficient number of participants to assess differences in BSI rates. A 1% tincture of chlorhexidine preparation is available in Canada and Australia, but not yet in the United States. No published trials have compared a 1% chlorhexidine preparation to povidone-iodine.

Catheter Site Dressing Regimens

Transparent, semipermeable polyurethane dressings have become a popular means of dressing catheter insertion sites. Transparent dressings reliably secure the device, permit continuous visual inspection of the catheter site, permit patients to bathe and shower without saturating the dressing, and require less frequent changes than do standard gauze and tape dressings; the use of these dressings saves personnel time.

In the largest controlled trial of dressing regimens on peripheral catheters, the infectious morbidity associated with the use of transparent dressings on approximately 2,000 peripheral catheters was examined (65). Data from this study suggest that the rate of colonization among catheters dressed with transparent dressings (5.7%) is comparable to that of those dressed with gauze (4.6%) and that no clinically substantial differences exist in either the incidences of catheter-site colonization or phlebitis. Furthermore, these data suggest that transparent dressings can be safely left on peripheral venous catheters for the duration of catheter insertion without increasing the risk for thrombophlebitis (65).

A meta-analysis has assessed studies that compared the risk for catheter-related BSIs for groups using transparent dressings versus groups using gauze dressing (76). The risk for CRBSIs did not differ between the groups. The choice of dressing can be a matter of preference. If blood is oozing from the catheter insertion site, gauze dressing might be preferred.

In a multi-center study, a chlorhexidine-impregnated sponge (Biopatch ") placed over the site of short-term arterial and CVCs reduced the risk for catheter colonization and CRBSI (77). No adverse systemic effects resulted from use of this device.

Catheter Securement Devices

Sutureless securement devices can be advantageous over suture in preventing catheter-related BSIs. One study, which involved only a limited number of patients and was underpowered, compared a sutureless device with suture for the securement of PICCS; in this study, CRBSI was reduced in the group of patients that received the sutureless device *(78).*

In-Line Filters

In-line filters reduce the incidence of infusion-related phlebitis *(79,80).* No data support their efficacy in preventing infections associated with intravascular catheters and infusion systems. Proponents of filters cite several potential benefits to using these filters, including 1) reducing the risk for infection from contaminated infusate or proximal contamination (i.e., introduced proximal to the filter); 2) reducing the risk for phlebitis in patients who require high doses of medication or in those in whom infusion-related phlebitis already has occurred; 3) removing particulate matter that might contaminate IV fluids *(81)* and 4) filtering endotoxin produced by gram-negative organisms in contaminated infusate *(82).* These theoretical advantages should be tempered by the knowledge that infusate-related BSI is rare and that filtration of medications or infusates in the pharmacy is a more practical and less costly way to remove the majority of particulates. Furthermore, in-line filters might become blocked, especially with certain solutions (e.g., dextran, lipids, and mannitol), thereby increasing the number of line manipulations and decreasing the availability of administered drugs (Si). Thus, for reducing the risk for CRBSI, no strong recommendation can be made in favor of using in-line filters.

Antimicrobial/Antiseptic Impregnated Catheters and Cuffs

Certain catheters and cuffs that are coated or impregnated with antimicrobial or antiseptic agents can decrease the risk for CRBSI and potentially decrease hospital costs associated with treating CRBSIs, despite the additional acquisition cost of an antimicrobial/antiseptic impregnated catheter *(84).* All of the studies involving antimicrobial/antiseptic impregnated catheters have been conducted using triple-lumen, noncuffed catheters in adult patients whose catheters remained in place <30 days. Although all of the studies have been conducted in adults, these catheters have been approved by FDA for use in patients weighing >3 kg. No antiseptic or antimicrobial impregnated catheters currently are available for use in weighing <3 kg.

Chlorhexidine/Silver sulfadiazine. Catheters coated with chlorhexidine/silver sulfadiazine only on the external luminal surface have been studied as a means to reduce CRBSI. Two meta-analyses *(2,85)* demonstrated that such catheters reduced the risk for CRBSI compared with standard noncoated catheters. The mean duration of catheter placement in one meta-analysis ranged from 5.1 to 11.2 days ***(86).*** The half-life of antimicrobial activity against *S. epidermiclis* is 3 days in vitro for catheters coated with chlorhexidine/silver sulfadiazine; this antimicrobial activity decreases over time *(87).* The benefit for the patients who receive these catheters will be realized within the first 14 days ***(86).*** A second-generation catheter is now available with chlorhexidine coating both the internal and external luminal surfaces. The external surface has three times the amount of chlorhexidine and extended release of the surface bound antiseptics than that in the first generation catheters. The external surface coating of chlorhexidine is combined with silver-sulfadiazine, and the internal surface is coated with chlorhexidine alone. Preliminary studies indicate that prolonged anti-infective activity provides improved efficacy in preventing infections (88). Although rare, anaphylaxis has been reported with the use of these chlorhexidine/silver sulfadiazine catheters in Japan (89). Whether patients will become colonized or infected with organisms resistant to chlorhexidine/silver sulfadiazine has not been determined ***(86).***

Chlorhexidine/silver sulfadiazine catheters are more expensive than standard catheters. However, one analysis has suggested that the use of chlorhexidine/silver sulfadiazine catheters should lead to a cost savings of $68 to $391 per catheter *(90)* in settings in which the risk for CRBSI is high despite usage to other preventive strategies (e.g., maximal barrier precautions and aseptic techniques). Use of these catheters might be cost effective in ICU patients, burn patients, neutropenic patients, and other patient populations in which the rate of infection exceeds 3.3 per 1,000 catheter days ***(86).***

