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Pediatrics 2008;121;915
DOI: 10.1542/peds.2007-1577

ARTICLE

Systematic Intervention to Reduce Central Line–Associated Bloodstream Infection Rates in a Pediatric Cardiac Intensive Care Unit

John M. Costello, MD[a], Debra Forbes Morrow, RN[b], Dionne A. Graham, PhD[a,c], Gail Potter-Bynoe, BS[d], Thomas J. Sandora, MD, MPH[d,e], Peter C. Laussen, MBBS[a]

Departments of [a]Cardiology and [b]Nursing, [c]Clinical Research Program, [d]Infection Control Program, and [e]Division of Infectious Diseases, Children's Hospital Boston, Harvard Medical School, Boston, Massachusetts

The authors have indicated they have no financial relationships relevant to this article to disclose.

What's Known on This Subject

CLABs occur commonly and are associated with increased morbidity rates, mortality rates, and health care expenditures in critically ill patients. Systematic interventions may reduce CLAB rates.

What This Study Adds

For the first time, we report CLAB rates for patients being treated in a large, dedicated, pediatric CICU. We also describe the implementation of a number of interventions that were associated with significant reductions in CLAB rates.

ABSTRACT

OBJECTIVE. Our goal was to determine whether an intervention involving staff education, increased awareness, and practice changes would decrease central line–associated bloodstream infection rates in a pediatric cardiac ICU.

METHODS. A retrospective, interventional study using an interrupted time-series design was conducted to compare central line–associated bloodstream infection rates during 3 time periods for all patients admitted to our pediatric cardiac ICU between April 1, 2004, and December 31, 2006. During the preintervention period (April 2004 to December 2004), a committee was convened to track and prevent nosocomial infections. Pretesting demonstrated knowledge deficits regarding nosocomial infection prevention, and educational tools were developed. During the partial intervention period (January 2005 to March 2006), a comprehensive central line–associated bloodstream infection prevention initiative was implemented, including establishment of a unit-based infection control nurse position, education for physicians and nurses, real-time feedback on central line–associated bloodstream infection data, implementation of central venous line insertion, access, and maintenance bundles, and introduction of daily goal sheets on rounds that emphasized timely central venous line removal. Central line–associated bloodstream infection rates in the preintervention, partial intervention, and full intervention (April 2006 to December 2006) periods were compared.

RESULTS. The estimated mean preintervention central line–associated bloodstream infection rate was 7.8 infections per 1000 catheter-days, which decreased to 4.7 infections per 1000 catheter-days in the partial intervention period and 2.3 infections per 1000 catheter-days in the full intervention period. The preintervention central line–associated bloodstream infection rate was significantly higher than the median rate of 3.5 infections per 1000 catheter-days for multidisciplinary PICUs reporting to the National Healthcare Safety Network. During the full intervention period, our central line–associated bloodstream infection rate was lower than this pediatric benchmark, although statistical significance was not achieved.

CONCLUSIONS. A multidisciplinary, evidence-based initiative resulted in a significant reduction in central line–associated bloodstream infections in our pediatric cardiac ICU.

www.pediatrics.org/cgi/doi/10.1542/peds.2007-1577

doi:10.1542/peds.2007-1577

This work was presented in part at Cardiology 2007: 10th Annual Update on Pediatric Cardiovascular Disease; February 23, 2007; Orlando, FL.

Key Words
nosocomial infection, pediatric intensive care units, bacterial infection, congenital heart defect, infection control, catheter

Abbreviations
BCBS-MA—BlueCross BlueShield of Massachusetts
CLAB— central line–associated bloodstream infection
BSI— bloodstream infetion
CVL— central venous line
CICU— cardiac ICU
NHSN—National Healthcare Safety Network

Accepted for publication Sep 14, 2007

Address correspondence to John M. Costello, MD, Division of Cardiac Intensive Care, Department of Cardiology, Children's Hospital Boston, 300 Longwood Ave, Bader 600, Boston, MA 02115. E-mail: john.costello@cardio.chboston.org

EACH YEAR IN the United States alone, an estimated 48 600 to 80 000 central line–associated bloodstream infections (CLABs) occur in patients cared for in ICUs.[1] These infections are associated with increased attributable morbidity and mortality rates in adult ICU patients.[2] A pediatric matched case-control study found that an additional 14.6 ICU days and 21.1 hospital days were required for children who acquired a nosocomial bloodstream infection (BSI), and the attributable mortality rate was 13%.[3] CLABs are the most common type of health care–associated infection occurring in patients in multidisciplinary PICUs.[4,5] In addition to the adverse effects on

patient outcomes, CLABs result in a significant financial burden to the health care system, with attributable costs estimated at $11 971 to $39 219 per episode.[6,7] For critically ill patients, there is growing evidence that CLABs are largely preventable. Systematic initiatives that emphasize staff education and the sterile insertion and timely removal of central venous lines (CVLs) have been associated with substantial reductions in CLAB rates in single-center reports and multicenter collaborative studies.[8–12] The prevention of CLABs has become a priority for hospitals, regulatory agencies, and third-party payers.

