Reducing Catheter-Associated Urinary Tract Infections: A Quality-Improvement Initiative

BACKGROUND: Catheter-associated urinary tract infections (CAUTIs) are among the most common health care–associated infections in the United States, yet little is known about the prevention and epidemiology of pediatric CAUTIs.

METHODS: An observational study was conducted to assess the impact of a CAUTI quality improvement prevention bundle that included institution-wide standardization of and training on urinary catheter insertion and maintenance practices, daily review of catheter necessity, and rapid review of all CAUTIs. Poisson regression was used to determine the impact of the bundle on CAUTI rates. A retrospective cohort study was performed to describe the epidemiology of incident pediatric CAUTIs at a tertiary care children’s hospital over a 3-year period (June 2009 to June 2012).

RESULTS: Implementation of the CAUTI prevention bundle was associated with a 50% reduction in the mean monthly CAUTI rate (95% confidence interval: 21.28 to 20.12; P = .02) from 5.41 to 2.49 per 1000 catheter-days. The median monthly catheter utilization ratio remained unchanged; ∼90% of patients had an indication for urinary catheterization. Forty-four patients experienced 57 CAUTIs over the study period. Most patients with CAUTIs were female (75%), received care in the pediatric or cardiac ICUs (70%), and had at least 1 complex chronic condition (98%). Nearly 90% of patients who developed a CAUTI had a recognized indication for initial catheter placement.


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ABBREVIATIONS
CAUTI—catheter-associated urinary tract infection
CDC—Centers for Disease Control and Prevention
CHOP—The Children’s Hospital of Philadelphia
IHI—Institute for Healthcare Improvement
IP—infection preventionist
NHSN—National Healthcare Safety Network
PDSA—Plan, Do, Study, Act
QI—quality improvement

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Health care–associated infections are common complications among hospitalized patients in the United States.\(^1\) In adults, the urinary tract is the most common site of infection and accounts for \(\sim 40\%\) of all reported health care–associated infections, the majority of which are catheter-associated urinary tract infections (CAUTIs).\(^2\) Adults with CAUTI are at risk of serious sequelae, including pyelonephritis, bacteremia, and meningitis.\(^3\) In addition, CAUTI has been associated with poor outcomes among hospitalized patients, including increased length of stay, higher hospital costs, and death.\(^4\)\(^,\)\(^5\) Annually, CAUTI is associated with up to 13 000 deaths\(^1\) and \(\sim 450\) million of direct health care costs in the United States.\(^6\) However, little is known about the complications and costs associated with pediatric CAUTI. Although research and quality improvement (QI) efforts have yielded valuable information about effective strategies to prevent adult CAUTI,\(^7\)\(^,\)\(^8\) much less is known about the epidemiology and prevention of CAUTI in children. A point prevalence survey conducted in 1999 by the Pediatric Prevention Network found the multicenter rate of pediatric CAUTI in PICUs to be 13.3 infections per 1000 urinary catheter-days.\(^8\) A recent report from the Centers for Disease Control and Prevention’s (CDC’s) National Healthcare Safety Network (NHSN) revealed that the pooled mean rates of CAUTI were similar in adult and PICUs in 2011.\(^2\) National guidelines for CAUTI prevention published by the Institute for Healthcare Improvement (IHI), CDC, and the Society for Healthcare Epidemiology of America are based largely on data from adult studies.\(^7\)\(^,\)\(^8\) Two pediatric facilities recently reported CAUTI reductions associated with a hospital-wide initiative to eliminate serious harm\(^10\) and a PICU initiative to reduce device-associated infections.\(^11\) Recognizing that 65% to 70% of CAUTIs are considered preventable,\(^12\) we initiated a hospital-wide CAUTI prevention effort in July of 2010. At that time, our hospital’s overall CAUTI rate was significantly higher than the national pooled mean for PICUs (5.4 vs 2.2 infections per 1000 catheter-days). Our goal was to reduce our hospital-wide CAUTI rate by at least 50% within 1 year by implementing an evidence-based bundle of practices based on adult CAUTI prevention strategies. Below, we describe our QI project to develop and implement a CAUTI prevention bundle, compare the hospital-wide CAUTI rates before and after implementation of our multifaceted intervention, and describe the epidemiology of pediatric CAUTI at our center.