Minocycline/Rifampin. In a multicenter randomized trial, CVCs impregnated on both the external and internal surfaces with minocycline/rifampin were associated with lower rates of CRBSI when compared with the first-generation chlorhexidine-silver sulfadiazine impregnated catheters *(91).* The beneficial effect began after day 6 of catheterization. None of the catheters were evaluated beyond 30 days. No minocycline/rifampin-resistant organisms were reported. However, in vitro data indicate that these impregnated catheters could increase the incidence of minocycline and rifampin resistance among pathogens, especially staphylococci. The half-life of antimicrobial activity against *S. epidermidis* is 25 days with catheters coated with minocycline/rifampin, compared with 3 days for the first-generation catheters coated with chlorhexidine/silver sulfadiazine in vitro *(87).* In vivo, the duration of antimicrobial activity of the minocycline/rifampin catheter is longer than that of the first-generation chlorhexidine/silver sulfadiazine catheter *(91).* No comparative studies have been published using the second-generation chlorhexidine/ silver sulfadiazine catheter. Studies are needed to evaluated whether the improved performance of the minocyline/rifampin catheters results from the antimicrobial agents used or from the coating of both the internal and external surfaces. As with chlorhexidine/silver sulfadiazine catheters, some clinicians have recommended that the minocycline/rifampin catheters be considered in patient populations when the rate of CRBSI exceeds 3.3 per 1,000 catheter days ***(86).*** Others suggest that reducing all rates of CRBSI should be the goal (92). The decision to use chlorhexidine/silver sulfadiazine or minocycline/rifampin impregnated catheters should be based on the need to enhance prevention of CRBSI after standard procedures have been implemented (e.g., educating personnel, using maximal sterile barrier precautions, and using 2% chlorhexidine skin antisepsis) and then balanced against the concern for emergence of resistant pathogens and the cost of implementing this strategy.

Platinum/Silver. Ionic metals have broad antimicrobial activity and are being used in catheters and cuffs to prevent CRBSI. A combination platinum/silver impregnated catheter is available in Europe and has recently been approved by FDA for use in the United States. Although these catheters are being marketed for their antimicrobial properties, no published studies have been presented to support an antimicrobial effect.

Silver cuffs. Ionic silver has been used in subcutaneous collagen cuffs attached to CVCs *(93).* The ionic silver provides antimicrobial activity and the cuff provides a mechanical barrier to the migration of microorganisms along the external surface of the catheter. In studies of catheters left in place >20 days, the cuff failed to reduce the incidence of CRBSI *(94,95).* Two other studies of short-term catheters could not demonstrate efficacy because of the minimal number of CRBSIs observed *(93,96).*

Systemic Antibiotic Prophylaxis

No studies have demonstrated that oral or parenteral antibacterial or antifungal drugs might reduce the incidence of CRBSI among adults (97—99). However, among low birth weight infants, two studies have assessed vancomycin prophylaxis; both demonstrated a reduction in CRBSI but no reduction in mortality *(100,101).* Because the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococcus (VRE) *(102),* the risk for acquiring VRE likely outweighs the benefit of using prophylactic vancomycin.

Antibiotic/Antiseptic Ointments

Povidone-iodine ointment applied at the insertion site of hemodialysis catheters has been studied as a prophylactic intervention to reduce the incidence of catheter-related infections. One randomized study of 129 hemodialysis catheters demonstrated a reduction in the incidence of exit-site infections, catheter-tip colonization, and BSIs with the routine use of povidone-iodine ointment at the catheter insertion site compared with no ointment at the insertion site *(103).*

Several studies have evaluated the effectiveness of mupirocin ointment applied at the insertion sites of CVCs as a means to prevent CRBSI *(104-106).* Although mupirocin reduced the risk for CRBSI *(106),* mupirocin ointment also has been associated with mupirocin resistance *(107,108),* and might adversely affect the integrity of polyurethane catheters *(109,110).*

Nasal carriers of *S. aureus* have a higher risk for acquiring CRBSI than do noncarriers *(103,111).* Mupirocin ointment has been used intranasally to decrease nasal carriage of *S. aureus* and lessen the risk for CRBSI. However, resistance to mupirocin develops in both *S. aureus* and coagulase-negative staphylococci soon after routine use of mupirocin is instituted *(107,108).*

Other antibiotic ointments applied to the catheter insertion site also have been studied and have yielded conflicting results *(112—114).* In addition, rates of catheter colonization with *Candida* spp. might be increased with the use of antibiotic ointments that have no fungicidal activity *(112,114).* To avoid compromising the integrity of the catheter, any ointment that is applied to the catheter insertion site should be checked against the catheter and ointment manufacturers' recommendations regarding compatibility.

Antibiotic Lock Prophylaxis

To prevent CRBSI, antibiotic lock prophylaxis has been attempted by flushing and filling the lumen of the catheter with an antibiotic solution and leaving the solution to dwell in the lumen of the catheter. Three studies have demonstrated the usefulness of such prophylaxis in neutropenic patients with long-term catheters *(115-117).* In two of the studies, patients received either heparin alone (10 U/ml) or heparin plus 25 micrograms/ml of vancomycin. The third study compared vancomycin/ciprofloxacin/heparin (VCH) to vancomycin/heparin (VH)and then to heparin alone. The rate of CRBSI with vancomycin-susceptible organisms was significantly lower (VCH $p = 0.022$; VH $p = 0.028$) and the time to the first episode of bacteremia with vancomycin-susceptible organisms was substantially longer (VCH $p = 0.036$; VH $p = 0.011$) in patients receiving either vancomycin/ciprofloxacin/heparin or vancomycin/heparin compared with heparin alone *(115—117).* One study involving a limited number of children revealed no difference in rates of CRBSI between children receiving a heparin flush compared with those receiving heparin and vancomycin

(118). However, because the use of vancomycin is an independent risk factor for the acquisition of VRE *(102),* this practice is not recommended routinely.

An anticoagulant/antimicrobial combination comprising minocycline and ethylenediaminetetraraacetic acid (EDTA) has been proposed as a lock solution because it has antibiofdm and antimicrobial activity against gram-positive, gram-negative, and *Candida* organisms *(119),* as well as anticoagulant properties. However, no controlled or randomized trials have demonstrated its efficacy.

Anticoagulants

Anticoagulant flush solutions are used widely to prevent catheter thrombosis. Because thrombi and fibrin deposits on catheters might serve as a nidus for microbial colonization of intravascular catheters *(120,121),* the use of anticoagulants might have a role in the prevention of CRBSI.

In a meta-analysis evaluating the benefit of heparin prophylaxis (3 U/ml in TPN, 5,000 U every 6 or 12 hours flush, or 2,500 U low molecular weight heparin subcutaneously) in patients with short-term CVCs, the risk for catheter-related central venous thrombosis was reduced with the use of prophylactic heparin *(122).* However, no substantial difference in the rate for CRBSI was observed. Because the majority of heparin solutions contain preservatives with antimicrobial activity, whether any decrease in the rate of CRBSI is a result of the reduced thrombus formation, the preservative, or both is unclear.