Several reports described BSI rates in children recovering from cardiac surgery.[13–16] However, those studies used variable definitions of BSIs, and the reported rates were not indexed per 1000 catheter-days, as is currently recommended by the Centers for Disease Control and Prevention National Healthcare Safety Network (NHSN) (formerly known as the National Nosocomial Infection Surveillance System).[1,17] Furthermore, total CLAB rates for children with heart disease necessitating medical and/or surgical management who are cared for in dedicated pediatric cardiac ICU (CICU) have not been published. These patients may be at increased risk for developing CLABs because of their young age, high incidence of major surgical procedures, frequent use of multiple invasive devices, and common exposure to the immunosuppressive effects of cardiopulmonary bypass.[18,19]

This retrospective study aimed to establish a baseline CLAB rate in a large, dedicated, pediatric CICU. Using an interrupted time-series design, we also sought to determine whether a multifaceted intervention would reduce the CLAB rate.[20] We hypothesized that the preintervention CLAB rate in this setting would exceed the rates reported to the NHSN by medical/surgical PICUs because of differences in case mixtures and device utilization. We also hypothesized that the CLAB rate would decrease following a multidisciplinary systematic intervention that included staff education, implementation of evidenced-based bundles for CVL insertion, access and maintenance, and timely feedback on BSI rates to ICU staff members.

METHODS

The study was approved by the committee on clinical investigation at Children's Hospital Boston, and the requirement for written informed consent was waived. The study was conducted in the dedicated pediatric CICU at Children's Hospital Boston, a quaternary care, freestanding, pediatric institution. In June 2005, the CICU was relocated from a 21-bed unit to a 24-bed unit in a new inpatient tower. All patients who require intensive care primarily for management of heart disease are admitted to this ICU, including patients recovering from congenital heart disease surgery, preoperative newborns with duct-dependent congenital heart disease, and patients with heart disease who require medical or transcatheter interventions. Patients with significant underlying heart disease who require intensive care for management of noncardiac disorders are also admitted to this unit, as are adults with congenital heart disease.

A retrospective review completed in late 2003 of 1106 admissions to our CICU during calendar year 2002 revealed 77 primary BSIs (11.6 BSIs per 1000 patient-days; CVL utilization data were not available). These concerning data stimulated the formation of a cardiovascular program nosocomial infection committee, which convened at monthly meetings beginning in April 2004. This multidisciplinary committee was chaired by the chief of the Division of Cardiac Intensive Care (Dr Laussen). Committee members included representatives from the CICU's medical and nursing staff, cardiac anesthesia service, cardiac surgery service, cardiac catheterization laboratory, inpatient cardiac floor, and outpatient cardiac clinic and the hospital's Division of Infectious Diseases, infection control program, respiratory therapy service, and pharmacy. Administrative support was provided by the hospital's program for patient safety and quality. The committee's goals were to track nosocomial infections prospectively, to increase awareness of nosocomial infections, to provide education for staff members, and to implement practice changes when indicated.

During a preintervention period that lasted from April through December 2004, the committee members obtained consultations from internal and external infection control experts and reviewed the available literature regarding CLAB prevention.[1,9,21–23] All practices relevant to CVL insertion, access, and maintenance were thoroughly reviewed. A pretest was administered to all CICU staff members and identified knowledge deficits regarding CLAB prevention, such as the Centers for Disease Control and Prevention preferred agents for skin antisepsis before CVL insertion, the need for hand hygiene before donning sterile gloves, and the implications of the phrase "maximal sterile barriers." Educational tools were developed that addressed CLAB epidemiologic features and outlined optimal techniques for CVL insertion, access, and maintenance. The basic diagnostic evaluation for all CICU patients with a possible nosocomial infection was standardized and included obtaining ≥2 blood cultures during each evaluation. In collaboration with the infection control program, committee members began active participation in prospective surveillance for CLABs attributable to the CICU.

Throughout the entire study period, all positive blood cultures that occurred while patients were in (or within 48 hours after transfer from) the CICU were subcategorized jointly by 2 cardiovascular program nosocomial infection committee members (Ms Forbes Morrow and Ms Potter-Bynoe) as either a CLAB, a secondary BSI, a primary BSI, or a contaminant, by using NHSN surveillance definitions.[1,24] When uncertainty existed, additional input was sought from other committee members (Drs Costello, Laussen, and Sandora) until a consensus was reached. A CLAB was defined by using NHSN criteria for a laboratory-confirmed BSI in a patient with a central access device that terminated at or close to the heart or one of the great vessels and had been in use during the 48-hour period before the development of the BSI. A laboratory-confirmed BSI was identified if 1 of 3 criteria found in Table 1 was met. We excluded any