**METHODS**

**Study Designs, Setting, and Population**

We conducted 2 observational studies by using data from July 2009 to June 2012. First, we performed an observational, retrospective analysis to assess changes in infection rates before and after a multidisciplinary QI project was initiated (July 2010) to reduce the rate of pediatric CAUTI throughout the institution, a 500-bed tertiary care children’s hospital where \(\sim 40\%\) of beds are in ICUs. We also performed a retrospective analysis of CAUTI at our hospital during the same 3-year period. We conducted house-wide surveillance for CAUTI in accordance with state regulations with the use of NHSN definitions for symptom-atric urinary tract infection throughout this period; episodes of asymptomatic bacteruria were not included.\(^10\) Because our CAUTI surveillance and QI efforts targeted all units within the hospital, patients \(> 18\) years of age were included in this analysis.

The Institutional Review Board at The Children’s Hospital of Philadelphia (CHOP) reviewed and approved this study. This article was prepared in accordance with the SQUIRE (Standards for QUality Improvement Reporting Excellence) guidelines.\(^13\)

**Prevent CAUTI QI Plan**

The Prevent CAUTI leadership team was formed in July 2010 and consisted of stakeholders with complementary expertise and spheres of influence (Table 1) in response to the recognized gap between our institution’s performance and that of other pediatric institutions. Senior hospital leaders sponsored this initiative after recognizing an opportunity to build on other improvement work being done at CHOP to prevent central line–associated bloodstream infections and ventilator-associated pneumonia. The Prevent CAUTI project was a component of a newly initiated hospital-wide effort to adopt a pervasive “culture of safety” in which all members of the hospital community (including nonclinical support staff, frontline clinicians, and administrators) were expected to prioritize local and institution-wide safety. Each member of the Prevent CAUTI team agreed to take ownership for the initiative and to assume accountability for the institution’s ability to achieve both desired outcomes and sustainable results. The team also had responsibility for establishing the scope and direction of the project.

In an effort to effect rapid change, the team met weekly and created a driver diagram (Fig 1), set goals, developed and implemented an education plan, monitored progress, and addressed any identified or perceived barriers to success. The CHOP Prevent CAUTI team joined the IHI’s CAUTI prevention collaborative (http://www.ihi.org/Topics/CAUTI/Pages/default.aspx) and developed our own CAUTI bundle composed of 4 elements that focused on 2 basic principles: using catheters only when indicated and using...
aseptic technique at all points of care (Table 2). The Prevent CAUTI project used the IHI’s Plan, Do, Study, Act (PDCA) methodology to implement the CAUTI prevention bundle.14

**Collaborative Improvement Work**

The Prevent CAUTI team with the CHOP Simulation Education Center created an intensive education module for all clinicians in areas with the highest rates of urinary catheter placement and/or utilization (including ICUs, oncology unit, emergency department, operating and radiology suites) to accompany the institution-wide rollout of the CAUTI bundle. This educational module included an online tutorial and simulation training (focused on urinary catheter insertion technique) led by a qualified observer. Three of the CAUTI leaders (B.L.E., N.P., and A.T.) trained qualified observers with the use of the insertion checklist (Supplemental Fig 3) to ensure competency. Each qualified observer had to repeat the entire procedure from the beginning until all steps were performed accurately without a prompt. Approximately 200 physicians, advanced practice providers, registered nurses, and radiology technicians completed the initial training and became qualified observers. These qualified observers then validated the insertion skill by observing a return demonstration for all clinicians on high-risk units and preceptors for new nurses. The module was then rolled out to other areas where urinary catheters were in use.