The majority of pulmonary artery, umbilical, and central venous catheters are available with a heparin-bonded coating. The majority are heparin-bonded with benzalkonium chloride, which provides the catheters with antimicrobial activity *(123)* and provides an anti-thrombotic effect *(124).*

Warfarin also has been evaluated as a means for reducing CRBSI by reducing thrombus formation on catheters *(125,126).* In patients with long-term CVCs, low-dose warfarin (i.e., 1 mg/day) reduced the incidence of catheter thrombus. No data demonstrate that warfarin reduces the incidence of CRBSI.

Replacement of Catheters

Peripheral Venous Catheters

Scheduled replacement of intravascular catheters has been proposed as a method to prevent phlebitis and catheter-related infections. Studies of short peripheral venous catheters indicate that the incidence of thrombophlebitis and bacterial colonization of catheters increases when catheters are left in place >72 hours *(66,67,127).* However, rates of phlebitis are not substantially different in peripheral catheters left in place 72 hours compared with 96 hours *(128).* Because phlebitis and catheter colonization have been associated with an increased risk for catheter-related infection, short peripheral catheter sites commonly are rotated at 72—96-hour intervals to reduce both the risk for infection and patient discomfort associated with phlebitis.

Midline Catheters

Midline catheters have been associated with lower rates of phlebitis than short peripheral catheters and with lower rates of infection than CVCs (*129--131*). In one prospective study of 140 midline catheters, their use was associated with a BSI rate of 0.8 per 1,000 catheter-days *(131).* No specific risk factors, including duration of catheterization, were associated with infection. Midline catheters were in place a median of 7 days, but for as long as 49 days. Although the findings of this study suggested that midline catheters can be changed only when there is a specific indication, no prospective, randomized studies have assessed the benefit of routine replacement as a strategy to prevent CRBSI associated with midline catheters.

CVCs, Including PICCs and Hemodialysis Catheters

Catheter replacement at scheduled time intervals as a method to reduce CRBSI has not lowered rates. Two trials have assessed a strategy of changing the catheter every 7 days compared with a strategy of changing catheters as needed *(132,133).* One of these studies involved 112 surgical ICU patients needing CVCs, pulmonary artery catheters, or peripheral arterial catheters *(132),* whereas the other study involved only subclavian hemodialysis catheters *(133).* In both studies, no difference in CRBSI was observed in patients undergoing scheduled catheter replacement every 7 days compared with patients whose catheters were replaced as needed.

Scheduled guidewire exchanges of CVCs is another proposed strategy for preventing CRBSI. The results of a meta-analysis of 12 randomized controlled trials assessing CVC management failed to prove any reduction of CRBSI rates through routine replacement of CVCs by guidewire exchange compared with catheter replacement on an as-needed basis *(134).* Thus, routine replacement of CVCs is not necessary for catheters that are functioning and have no evidence of causing local or systemic complications.

Catheter replacement over a guidewire has become an accepted technique for replacing a malfunctioning catheter or exchanging a pulmonary artery catheter for a CVC when invasive monitoring no longer is needed. Catheter insertion over a guidewire is associated with less discomfort and a significantly lower rate of mechanical complications than are those percutaneously inserted at a new site (755); in addition, this technique provides a means of preserving limited venous access in some patients. Replacement of temporary catheters over a guidewire in the presence of bacteremia is not an acceptable replacement strategy, because the source of infection is usually colonization of the skin tract from the insertion site to the vein *(22,135).* However, in selected patients with tunneled hemodialysis catheters and bacteremia, catheter exchange over a guidewire, in combination with antibiotic therapy, might be an alternative as a salvage strategy in patients with limited venous access *{136-139).*

Hemodialysis Catheters

The use of catheters for hemodialysis is the most common factor contributing to bacteremia in dialysis patients *(140,141).* The relative risk for bacteremia in patients with dialysis catheters is sevenfold the risk for patients with primary arteriovenous fistulas *(142).* Despite the National Kidney Foundation's effort to reduce the number of hemodialysis patients maintained with catheter access, catheter use increased from 12.7% in 1995 to 22.2% in 1999 *(143).* Rates for bacteremia per 100 patient months were 0.2 for arteriovenous fistulas, 0.5 for grafts, 5.0 for cuffed catheters, and 8.5 for noncuffed catheters (CDC, unpublished data, 1999).

To reduce the rate of infection, hemodialysis catheters should be avoided in favor of arteriovenous fistulas and grafts. If temporary access is needed for dialysis, a cuffed catheter is preferable to a noncuffed catheter, even in the ICU setting, if the catheter is expected to stay in place for >3 weeks *(11,144).*

Pulmonary Artery Catheters

Pulmonary artery catheters are inserted through a Teflon® introducer and typically remain in place an average of 3 days. The majority of pulmonary artery catheters are heparin bonded, which reduces not only catheter thrombosis but also microbial usage to the catheter *(145).* Meta-analysis indicates that standard nonheparin-bonded pulmonary artery catheter rates of CRBSI are 5.5 per 1,000 catheter days; for heparin-bonded pulmonary artery catheters, this rate is 2.6 per 1,000 catheter days *(11).* Because the majority of pulmonary artery catheters are heparin-bonded, the relative risk of infection with these catheters is similar to that of CVC (2.6 versus 2.3 per 1,000 catheter days) ***(11).***

A prospective study of 442 pulmonary artery catheters demonstrated an increased risk for CRBSI after 5 days (0/442 CRBSI before 5 days versus 5/442 CSBSI after 5 days; p < 0.001) *(146).* A prospective observational study of 71 pulmonary artery catheters demonstrated higher infection rates in catheters left in place longer than 7 days (2% before 7 days versus 16% after 7 days; p = 0.056) *(147).* However, no studies indicate that catheter replacement at scheduled time intervals is an effective method to reduce CRBSI *(132,135).* In patients who continue to require hemodynamic monitoring, pulmonary artery catheters do not need to be changed more frequently than every 7 days. No specific recommendation can be made regarding routine replacement of catheters that need to be in place for >7 days.