TABLE 1 **NHSN Criteria for Laboratory-Confirmed BSIs**

Criterion 1	Patient has a recognized pathogen cultured from ≥1 blood culture, and the pathogen cultured from the blood is not related to an infection at another site.
Criterion 2	Patient has ≥1 of the following: fever of >38°C, chills, or hypotension and ≥1 of the following: (1) common skin contaminant (eg, diphtheroids, *Bacillus* spp, *Propionibacterium* spp, coagulase-negative staphylococci, or micrococci) cultured from ≥2 blood cultures drawn on separate occasions; (2) common skin contaminant (eg, diphtheroids, *Bacillus* spp, *Propionibacterium* spp, coagulase-negative staphylococci, or micrococci) cultured from ≥1 blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy; or (3) positive antigen test results on blood (eg, *Hemophilus influenzae*, *Streptococcus pneumoniae*, *Neisseria meningitidis*, or group B streptococcus) and symptoms with positive laboratory results that are not related to an infection at another site.
Criterion 3	Patient <1 year of age has ≥1 of the following: fever of >38°C, hypothermia of <37°C, apnea, or bradycardia and ≥1 of the following: (1) common skin contaminant (eg, diphtheroids, *Bacillus* spp, *Propionibacterium* spp, coagulase-negative staphylococci, or micrococci) cultured from ≥2 blood cultures drawn on separate occasions; (2) common skin contaminant (eg, diphtheroids, *Bacillus* spp, *Propionibacterium* spp, coagulase-negative staphylococci, or micrococci) cultured from ≥1 blood culture from a patient with an intravenous line, and the physician institutes appropriate antimicrobial therapy; or (3) positive antigen test results on blood (eg, *H influenzae*, *S pneumoniae*, *N meningitidis*, or group B streptococcus) and symptoms with positive laboratory results that are not related to an infection at another site.

BSIs that developed within 48 hours after admission to our CICU if the CVL had been placed at an outside institution and there was clinical or laboratory evidence of active infection at the time of admission. The CLAB rate per 1000 catheter-days was obtained by dividing the number of CLABs by the number of CVL-days and multiplying this value by 1000. The device utilization ratio was obtained by dividing the number of CVL-days by the number of patient-days. Primary BSIs were defined as laboratory-confirmed BSIs in patients who did not have a central vascular access device in use within the 48-hour period before the development of the BSI.[1] Secondary BSIs were defined as laboratory-confirmed BSIs in patients who also met NHSN criteria for infection at another site (eg, urinary tract infection, pneumonia, or surgical site infection). A positive blood culture was determined to be contaminated if a common skin contaminant (eg, diphtheroids, *Bacillus* spp, *Propionibacterium* spp, coagulase-negative staphylococci, or micrococci) grew in a single blood culture and the physician did not institute appropriate antimicrobial therapy.[1] The number of days between CLABs was recorded throughout the study period.

During a partial intervention period that lasted from January 2005 through March 2006, a number of evidence-based interventions that aimed at reducing the CLAB rate were implemented (Table 2).[1] A CICU-based infection control nurse position (0.75 full-time equivalent) was established to facilitate the effort. The position

TABLE 2 **Dates of Introduction of Key Interventions to Reduce CLABs**

Implementation Date	Intervention
January 2005	CVL insertion bundle
January 2005	Chlorhexidine-based skin preparation
January 2005	Chlorhexidine-eluting disk applied to percutaneous CVL insertion sites[30]
January 2005	Real-time feedback on infection rates to CICU staff members
January 2005	Mandatory nurse education
February 2005	CICU-based infection control nurse position
March 2005	CVL access and maintenance bundles
May 2005	Mandatory physician education
June 2005	Daily goal sheets on rounds
February 2006	CVL insertion kit
March 2006	Needleless connector system with positive displacement valve

was filled by an experienced CICU nurse (Ms Forbes Morrow) who understood the nuances of pediatric cardiac critical care and routine processes and procedures used in our CICU. The manager of the hospital's infection control program provided mentoring and instruction critical to the development of this position. The unit-based infection control nurse applied 25% of her efforts to bedside patient care, which allowed direct assessment of the practicality of practice changes. This nurse collaborated closely with the hospital's infection control staff members and assumed primary responsibility for prospective BSI surveillance, instruction during educational sessions, and implementation of evidence-based practice changes. Mandatory, detailed, educational sessions regarding CLAB prevention were conducted for all CICU nursing and physician staff members and included PowerPoint (Microsoft, Redmond, WA) presentations, a 15-page handout, question-and-answer periods and, for nursing staff members, hands-on demonstrations of CVL access and maintenance techniques.[21,22]