**TABLE 1 Prevent CAUTI QI Team**

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<th>Role Within the Organization</th>
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<tr>
<td>Executive sponsor</td>
<td>Medical Director of Infection Prevention and Control</td>
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<tr>
<td>Team sponsors</td>
<td>Division Chief of Pediatric Urology and Director of Advanced Practice Nursing</td>
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<tr>
<td>Team leaders</td>
<td>Outpatient and inpatient advanced practice providers from high utilization areas</td>
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<td>Team participants</td>
<td>• Infection prevention and control staff</td>
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<td></td>
<td>• Physician/nursing champions on identified high-risk units</td>
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<td>• Supply-chain leadership staff</td>
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<td>• Nurse Researcher</td>
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<td>• Clinical Nurse Specialist</td>
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**FIGURE 1**

Diagram of goals and primary and secondary drivers of pediatric CAUTIs.
including the general medical and surgical units. An additional 1300 clinicians completed the online tutorial that included a training video with a detailed presentation of the appropriate insertion technique. Refresher education with return demonstration was incorporated into each high-risk unit’s annual skills fair. The online tutorial continues to be part of annual mandatory education for all clinicians.

After implementation of the prevention bundle, we began conducting bedside reviews of all CAUTIs to identify barriers and opportunities for improvement. These reviews involved frontline clinicians, infection preventionists (IPs), improvement advisors, and leaders of the Prevent CAUTI team. The Prevent CAUTI team used findings from these reviews to design future PDSA cycles, such as requirement for 2-person insertion, feedback of unit-specific outcome and process data, consistent use of a secure device, and appropriate emptying of the reservoir bag.

**Outcome Measures**

Our primary outcome measure was the monthly hospital-wide CAUTI rate per 1000 catheter-days. Our goal was to reduce our CAUTI rate by 50% in 1 year. Our secondary aim was to reduce total indwelling catheter days by 25% on the basis of our Prevent CAUTI leadership groups’ hypothesis that the duration of catheter placement was the most important risk factor in the development of CAUTI.

**Process Measures**

The primary process measure was review of catheter necessity at the time of insertion and for every day of use with the goal that ≥95% of indwelling catheters would meet ≥1 indication(s) defined by the bundle. The improvement advisor generated monthly, unit-specific, and hospital-wide compliance reports for use at unit-specific QI meetings. We designed PDSA cycles to facilitate and measure daily assessment of catheter necessity during patient care rounds. As part of our plan, daily monitoring of catheter necessity was first conducted on a small scale in 1 high-risk unit and then to all high-risk areas, including general medical and surgical units. Unit champions were identified, trained, and given the responsibility of discussing the necessity of the indwelling catheter with the patient care team on daily rounds. If no indication was identified, the patient care team discussed whether the catheter could be removed.

To determine compliance with the key bundle measure, unit charge nurses assessed daily all patients on their unit for the presence of and an indication for a urinary catheter. These data were then collated to measure the impact of the PDSA cycles.

Our secondary process measure evaluated compliance with the newly created catheter insertion checklist, including the recommendation that 2 care providers participate in catheter insertion, including a qualified observer who was instructed to provide immediate feedback if any steps were missed. If aseptic technique was compromised, the procedure was abandoned, a new catheter insertion kit was obtained, and then the procedure was repeated from the beginning. A commercial urinary catheter insertion kit is used that contains all materials necessary for catheter insertion other than the catheter itself (Vygon/Churchill Medical Systems, Lansdale, PA).

**Observational Study of CAUTI**

**Data Sources and Collection**

The study team used records from the CHOP Department of Infection Prevention and Control to identify all CAUTIs and capture hospital-wide urinary catheter device days. Certified IPs performed CAUTI surveillance through daily review of microbiology laboratory results to identify possible infections with supplemental chart review to determine whether the NHSN criteria for symptomatic CAUTI were met. Each unit’s charge nurse or designee performed a daily count of urinary catheter device days, which the IP team then compiled.

For the epidemiologic study, 2 members of the study team (A.T. and B.L.E.) gathered supplemental clinical data on patients with CAUTI from the medical record with the use of a structured data abstraction tool (Supplemental Information). Because there was not a standard location or an established person responsible for documenting the indication for the urinary catheter, we reviewed the admission notes and the progress notes 24 hours before placement through 48 hours after removal of the urinary catheter. Two people abstracted ∼20% of the charts to ensure interrater reliability; <5% of data elements showed discrepancies.