Pulmonary artery catheters are usually packaged with a thin plastic sleeve that prevents touch contamination when placed over the catheter. In a study of 166 catheters, patients who were randomly assigned to have their catheters self-contained within this sleeve had a reduced risk for CRBSI compared with those who had a pulmonary artery catheter placed without the sleeve ($p = 0.002$) *{148).*

Peripheral Arterial Catheters

Peripheral arterial catheters are usually inserted into the radial or femoral artery and permit continuous blood pressure monitoring and blood gas measurements. The rate of CRBSI is comparable to that of temporary CVCs (2.9 versus 2.3 per 1,000 catheter days) (11). One study of peripheral arterial catheters demonstrated no difference in infection rates between changing catheters at scheduled times and changing arterial catheters on an as-needed basis *(132).* One observational study of 71 arterial catheters revealed that 10 local infections and four CRBSIs occurred in patients who had peripheral arterial catheters in place for >4 days compared with one local infection and no CRBSIs in patients whose catheters were in place <4 days ($p < 0.05$) *(147).* Because the risk for CRBSI is likely similar to that of short-term CVCs, arterial catheters can be approached in a similar way. No specific recommendation can be made regarding replacement of catheters that need to be in place for >5 days.

Replacement of Administration Sets

The optimal interval for routine replacement of IV administration sets has been examined in three well-controlled studies. Data from each of these studies reveal that replacing administration sets no more frequently than 72 hours after initiation of use is safe and cost-effective *(149-151).* Data from a more recent study demonstrated that rates of phlebitis were not substantially different if administration sets were left in place 96 hours compared with 72 hours *(128).* When a fluid that enhances microbial growth is infused (e.g., lipid emulsions and blood products), more frequent changes of administration sets are indicated, because these products have been identified as independent risk factors for CRBSI *(152-158).*

Stopcocks (used for injection of medications, administration of IV infusions, and collection of blood samples) represent a potential portal of entry for microorganisms into vascular access catheters and IV fluids. Stopcock contamination is common, occurring in 45% and 50% in the majority of series. Whether such contamination is a substantial entry point of CRBSI has been difficult to prove.

"Piggyback" systems are used as an alternative to stopcocks. However, they also pose a risk for contamination of the intravascular fluid if the device entering the rubber membrane of an injection port is exposed to air or comes into direct contact with nonsterile tape used to fix the needle to the port. Modified piggyback systems have the potential to prevent contamination at these sites *(159).*

Needleless Intravascular Catheter Systems

Attempts to reduce the incidence of sharp injuries and the resultant risk for transmission of bloodborne infections to health-care workers have led to the design and introduction of needleless infusion systems. When the devices are used according to manufacturers' recommendations, they do not substantially affect the incidence of CRBSI *(160-167).*

Multidose Parenteral Medication Vials

Parenteral medications commonly are dispensed in multidose, parenteral medication vials that might be used for prolonged periods for one or more patients. Although the overall risk for extrinsic contamination of multidose vials is likely minimal *(168),* the consequences of contamination might result in life-threatening infection *(169,170).* Single-use vials are frequently preservative-free and might pose a risk for contamination if they are punctured several times.

Special Considerations for Intravascular Catheter-Related Infections in Pediatric Patients

Prevention of CRBSI in children requires additional considerations, although only certain studies have been performed specifically in children. Pediatric data have been derived largely from studies in neonatal or pediatric ICUs and pediatric oncology patients.

Epidemiology

As in adults, the majority of BSIs in children are associated with the use of an intravascular catheter. From 1995 through 2000, the pooled mean catheter-associated BSI rate for all pediatric ICUs reporting data to NNIS was 7.7 per 1,000 catheter days *(171,172).* Umbilical catheter and CVC-associated BSI rates for neonatal ICUs ranged from 11.3 per 1,000 catheter days in children with birth weight <1,000 g to 4.0 per 1,000 catheter days in children whose birth weight was >2,500 g (171). Catheter utilization rates were comparable in adult and pediatric ICUs *(172,173).*

Microbiology

As in adults, the majority of CRBSIs in children are caused by coagulase-negative staphylococci. During 1992-1999, these bacteria accounted for 37.7% of BSIs in pediatric ICUs reporting to NNIS *(12).* Exposure to lipids has been identified as an independent risk factor for development of coagulase-negative staphylococcal bacteremia in very low birth weight infants (i.e., those weighing <1,000 g) (odds ratio [OR] = 9.4; 95% CI = 1.2-74.2) *(155),* as well as candidemia in the neonatal ICU (OR = 5.33; 95% CI = 1.23-48.4) *(154).* Gram-negative bacteria accounted for 25% of BSIs reported in pediatric ICUs *(172),* whereas enterococci and *Candida* spp. accounted for 10% and 9%, respectively *(172).*

Peripheral Venous Catheters

As in adults, the use of peripheral venous catheters in pediatric patients might be complicated by phlebitis, infusion extravasation, and catheter infection *(174).* Catheter location, infusion of parenteral nutritional fluids with continuous IV lipid emulsions, and length of ICU stay before catheter insertion have all increased pediatric patients' risk for phlebitis. However, contrary to the risk in adults, the risk for phlebitis in children has not increased with the duration of catheterization *(174,175).*

Peripheral Arterial Catheters

In a prospective study of 340 peripheral arterial catheters in children, the following two risk factors for catheter-related infection were identified: 1) use of an arterial system that permitted backflow of blood into the pressure tubing and 2) duration of catheterization *(176).* Although a correlation was found between duration of arterial catheterization and risk for catheter colonization, the risk remained constant for 2—20 days at 6.2% *(176).*

Umbilical Catheters

Although the umbilical stump becomes heavily colonized soon after birth, umbilical-vessel catheterization often is used for vascular access in newborn infants. Umbilical vessels can be cannulated easily and permit both collection of blood samples and measurement of hemodynamic status. The incidences of catheter colonization and BSI are similar for umbilical vein catheters and umbilical artery catheters. In several studies, an estimated 40%—55% of umbilical artery catheters were colonized and 5% resulted in CRBSI; umbilical vein catheters were associated with colonization in 22%—59% of cases *(177-179)* and with CRBSI in 3%-8% of cases *(178).* Although CRBSI rates are similar for umbilical catheters in the high position (i.e., above the diaphragm) compared with the low position (i.e., below the diaphragm and above the aortic bifurcation), catheters placed in the high position result in a lower incidence of vascular complications without an increase in adverse sequelae *(178).*

Risk factors for infection differ for umbilical artery and umbilical vein catheters. In one study, neonates with very low birth weight who also received antibiotics for >10 days were at increased risk for umbilical artery CRBSIs *(178).* In comparison, those with higher birth weight and receipt of parenteral nutrition fluids were at increased risk for umbilical vein CRBSI. Duration of catheterization was not an independent risk factor for infection of either type of umbilical catheter.