A CVL insertion bundle was implemented in the CICU, cardiac catheterization laboratory, and cardiac operating rooms.[9] This bundle included a CVL insertion checklist that emphasized assessment of vessel patency by using ultrasonography or previous catheterization reports, proper hand hygiene, and the use of maximal sterile barrier precautions. For patients with gestational age of >37 weeks, a 2% chlorhexidine gluconate with 70% isopropyl alcohol applicator was used for skin antisepsis, replacing the previously used povidone/iodine product. For patients with gestational age of <37 weeks, 70% alcohol remained the agent for skin antisepsis. A customized CVL insertion kit that contained all of the necessary equipment for sterile performance of the procedure (except for the actual central venous catheter and the appropriately sized sterile gloves) was also developed. Key items included in this kit were a cap, a mask, a gown, drapes, sterile towels, a marking pen, a 2% chlorhexidine gluconate with alcohol applicator with gloves for skin antisepsis, suture, and a second 2% chlorhexidine gluconate with alcohol applicator, for use be-

TABLE 3 **CVL Insertion, Access, and Maintenance Bundles**

CVL insertion bundle	Confirm CVL necessity with attending physician
	Review CVL insertion checklist
	Perform time-out to confirm patient identification and insertion site
	Use hand hygiene before donning and after removing gloves
	Use CVL insertion kit with maximal sterile barriers
	Skin antisepsis: 2% chlorhexidine if patient of EGA of >37 wk or 70% alcohol × 3 if patient of EGA of <37 wk
	Include CVL insertion "observer" with documented sign-off
CVL access bundle	Use hand hygiene
	Use clean gloves when accessing line
	Hub disinfection: 10-s alcohol scrub and dry with every entry
	Change end caps whenever removed to access lines
CVL maintenance bundle	No routine replacement of CVLs
	Use CVL dressing change kit to change dressing every 7 d or when damp, soiled, or loose
	Use hand hygiene and sterile gloves
	Skin antisepsis: 2% chlorhexidine if patient of EGA of >37 wk or 70% alcohol × 3 if patient of EGA of <37 wk
	Apply chlorhexidine-eluting disk after CVL insertion and every 7 d[30]
	Use transparent semipermeable dressing
	Use gauze only if bleeding or oozing; if required, change gauze at least every 2 d

EGA indicates estimated gestational age.

fore application of the transparent dressing. A CVL maintenance bundle, which standardized the technique for maintaining and changing CVL dressings, was developed and implemented. The CVL access bundle emphasized sterile technique, including a 10-second alcohol scrub before each entry into a CVL hub. The CVL insertion, access, and maintenance bundles are summarized in Table 3.

A daily goal sheet that emphasized the timely removal of CVLs once they were no longer clinically needed was introduced for use during morning rounds. For access to the CVLs, we converted our needleless connector system from a Luer lock-activated valve system (Clearlink IV access system [Baxter Healthcare, Deerfield, IL]) to a device that has a flat access surface and contains a positive-displacement valve (MaxPlus needleless connector [Medegen Medical Manufacturing Services, Ontario, CA]). The positive-displacement valve has a fully cleanable surface and eliminates retrograde flow into the catheter when an infusion device is disconnected from an infusion port.

Throughout this time period, feedback regarding current CLAB rates and initiatives was provided to all CICU physician and nursing staff members through educational sessions, morbidity and mortality conferences, and electronic communications. A hand hygiene campaign was also conducted throughout the hospital. In March 2005, the CICU began participating in the Child Health Corporation of America 2005 national collaborative to reduce CLABs, although many of the interventions noted above had already been implemented (Table 2). Because risk factors for CLABs have not been definitively identified for this patient population, the initiatives to prevent CLABs were applied to all patients.

Financial incentives to reduce CICU BSI rates were incorporated into the hospital's 3-year contract with a major third-party payer, BlueCross BlueShield of Massachusetts (BCBS-MA). The first year of the contract called for the establishment of baseline CLAB rates in the CICU. During the next 2 years, target CLAB rates that determined incentive payments to the hospital and the physicians' organization were established. BCBS-MA received a quarterly rolling average of CLABs per 1000 patient-days and per 1000 device-days, and they audited 20 medical charts each quarter, to ensure compliance with reporting. During the full intervention period, which lasted from April through December 2006, no new strategies aimed at CLAB reduction were introduced in the CICU, although feedback on infection rates and reminders regarding compliance with existing initiatives were commonly provided during bedside rounds and morbidity and mortality conferences.

Compliance with use of the CVL insertion bundle and the CVL maintenance bundle was assessed by qualified observers (either infection control personnel or trained nurses) during the partial intervention and full intervention periods. Compliance with use of the CVL insertion bundle was assessed for all percutaneous CVLs placed in the cardiac operating rooms. Compliance with use of the CVL insertion and maintenance bundles was assessed when the unit-based infection control nurse was available (three 12-hour shifts per week) for the procedure for all of 2005 and quarterly during 2006. Medical staff members were generally aware that compliance with use of CVL insertion and maintenance bundles was being assessed. Compliance with hand hygiene in the CICU was assessed by trained observers on a periodic basis throughout the study period. Compliance was deemed adequate when hand hygiene was performed by a health care provider before the provider touched a patient or any invasive device, before the provider donned gloves, after the provider removed gloves, and before the provider left the patient room. Medical staff members generally were not aware that compliance with hand hygiene was being assessed. Compliance with use of the CVL access bundle was not assessed.