**Definition of Variables**

Demographic and clinical data were collected including age, gender, date of
CAUTI, catheter insertion and removal date(s), organism(s) isolated, and hospital unit at the time of CAUTI. Additional data collected through chart review included the following: immunocompromised status, off-unit transport with catheter in place, patient location, functional or anatomic genitourinary condition, and other chronic conditions.

A clinical member of the Prevent CAUTI leadership team performed chart review to identify the indication for indwelling urinary catheter (Table 2) at the time of initial catheter placement. Documentation used to evaluate catheter indication included the following: admission, progress, and nursing notes; the medication administration record for oncology patients receiving caustic chemotherapeutic agents; anesthesia records for surgical patients; and palliative care team documents and/or Do Not Resuscitate orders. In critically ill children requiring catheter placement, the team assessed whether hemodynamically unstable patients met systemic inflammatory response syndrome criteria or received vasoactive medications; these patients were presumed to require monitoring of urine output every hour.

Statistical Analyses
We analyzed CAUTI rates before and after implementation of our prevention bundle by using Poisson regression with 95% confidence intervals. We conducted a sensitivity analysis allowing for a 1-month run-in time to account for more gradual adoption of the bundle practices. For our analysis of epidemiologic characteristics of CAUTI, we performed univariate analyses to summarize patient-level demographic, clinical, and microbiologic characteristics. We summarized results as frequencies and percentages. Comparisons were made by using Fisher’s exact test or Wilcoxon rank-sum (Mann-Whitney) test, as appropriate, with a 2-tailed P value of <.05 indicating statistical significance. Analyses were performed by using Stata version 10.0 (StataCorp, College Station, TX).

RESULTS
Rates of CAUTI Before and After Implementation of a Prevention Bundle
Over the 3-year period, 44 patients experienced 57 CAUTIs, including 23 CAUTIs during the 12 months pre-implementation and 34 during the 24 months after implementation of the CAUTI bundle. Before implementation of the CAUTI prevention bundle, the mean monthly CAUTI rate was 5.41 infections per 1000 catheter-days. The CAUTI prevention bundle was initially implemented in high-risk units that care for 90% of patients with urinary catheters. After implementation of the CAUTI prevention bundle, the mean monthly CAUTI rate was 2.49 infections per 1000 catheter-days (Fig 2). Adherence to the key process measure, indication for a urinary catheter, was not measured before implementation of the bundle but rapidly rose to >90%; ongoing assessments verify that this high level of compliance has persisted (data not shown). The most common indications for urinary catheters were for monitoring of hemodynamic status (50%) and managing urinary retention/obstruction (38%). The catheter utilization ratio on high-risk units remained stable at 0.12 after implementation of the CAUTI prevention bundle.

Analysis by Poisson regression indicated that the intervention was associated with a 50% reduction in the rate of CAUTI (95% confidence interval: −1.28 to −0.12; P = .02). We performed a sensitivity analysis to account for more gradual adoption of the bundle practices and included a 1-month lag into our model; this analysis confirmed that our intervention was associated with a similar reduction in CAUTIs (52% reduction; P < .001). The CAUTI prevention bundle was subsequently rolled out to all units that care for patients with urinary catheters. We did not observe any further reductions in CAUTIs associated with this second wave of implementation.

Epidemiology of CAUTI
Most of the 44 patients who experienced a CAUTI were female (n = 33, 75%) with a median age of 10.3 years (interquartile range: 0.5–15.5) at time of infection (Table 3). Five patients were >18 years at the time of CAUTI; the eldest patient was 42 years old, had multiple congenital anomalies, and was
chronically hospitalized with ventilator dependency. The majority of patients were receiving care in the pediatric or cardiac ICU at the time of CAUTI onset (n = 20 [45%] and n = 11 [25%], respectively). Nearly all patients had at least 1 chronic condition. Twenty-two (50%) patients had ≥1 recognized risk factor(s) for CAUTI, including an underlying genitourinary condition (n = 12, 27%), an immunocompromising condition (n = 5, 11%), and history of intermittent catheterization at home (n = 6, 13%). Patients with CAUTI before, compared with those after, implementation of the prevention bundle were more likely to have a history of intermittent catheterization at home (P = .008).