CVCs

Because of the limited vascular sites in children, attention should be given to the frequency with which catheters are replaced in these patients. In a study in which survival analysis techniques were used to examine the relation between the duration of central venous catheterization and complications in pediatric ICU patients, all of the patients studied (n = 397) remained uninfected for a median of 23.7 days *(180).* In addition, no relation was found between duration of catheterization and the daily probability of infection (r = 0.21; p > 0.1), suggesting that routine replacement of CVCs likely does not reduce the incidence of catheter-related infection *(180).*

Catheter Site Care

Although data regarding the use of the chlorhexidine-impregnated sponge (Biopatch"") in children are limited, one randomized, controlled study involving 705 neonates reported a substantial decrease in colonized catheter tips in infants in the Biopatch'" group compared with the group that had standard dressings (15% versus 24%; RR = 0.6; 95% CI = 0.5—0.9), but no difference in the rates of CRBSI or BSI without a source. Biopatch was associated with localized contact dermatitis in infants of very low birth weight. Of 98 neonates with very low birth weight, 15 (15%) developed localized contact dermatitis; four (1.5%) of 237 neonates weighing >1,000 g developed this reaction (p < 0.0001). Infants with gestational age <26 weeks who had CVCs placed at age <8 days were at increased risk for having localized contact dermatitis, whereas no infants in the control group developed this local reaction *(181).*

Performance Indicators

Performance indicators for reducing CRBSI are 1) implementation of educational programs that include didactic and interactive components for those who insert and maintain catheters; 2) use of maximal sterile barrier precautions during catheter placement; 3) use of chlorhexidine for skin antisepsis; and 4) rates of catheter discontinuation when the catheter is no longer essential for medical management. The impact these recommendations will have on individual institutions should be evaluated using specific performance indicators.

Recommendations for Placement of Intravascular Catheters in Adults and Children

These recommendations are designed to reduce the infectious complications associated with intravascular catheter use. Recommendations should be considered in the context of the institution's experience with catheter-related infections, experience with other adverse catheter-related complications (e.g., thrombosis, hemorrhage, and pneumothorax), and availability of personnel skilled in the placement of intravascular devices. Recommendations are provided for 1) intravascular-catheter use in general; 2) specific devices; and 3) special circumstances (i.e., intravascular-device use in pediatric patients and CVC use for parenteral nutrition and hemodialysis access). Recommendations regarding the frequency of replacing catheters, dressings, administration sets, and fluids also are provided (Appendix B).

As in previous guidelines issued by CDC and HICPAC, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability, and economic impact. The CDC/HICPAC system for categorizing recommendations is as follows:

Category IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies.
Category IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies, and a strong theoretical rationale.
Category IC. Required by state or federal regulations, rules, or standards.
Category II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale.

Unresolved issue. Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists.

I. Health-care worker education and training

A. Educate health-care workers regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections (*39,43,45-47,182-187*)**. Category IA**

B. Assess knowledge of and usage to guidelines periodically for all persons who insert and manage intravascular catheters *(39, 43,46,182,188).* **Category IA**

C. Ensure appropriate nursing staff levels in ICUs to minimize the incidence of CRBSIs (*48,189,190*)**. Category IB**

II. Surveillance

A. Monitor the catheter sites visually or by palpation through the intact dressing on a regular basis, depending on the clinical situation of individual patients. If patients have tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or BSI, the dressing should be removed to allow thorough examination of the site (*1,191-193*)**. Category IB**

B. Encourage patients to report to their health-care provider any changes in their catheter site or any new discomfort. **Category II|**

C. Record the operator, date, and time of catheter insertion and removal, and dressing changes on a standardized form. **Category II**

D. Do not routinely culture catheter tips (*8,194,195*)**. Category IA**

III. Hand hygiene

A. Observe proper hand-hygiene procedures either by washing hands with conventional antiseptic-containing soap and water or with waterless alcohol-based gels or foams. Observe hand hygiene before and after palpating catheter insertion sites, as well as before and after inserting, replacing, accessing, repairing, or dressing an intravascular catheter. Palpation of the insertion site should not be performed after the application of antiseptic, unless aseptic technique is maintained (*43,70,196-200*)**. Category IA**

B. Use of gloves does not obviate the need for hand hygiene (*43,198,199*)**. Category IA**

IV. Aseptic technique during catheter insertion and care

A. Maintain aseptic technique for the insertion and care of intravascular catheters *(22,71,201,202).* **Category IA**

B. Wear clean or sterile gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration Bloodborne Pathogens Standard. **Category IC.** Wearing clean gloves rather than sterile gloves is acceptable for the insertion of peripheral intravascular catheters if the access site is not touched after the application of skin antiseptics. Sterile gloves should be worn for the insertion of arterial and central catheters *(201,203)*. **Category IA**

C. Wear clean or sterile gloves when changing the dressing on intravascular catheters. **Category IC**

V. Catheter insertion

Do not routinely use arterial or venous cutdown procedures as a method to insert catheters *(204-206)*. **Category IA**

VI. Catheter site care

A. Cutaneous antisepsis

1. Disinfect clean skin with an appropriate antiseptic before catheter insertion and during dressing changes. Although a 2% chlorhexidine-based preparation is preferred, tincture of iodine, an iodophor, or 70% alcohol can be used (*73,75,207,208*). **Category IA**

2. No recommendation can be made for the use of chlorhexidine in infants aged <2 months. **Unresolved issue**

3. Allow the antiseptic to remain on the insertion site and to air dry before catheter insertion. Allow povidone iodine to remain on the skin for at least 2 minutes, or longer if it is not yet dry before insertion (*73,75,207,208*). **Category IB**