Because this study had an interrupted time-series design, segmented regression models were used to model mean monthly CLAB rates and days between CLABs during the 3 study periods, that is, preintervention (April 2004 through December 2004), partial intervention (January 2005 through March 2006), and full intervention (April 2006 through December 2006).[25] The monthly CLAB rates were square root transformed and the days between CLABs were logarithmically transformed before analysis, to homogenize the variance of the residuals. Independent predictors in the models included time and study period. On the basis of the results of Durbin-Watson tests and Akaike's information criterion, a first-order autoregressive parameter was included

TABLE 4 **Cardiac ICU Demographic Data**

Period	Admissions, *n*	Age, Median (Interquartile Range), y	Patient-Days	CVL-Days	LOS, Median (Interquartile Range), d	ECMO Runs, *n* (%)	CPR, *n* (%)	Open Chest, *n* (%)
Preintervention (April 2004 to December 2004)	911	1.1 (0.1–6.8)	4449	2951	3 (2–6)	17 (1.9)	28 (3.1)	65 (7.1)
Partial intervention (January 2005 to March 2006)	1472	0.8 (0.1–6.9)	8135	5234	3 (2–7)	45 (3.1)	54 (3.7)	131 (8.9)
Full intervention (April 2006 to December 2006)	936	0.9 (0.2–9.0)	5649	3675	4 (2–8)	32 (3.4)	50 (5.3)	79 (8.4)

CPR indicates cardiopulmonary resuscitation; ECMO, extracorporeal membranous oxygenation; LOS, length of stay.

to adjust for serial autocorrelation. Model estimates for both outcomes were converted back to the natural units (BSIs per 1000 catheter-days or days between CLABs) for presentation.

Compliance with hand hygiene and with use of the CVL insertion and maintenance bundles was compared between study periods by using χ^2 tests or Fisher's exact tests, as appropriate. Our estimated mean CLAB rates and device utilization ratios were compared with the NHSN published values by using Wald tests. Statistical significance was achieved with a 2-sided P value of $<.05$. CVL device utilization data were collected in April, August, and November 2004 and then continuously beginning in February 2005. Because the monthly mean device utilization ratio for the entire study period was 0.65 ± 0.05, a device utilization ratio of 0.65 was imputed for all but 3 months between April 2004 and January 2005.

RESULTS

Between April 1, 2004, and December 31, 2006, there were 3319 admissions to the CICU and 18 233 total patient-days. Demographic data regarding the CICU patient population during the 3 study periods are presented in Table 4.

A total of 133 positive blood cultures and 67 CLABs occurred during the entire study period. The adjudication of all positive blood cultures obtained during each study period is shown in Table 5. Compared with the preintervention period, there was a significant reduction in CLAB rates during the partial intervention and full intervention periods (Table 6 and Fig 1). The mean time between CLABs increased from 6.8 days (95% confidence interval: 4.4–10.5 days) during the preintervention period to 20.1 days (95% confidence interval: 10.3–39.1 days) during the full intervention period ($P = .008$) (Fig 2).

The median pediatric medical/surgical ICU CLAB rate reported by the NHSN from January to December 2006, based on 48 144 catheter-days, was 3.5 CLABs per 1000 catheter-days.[17] The preintervention rate of 7.8 CLABs per 1000 catheter-days in our CICU was significantly higher than the NHSN benchmark ($P < .0001$), ranking among the highest quartile of reported hospital-specific rates. Our full intervention rate of 2.3 CLABs per 1000 catheter-days was lower than the NHSN benchmark and trended toward statistical significance ($P = .09$). The device utilization ratio in our CICU throughout the entire study period (0.65; 11 860 CVL-days per 18 233 patient-days) varied little over time (Fig 1). Our device utilization ratio was significantly greater than the median value reported by the NHSN for pediatric medical/surgical ICUs (0.44; $P < .0001$) and ranked above the 90th percentile of hospitals reporting to the NHSN.

Compliance with use of the CVL insertion bundle in the cardiac operating rooms and CICU improved from 87% ($n = 323$ observations) during the partial intervention period to 94% ($n = 357$ observations) during the full intervention period ($P < .001$). Compliance with use of the CVL maintenance bundle in the CICU improved from 85% ($n = 92$ observations) during the partial intervention period to 99% ($n = 60$ observations) during the full intervention period ($P = .004$). Compliance with hand hygiene in the CICU improved from 38% ($n = 84$ observations) during the preintervention period to 85.5% ($n = 273$ observations) during the full intervention period ($P < .001$).