4. Do not apply organic solvents (e.g., acetone and ether) to the skin before insertion of catheters or during dressing changes *(209)*. **Category IA**

VII. Catheter-site dressing regimens

A. Use either sterile gauze or sterile, transparent, semipermeable dressing to cover the catheter site *(146,210-212)*. **Category IA**

B. Tunneled CVC sites that are well healed might not require dressings. **Category II**

C. If the patient is diaphoretic, or if the site is bleeding or oozing, a gauze dressing is preferable to a transparent, semi-permeable dressing (*146,210-212*). **Category II**

D. Replace catheter-site dressing if the dressing becomes damp, loosened, or visibly soiled *(146,210)*. **Category IB**

E. Change dressings at least weekly for adult and adolescent patients depending on the circumstances of the individual patient *(211)*. **Category II**

F. Do not use topical antibiotic ointment or creams on insertion sites (except when using dialysis catheters) because of their potential to promote fungal infections and antimicrobial resistance *(107,213)*. **Category IA** (See Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients, Section II.I.)

G. Do not submerge the catheter under water. Showering should be permitted if precautions can be taken to reduce the likelihood of introducing organisms into the catheter (e.g., if the catheter and connecting device are protected with an impermeable cover during the shower *(214,215)*. **Category II**

VIII. Selection and replacement of intravascular catheters

A. Select the catheter, insertion technique, and insertion site with the lowest risk for complications (infectious and noninfectious) for the anticipated type and duration of IV therapy (*22,55,59, 216-218).* **Category IA**

B. Promptly remove any intravascular catheter that is no longer essential *(219,220).* **Category IA**

C. Do not routinely replace central venous or arterial catheters solely for the purposes of reducing the incidence of infection *(134,135,221).* **Category IB**

D. Replace peripheral venous catheters at least every 72—96 hours in adults to prevent phlebitis *(128).* Leave peripheral venous catheters in place in children until IV therapy is completed, unless complications (e.g., phlebitis and infiltration) occur *(174,175,222,223).* **Category IB**

E. When usage to aseptic technique cannot be ensured (i.e., when catheters are inserted during a medical emergency), replace all catheters as soon as possible and after no longer than 48 hours (*22,71,201,202).* **Category II**

F. Use clinical judgment to determine when to replace a catheter that could be a source of infection (e.g., do not routinely replace catheters in patients whose only indication of infection is fever). Do not routinely replace venous catheters in patients who are bacteremic or fungemic if the source of infection is unlikely to be the catheter *(224).* **Category II**

G. Replace any short-term CVC if purulence is observed at the insertion site, which indicates infection *(224,225).* **Category IB**

H. Replace all CVCs if the patient is hemodynamically unstable and CRBSI is suspected *(224,225).* **Category II**

I. Do not use guidewire techniques to replace catheters in patients suspected of having catheter-related infection *(134,135).* **Category IB**

IX. Replacement of administration sets*, needleless systems, and parenteral fluids

A. Administration sets

1. Replace administration sets, including secondary sets and add-on devices, no more frequently than at 72-hour intervals, unless catheter-related infection is suspected or documented *(23, 149-151).* **Category** IA
2. Replace tubing used to administer blood, blood products, or lipid emulsions (those combined with amino acids and glucose in a 3-in-l admixture or infused separately) within 24 hours of initiating the infusion *(158,226- 229).* **Category IB.** If the solution contains only dextrose and amino acids, the administration set does not need to be replaced more frequently than every 72 hours *(226).* **Category II**
3. Replace tubing used to administer propofol infusions every 6 or 12 hours, depending on its use, per the manufacturer's recommendation *(230).* **Category IA**

B. Needleless intravascular devices

1. Change the needleless components at least as frequently as the administration set *(160-162, 164-167).* **Category II**
2. Change caps no more frequently than every 72 hours or according to manufacturers' recommendations *(160,162,165,166).* **Category II**
3. Ensure that all components of the system are compatible to minimize leaks and breaks in the system *(163).* **Category II**
4. Minimize contamination risk by wiping the access port with an appropriate antiseptic and accessing the port only with sterile devices (*162,163,165*)**.** **Category IB**

C. Parenteral fluids

1. Complete the infusion of lipid-containing solutions (e.g., 3-in-l solutions) within 24

hours of hanging the solution (*156-158,226,229*). **Category IB**
2. Complete the infusion of lipid emulsions alone within 12 hours of hanging the emulsion. If volume considerations require more time, the infusion should be completed within 24 hours *(156-158)*. **Category IB**
3. Complete infusions of blood or other blood products within 4 hours of hanging the blood *(231-234)*. **Category II**
4. No recommendation can be made for the hang time of other parenteral fluids. **Unresolved issue**

X. IV-injection ports

A. Clean injection ports with 70% alcohol or an iodophor before accessing the system *(164,235,236)*. **Category IA**

B. Cap all stopcocks when not in use *(235)*. **Category IB**

XI. Preparation and quality control of IV admixtures

A. Admix all routine parenteral fluids in the pharmacy in a laminar-flow hood using aseptic technique *(237,238)*. **Category IB**

B. Do not use any container of parenteral fluid that has visible turbidity, leaks, cracks, or particulate matter or if the manufacturer's expiration date has passed *(237)*. **Category IB**

C. Use single-dose vials for parenteral additives or medications when possible *(237,239)*. **Category II**

D. Do not combine the leftover content of single-use vials for later use *(237,239)*. **Category IA**

E. If multidose vials are used
1. Refrigerate multidose vials after they are opened if recommended by the manufacturer. **Category II**
2. Cleanse the access diaphragm of multidose vials with 70% alcohol before inserting a device into the vial *(236)*. **Category IA**
3. Use a sterile device to access a multidose vial and avoid touch contamination of the device before penetrating the access diaphragm *(235,240)*. **Category IA**
4. Discard multidose vial if sterility is compromised *(235,240)*. **Category IA**

XII. In-line filters

Do not use filters routinely for infection-control purposes *(80,241)*. **Category IA**

XIII. IV-therapy personnel

Designate trained personnel for the insertion and maintenance of intravascular catheters *(46,47,210,242)*. **Category IA**