DISCUSSION

In this study, we established a baseline CLAB rate for a large, dedicated, pediatric CICU. We also found that a systematic initiative that included the creation of a unit-based infection control nurse position and several evidence-based interventions was associated with a significant reduction in the CLAB rate.

Ideally, our baseline preintervention CLAB rate would be compared with data from other pediatric CICUs of comparable size and case mixture. Despite the increase in the number of pediatric CICUs in recent years, CLAB

TABLE 5 **Adjudication of All Positive Blood Culture Results in the CICU**

Period	*n*				
	Total Positive Blood Cultures	Contaminant	Primary Non–CVL-Associated BSI	Secondary BSI	CLAB
Preintervention (April 2004 to December 2004)	43	11	0	6	26
Partial intervention (January 2005 to March 2006)	60	13	3	14	30
Full intervention (April 2006 to December 2006)	30	12	0	7	11

TABLE 6 **CLAB Rates During the 3 Study Time Periods**

Period	CLAB, Mean (95% CI), Cases per 1000 Device-Days	*P*[a]
Preintervention	7.8 (5.6–10.5)	
Partial intervention	4.7 (3.4–6.3)	.029
Full intervention	2.3 (1.2–3.8)	.0002

CI indicates confidence interval.

[a] Compared with preintervention.

data from these specialized ICUs have not been published. The pooled mean CLAB rate derived from data submitted by 36 pediatric medical/surgical ICUs to the NHSN in 2006 was 5.3 BSIs per 1000 device-days. Our preintervention CLAB rate of 7.8 CLABs per 1000 catheter-days significantly exceeded this NHSN benchmark.

The CVL device utilization ratio in the NHSN pediatric medical/surgical ICUs was 0.49, which is significantly lower than the mean device utilization ratio of 0.65 in our CICU during this study; this suggests differences in case mixtures, patient acuity, and/or practice patterns. Despite the introduction of daily goals sheets on morning rounds that automatically triggered an inquiry regarding whether any CVLs could be removed, our device utilization ratio changed little over time. We speculate that unnecessary CVLs were generally removed in a timely manner before the onset of the CLAB initiative, leaving little room for improvement. However, we continue to use the daily goals sheets, because they may serve to maintain awareness of other CLAB interventions.

The interventions chosen for this initiative addressed both individual provider factors (eg, education and feedback) and systems factors (eg, checklists and the CVL insertion kit).[8,26] The association between the introduction of these interventions and the reduction in CLAB rates is consistent in timing and magnitude with the results of similar evidence-based approaches reported in single-center studies and multicenter collaborative studies.[9–12] As was the case with those studies, the importance of the individual components of our initiative cannot be determined, because many factors were introduced simultaneously. Identifying the impact of individual components might have limited utility, however, because most ICUs would implement multifactorial interventions to reduce CLAB rates.

We also did not attempt to adjust for patient demographic features, severity of illness, or surgical procedures during the study period. We acknowledge that there may be specific circumstances related to the intensity or complexity of care that could be identified and that would allow additional measures to be incorporated to reduce the incidence of CLABs in an at-risk population. By establishing and sustaining a successful system for reducing CLABs as outlined, it may be possible to determine realistically patient-related risk factors that contribute to CLABs and health care-associated infections in general.

Our pretesting identified substantial knowledge deficits regarding optimal techniques to minimize CLABs, and we think that staff education was important for the success of the initiative.[21,22] The real-time feedback on CLAB rates served to keep staff members fully informed and engaged in the initiative. Leadership came from within the CICU, which we think increased our ability to achieve cooperation from the staff and to create a change in culture regarding CLAB prevention. A commitment to this effort by hospital administrators and our program for patient safety and quality was also important, particularly for the establishment of an ICU-based infection control nurse position.

We think it is both practically and financially feasible to sustain this intervention over the long term. There were 15 fewer CLABs in the 9-month full intervention period, compared with the 9-month preintervention period (Table 5). Using published cost analyses from adult ICUs and general PICUs and assuming that our initiative prevented ~20 CLABs per year in our CICU, we estimate