XIV. Prophylactic antimicrobials

Do not administer intranasal or systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or **BSI** *(97,98,108,243)*. **Category IA**

Peripheral Venous Catheters, Including Midline Catheters, in Adult and Pediatric Patients

I. Selection of peripheral catheter

A. Select catheters on the basis of the intended purpose and duration of use, known complications (e.g., phlebitis and infiltration), and experience of individual catheter operators (*67,68,244*). **Category IB**

B. Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis if extravasation occurs *(67,68).* **Category IA**

C. Use a midline catheter or **PICC** when the duration of **IV** therapy will likely exceed 6 days *(244).* **Category IB**

II. Selection of peripheral-catheter insertion site

A. In adults, use an upper- instead of a lower-extremity site for catheter insertion. Replace a catheter inserted in a lower-extremity site to an upper-extremity site as soon as possible *(67,245).* **Category IA**

B. In pediatric patients, the hand, the dorsum of the foot, or the scalp can be used as the catheter insertion site. **Category II**

C. Replacement of catheter

1. Evaluate the catheter insertion site daily, by palpation through the dressing to discern tenderness and by inspection if a transparent dressing is in use. Gauze and opaque dressings should not be removed if the patient has no clinical signs infection. If the patient has local tenderness or other signs of possible CRBSI, an opaque dressing should be removed and the site inspected visually. **Category II**

2. Remove peripheral venous catheters if the patient develops signs of phlebitis (e.g., warmth, tenderness, erythema, and palpable venous cord), infection, or a malfunctioning catheter *(66).* **Category IB**

3. In adults, replace short, peripheral venous catheters at least 72—96 hours to reduce the risk for phlebitis. If sites for venous access are limited and no evidence of phlebitis or infection is present, peripheral venous catheters can be left in place for longer periods, although the patient and the insertion sites should be closely monitored *(66,128,246).* **Category IB**

4. Do not routinely replace midline catheters to reduce the risk for infection *(131).* **Category IB**

5. In pediatric patients, leave peripheral venous catheters in place until IV therapy is completed, unless a complication (e.g., phlebitis and infiltration) occurs *(174,175,222,223).* **Category IB**

III. Catheter and catheter-site care

Do not routinely apply prophylactic topical antimicrobial or antiseptic ointment or cream to the insertion site of peripheral venous catheters *(107,213).* **Category IA**

Central Venous Catheters, Including PICCs, Hemodialysis, and Pulmonary Artery Catheters, in Adult and Pediatric Patients

I. Surveillance

A. Conduct surveillance in ICUs and other patient populations to determine CRBSI rates, monitor trends in those rates, and assist in identifying lapses in infection-control practices *(3,12,16,247-250)-* **Category IA**

B. Express ICU data as the number of catheter-associated BSIs per 1,000 catheter-days for both adults and children and stratify by birth weight categories for neonatal ICUs to facilitate comparisons with national data in comparable patient populations and health-care settings *(3,12,16,247-250)-* **Category IB**

C. Investigate events leading to unexpected life-threatening or fatal outcomes. This includes any process variation for which a recurrence would likely present an adverse outcome *(13)*. **Category IC**

II. General principles

A. Use a CVC with the minimum number of ports or lumens essential for the management of the patient *(251-254)*. **Category IB**

B. Use an antimicrobial or antiseptic-impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after implementing a comprehensive strategy to reduce rates of CRBSI, the CRBSI rate remains above the goal set by the individual institution based on benchmark rates (Table 2) and local factors. The comprehensive strategy should include the following three components: educating persons who insert and maintain catheters, use of maximal sterile barrier precautions, and a 2% chlorhexidine preparation for skin antisepsis during CVC insertion (*84-86,90,91,255)*. Category **IB**

C. No recommendation can be made for the use of impregnated catheters in children. **Unresolved issue**

D. Designate personnel who have been trained and exhibit competency in the insertion of catheters to supervise trainees who perform catheter insertion *(39,43,46,182,187,188)*. **Category IA**

E. Use totally implantable access devices for patients who require long-term, intermittent vascular access. For patients requiring frequent or continuous access, a PICC or tunneled CVC is preferable *(256,257)*. Category **II**

F. Use a cuffed CVC for dialysis if the period of temporary access is anticipated to be prolonged (e.g., >3 weeks) *(144,258)*. **Category IB**

G. Use a fistula or graft instead of a CVC for permanent access for dialysis *(142)*. **Category IB**

H. Do not use hemodialysis catheters for blood drawing or applications other than hemodialysis except during dialysis or under emergency circumstances. **Category II**

I. Use povidone-iodine antiseptic ointment at the hemodialysis catheter exit site after catheter insertion and at the end of each dialysis session only if this ointment does not interact with the material of the hemodialysis catheter per manufacturer's recommendation *(103,114,144)*. **Category II**

III. Selection of catheter insertion site

A. Weigh the risk and benefits of placing a device at a recommended site to reduce infectious complications against the risk for mechanical complications (e.g., pneumothorax, subclavian artery puncture, subclavian vein laceration, subclavian vein stenosis, hemothorax, thrombosis, air embolism, and catheter misplacement) *(22,55,59,218)*. **Category IA**

B. Use a subclavian site (rather than a jugular or a femoral site) in adult patients to minimize infection risk for nontunneled CVC placement *(22,55,59,60)*. Category **IA**

C. No recommendation can be made for a preferred site of insertion to minimize infection risk for a nontunneled CVC *(61-63)*. **Unresolved issue**

D. Place catheters used for hemodialysis and pheresis in a jugular or femoral vein rather than a subclavian vein to avoid venous stenosis if catheter access is needed (259--*263)*. **Category IA**

IV. Maximal sterile barrier precautions during catheter insertion

A. Use aseptic technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet, for the insertion of CVCs (including PICCS) or guidewire exchange (22,77). **Category IA**

B. Use a sterile sleeve to protect pulmonary artery catheters during insertion *{148)*. **Category IB**

V. Replacement of catheter

A. Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections (*132,134,135*)**. Category IB**

B. Do not remove CVCs or PICCs on the basis of fever alone. Use clinical judgment regarding the appropriateness of removing the catheter if infection is evidenced elsewhere or if a noninfectious cause of fever is suspected *(224,264)*. **Category II**