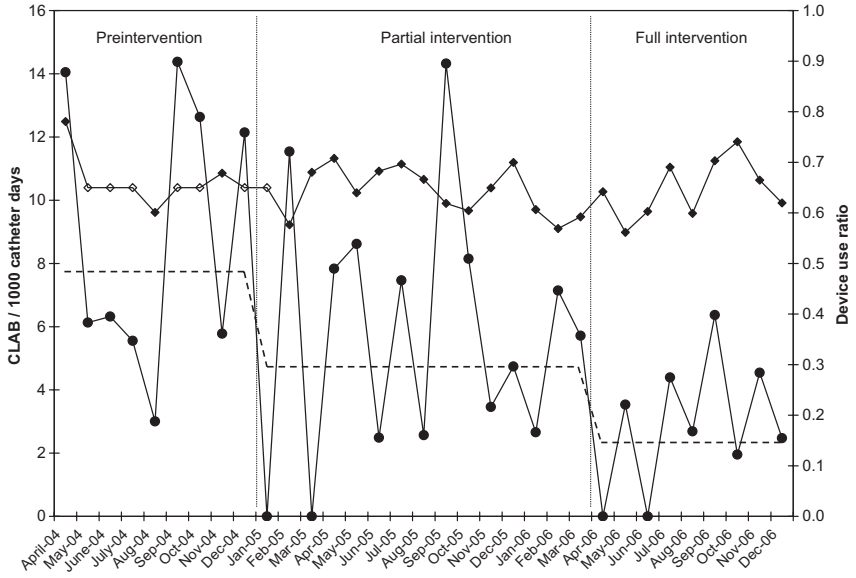

FIGURE 1
Monthly CLAB rates (circles) and CVL device use ratios (diamonds) during the 3 study periods. Closed diamonds indicate months when device use ratio data were prospectively collected; open diamonds, months when device use ratio data were imputed; dashed horizontal line, the estimated mean CLAB rate for each study period.

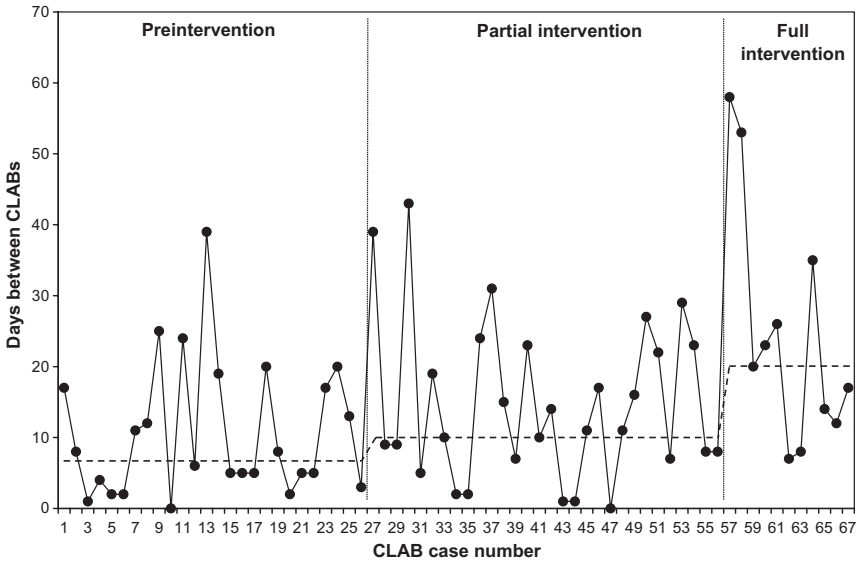

FIGURE 2
Days between CLABs from April 2004 through December 2006. The horizontal dashed line represents the estimated mean number of days between CLABs during each study period.

an annual attributable cost savings of $236 000 to $782 000.[6,7] Furthermore, the interventions reported in this study should be generalizable to other ICUs with baseline CLAB rates that approximate or exceed our preintervention CLAB level. It is possible that a threshold CLAB rate exists, below which implementation of these interventions confers no measurable benefit.

The BCBS-MA "pay-for-performance" incentive to reduce CLAB rates in our CICU was an important external driver to effect change. We did not perceive the involvement of BCBS-MA as excessive oversight; instead, we accepted this third-party payer as another stakeholder with legitimate interest in improving the quality of care. BCBS-MA did not introduce new changes or care bundles and did not interfere with our clinical practice in any way. The contract negotiations were collaborative, and CLAB rate targets were established through direct discussions and review of existing data by all parties. The first year of the contract (July 2004 through June 2005) called for submission of baseline CLAB data. Target CLAB rates for the second and third years of the contract (July 2005 through June 2006 and July 2006 through June 2007, respectively) were based on the CLAB rolling quarterly average during the previous year. The BCBS-MA target CLAB rates and our corresponding CLAB rates were routinely presented to the CICU nursing and physician staff members at monthly morbidity and mortality conferences. To date, our CLAB rates have always been under the set targets and incentive payments have been distributed.

There are several interventions that may have a role in CLAB prevention that we elected not to incorporate into our initiative. Antibiotic-impregnated catheters were not placed in any of our patients during this study, because current guidelines do not recommend their use unless basic interventions are ineffective.[1] After completion of an ongoing study to identify risk factors for CLABs in this patient population, we plan to use antibiotic-impregnated catheters for patients at greatest risk. We also did not monitor or take steps to minimize the number of times that arterial or central venous catheters were accessed during the study period.[27] Periodic audits of the frequency of CVL access were initiated after the conclusion of this study, however, and education is planned to minimize the frequency of CVL access through consolidation of laboratory draws and to encourage administration of medications through peripheral intravenous catheters when appropriate. Finally, although maintenance of normoglycemia may reduce nosocomial infections in adult surgical ICU patient populations, the safety and efficacy of this practice have not been demonstrated in critically ill children.[28] We are currently enrolling children in a clinical trial (clinicaltrials.gov identifier NCT00443599) to determine whether strict glycemic control improves early postoperative outcomes after cardiac surgery.

There are several limitations to this study. First, the NHSN surveillance definitions for CLABs are subject to adjudication bias, because they allow variability in clinical practices or recognition of a secondary source of infection to influence the categorization of blood culture results in selected circumstances.[29] Application of the more-rigorous NHSN criteria for catheter-related BSIs was not possible because our clinical microbiology laboratory does not perform quantitative blood cultures routinely, and use of stricter criteria would limit our ability to benchmark results against those of other centers that use the surveillance definitions.[1] Second, the categorization of positive blood culture results was not made by an independent outcomes committee. However, adjudication bias seems unlikely, because the reduction in the total number of positive blood cultures after our intervention was clearly related to a decreased number of CLABs, whereas the numbers of secondary BSIs and contaminants remained constant (Table 5). Another potential limitation of this study is that patient acuity was not quantified over the study period, largely because validated severity-of-illness scores do not exist

for pediatric CICU patients. During the study period, however, there were no changes in our referral patterns, surgical volume, microbiology laboratory practices, or nursing staffing ratios, and selected measures suggested that our patient acuity tended to increase over the course of the study (Table 4). Compliance with our interventions was assessed only intermittently, and preintervention compliance data were not collected. Causality between our interventions and the reduction in CLAB rates cannot be definitively proved. We note that the timing and magnitude of the improvement in CLAB rates in our CICU were consistent with those observed in other ICUs that implemented similar initiatives.[8–12] Finally, a randomized trial is the optimal study design to control for potential, unrecognized, confounding variables in assessments of health care interventions, but such trials are not always feasible. Although the interrupted time-series design we used is a robust method for examining observational data of this nature, no design entirely eliminates the possibility that unmeasured confounders influenced the study outcomes.[20,25]

CONCLUSIONS

The implementation of a multifactorial, evidence-based initiative was associated with a significant reduction in the CLAB rate in our large, dedicated, pediatric CICU. The CLAB rate during the full intervention period may serve as a new benchmark for large, dedicated, pediatric CICUs. Additional research is ongoing to identify risk factors for CLABs in this setting and to determine outcomes for patients who experience CLABs.

ACKNOWLEDGMENTS

We acknowledge the CICU nursing and physician staff members for their efforts with this project and the program for patient safety and quality at Children's Hospital Boston, which provided administrative and statistical support for this study.

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FOR TOP MEDICAL STUDENTS, APPEARANCES OFFER AN ATTRACTIVE FIELD

"Boston—As thousands of medical students await word this week on residency programs, two specialties concerned with physical appearance—dermatology and plastic surgery—are among the most competitive. Only 61 percent of seniors at American medical schools whose first choice was dermatology received a residency in that field last year, compared with 98 percent for those whose first choice was internal medicine and 99 percent for those seeking family medicine, according to a report by the Association of American Medical Colleges and the National Resident Matching Program, which pairs candidates and programs. Although there are far fewer positions in dermatology (320 residencies in 2007) than in internal medicine (5517) and family medicine (2603), the field is attracting some of the best and brightest future doctors. Seniors accepted in 2007 as residents in dermatology and two other appearance-related fields—plastic surgery and otolaryngology (ear, nose and throat doctors, some of whom perform facial cosmetic surgery)—had the highest median medical-board scores and the highest percentage of members in the medical honor society among 18 specialties, the report said. The vogue for such specialties is part of a migration of a top tier of American medical students from branches of health care that manage major diseases toward specialties that improve the life of patients—and the lives of physicians, with better pay, more autonomy and more-controllable hours."

US Seniors Who Matched in 2007

	Percent Matched to Preferred Specialty	No. of Residencies Offered	Average Salary for Doctors, $
Dermatology	61	320	390 274
Plastic surgery	63	92	408 065
General surgery	90	1057	330 215
Emergency medicine	92	1384	258 088
Pediatrics	97	2424	188 496
Internal medicine	98	5517	191 525
Family medicine	99	2603	178 859

Sources: National Resident Match Program; Association of American Medical Colleges; Medical Group Management Association

Singer N. *New York Times*. March 19, 2008
Noted by JFL, MD

Systematic Intervention to Reduce Central Line–Associated Bloodstream Infection Rates in a Pediatric Cardiac Intensive Care Unit

John M. Costello, Debra Forbes Morrow, Dionne A. Graham, Gail Potter-Bynoe, Thomas J. Sandora and Peter C. Laussen

Pediatrics 2008;121;915
DOI: 10.1542/peds.2007-1577