C. Guidewire exchange

1. Do not use guidewire exchanges routinely for nontunneled catheters to prevent infection *(135,265)*. **Category IB**

2. Use a guidewire exchange to replace a malfunctioning nontunneled catheter if no evidence of infection is present *(135,265)*. **Category IB**

3. Use a new set of sterile gloves before handling the new catheter when guidewire exchanges are performed *(22,71)*. **Category II**

VI. Catheter and catheter-site care

A. General measures

Designate one port exclusively for hyperalimen-tation if a multilumen catheter is used to administer parenteral nutrition *(266)*. **Category II**

B. Antibiotic lock solutions

Do not routinely use antibiotic lock solutions to prevent CRBSI. Use prophylactic antibiotic lock solution only in special circumstances (e.g., in treating a patient with a long-term cuffed or tunneled catheter or port who has a history of multiple CRBSIs despite optimal maximal usage to aseptic technique) *(115,116,267,268)*. **Category II**

C. Catheter-site dressing regimens

1. Replace the catheter-site dressing when it becomes damp, loosened, or soiled or when inspection of the site is necessary *(65,146,211)*. **Category IA**

2. Replace dressings used on short-term CVC sites every 2 days for gauze dressings and at least every 7 days for transparent dressings, except in those pediatric patients in which the risk for dis-lodging the catheter outweighs the benefit of changing the dressing (277). **Category IB**

3. Replace dressings used on tunneled or implanted CVC sites no more than once per week, until the insertion site has healed (277). **Category IB**

4. No recommendation can be made regarding the necessity for any dressing on well-healed exit sites of long-term cuffed and tunneled CVCs. **Unresolved issue**

D. No recommendation can be made for the use of chlorhexidine sponge dressings to reduce the incidence of infection. **Unresolved issue**

E. Do not use chlorhexidine sponge dressings in neonates aged <7 days or of gestational age <26 weeks *(181)*. **Category II**

F. No recommendation can be made for the use of sutureless securement devices. **Unresolved issue**

G. Ensure that catheter-site care is compatible with the catheter material *(109,110)*. **Category IB**

H. Use a sterile sleeve for all pulmonary artery catheters *(148).* **Category IB**

Additional Recommendations for Peripheral Arterial Catheters and Pressure Monitoring Devices for Adult and Pediatric Patients

I. Selection of pressure monitoring system

Use disposable, rather than reusable, transducer assemblies when possible *(269-273).* **Category IB**

II. Replacement of catheter and pressure monitoring system

A. Do not routinely replace peripheral arterial catheters to prevent catheter-related infections *(132,147, 221,274).* **Category II**

B. Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system (including the tubing, continuous-flush device, and flush solution) at the time the transducer is replaced *(22,270).* **Category IB**

III. Care of pressure monitoring systems

A. General measures

1. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile *(269,275-277).* **Category IA**

2. Minimize the number of manipulations of and entries into the pressure monitoring system. Use a closed-flush system (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain the patency of the pressure monitoring catheters *(272,278).* **Category II**

3. When the pressure monitoring system is accessed through a diaphragm rather than a stopcock, wipe the diaphragm with an appropriate antiseptic before accessing the system (272). **Category IA**

4. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit *(272,279,280).* **Category IA**

B. Sterilization or disinfection of pressure monitoring systems

1. Use disposable transducers *(272,279-282).* **Category IB**

2. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible *(272,279-282).* **Category IA**

Recommendations for Umbilical Catheters

I. Replacement of catheters

A. Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency, or thrombosis are present *(283).* **Category II**

B. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present *(283).* **Category II**

C. No recommendation can be made for treating through an umbilical venous catheter suspected of being infected. **Unresolved issue**

D. Replace umbilical venous catheters only if the catheter malfunctions. **Category II**

II. Catheter-site care

A. Cleanse the umbilical insertion site with an antiseptic before catheter insertion. Avoid tincture of iodine because of the potential effect on the neonatal thyroid. Other iodine-containing products (e.g., povidone-iodine) can be used *(75,177,178,284,285).* **Category IB**

B. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance *(107,213).* **Category IA**

C. Add low doses of heparin (0.25-1.0 F/ml) to the fluid infused through umbilical arterial catheters *(286-288).* **Category IB**

D. Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed. Optimally, umbilical artery catheters should not be left in place >5 days *(283,289).* **Category II**

E. Umbilical venous catheters should be removed as soon as possible when no longer needed but can be used up to 14 days if managed aseptically *(290,291).* **Category II**

*** Administration sets include the area from the spike of tubing entering the fluid container to the hub of the vascular access device. However, a short extension tube might be connected to the catheter and might be considered a portion of the catheter to facilitate aseptic technique when changing administration sets.**

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TABLE 2. Pooled moans of the distribution of central vonous catheter-associated bloodstream infection rates in hospitals reporting to the National Nosocomial Infection Surveillance System, January 1992-June 2001 (issued August 2001)

Type of intensive care unit	No.	Catheter days	Pool mean/1,000 catheter-days
Coronary	102	252.325	4.5
Carctothofacic	64	419,674	2.9
Me (Seal	135	671.632	59
Medical,'sutgical			
Major teaching	123	579,704	5.3
All ottiers	180	863.757	38
Neurosurgical	47	123,780	4.7
Nursery, high risk (HRN)			
<1,000g	138	438,261	11.3
1.001-1.500 g	136	213,351	6.9
1,501-2.500 g	132	163,697	40
>2,500 g	133	231,573	3.8
Pedalrtc	74	291,631	7.6
Surgical	153	900.948	5-3
Trai*na	25	116.709	7.9
Bum	18	43.196	9.7
Respiratory	7	21,265	3.4

TABLE 3. Most common pathogens isolated from hospital acquired bloodstream infections

Pathogen	1986-1989 (%)	1992-1999 (%)
Coagulase-rwsgallve staprtiylooocci	27	37
Staphylococcus aureus	16	13
Ertlarococcus	8	13
Gram-rtegallve rods	19	14
Escherichia colt	6	2
Ertlerobaclw	5	5
Fseudomonas aeruginosa	4	4
Klebsiella pneumoniae	4	3
Candida spp.	8	8

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