**Microbiology of CAUTI**

The majority of CAUTIs were caused by *Enterobacteriaceae* spp (n = 24, 55%) and *Pseudomonas aeruginosa* (n = 11, 25%) (data not shown). The remaining infections were due to yeast (n = 5, 11%), *Enterococcus* spp (n = 3, 7%), and *Lactobacillus* spp (n = 1, 2%). Nearly all CAUTIs were due to a single organism (n = 42, 95%). There were no observed differences in the spectrum of organisms before versus after the intervention (data not shown).

**DISCUSSION**

We report the changing rates of pediatric CAUTI before and after implementation of a prevention bundle and describe the epidemiology of CAUTI in a tertiary care children’s hospital. We found that hospitalized children with a urinary catheter had a substantial risk of CAUTI before our intervention. A recent report from the CDC’s NHSN revealed that in 2011 the pooled means of CAUTI rates were similar for adult ICUs, which is consistent with our observation that >80% of CAUTIs occurred in critically ill patients. Our findings also suggest that female patients are more likely than male patients to acquire a CAUTI and chronic conditions were prevalent among patients who developed CAUTI. Approximately one-third of patients who developed a CAUTI had either an anatomic or a functional abnormality of their genitourinary tract.

Despite multiple previous reports of successful CAUTI prevention QI projects directed at adult patients, little is known about the ability of these evidence-based bundles to prevent CAUTI in hospitalized children. A recent report from a US children’s hospital described a nonsignificant reduction in the hospital-wide rate of CAUTIs after implementation of a comprehensive patient safety program designed to eliminate preventable harm. A Spanish PICU reported a reduction in CAUTIs associated with implementation of a nosocomial infection prevention bundle, although the CAUTI rates were markedly elevated in this unit (23.3 infections per 1000 urinary catheter-days) before implementation. Our bundle, which focused on minimizing the inappropriate use of urinary catheters and improving adherence to aseptic technique when placing or manipulating a catheter, relied on 2 of the most common elements of adult CAUTI prevention bundles, consistent with our assumption that the pathogenesis of adult and pediatric CAUTI is similar. However, unlike reports in adults, we did not note a marked reduction in device utilization with the
implementation of our bundle. This difference is consistent with our observation that ~90% of our patients had a recognized indication for urinary catheter. Because we did not observe a marked reduction in the utilization of urinary catheters, we hypothesize that improved adherence to aseptic technique, both at the time of catheter placement and during subsequent use, may have played the major role in CAUTI prevention. However, we do not have process data that describe the frequency of breaks in aseptic technique before and after our intervention.

On the basis of success achieved by adult CAUTI prevention efforts,16,17 we now aim to eliminate CAUTI in our patient population. To accomplish this goal, we are focused on sustaining the improvements attained by this work in insertion and routine care of patients with urinary catheters while expanding the components of our maintenance bundle. To prevent diminished compliance with CAUTI prevention practices, we continue to feedback performance data from our insertion checklist. Additionally, unit leaders conduct point prevalence surveys to assess compliance with maintenance practices related to urinary catheters and other indwelling medical devices. New interventions designed by our Prevent CAUTI working group focus on appropriate handling of the urinary reservoir bag during patient transport and movement.

This study has several limitations. First, we were unable to determine whether the interventions introduced actually caused the observed reduction in CAUTI rates or if this improvement was related to enhanced attention paid to the issue or another unmeasured factor. As a retrospective study, it is subject to misclassification bias. Although the comprehensive nature of CAUTI surveillance performed at our hospital likely minimized this bias, others have noted that there can be significant variation in the application of surveillance definitions for CAUTI and other healthcare-associated infections.19 Additionally, this report describes the experience of a single, large, tertiary care freestanding children’s hospital and the findings may not be generalizable to all pediatric settings. Because frontline clinicians were responsible for collecting process measures, such as adherence to the insertion bundle, these data were potentially biased by the Hawthorne effect. We did not assess the compliance with every individual component of the insertion or maintenance bundles and therefore were unable to identify all potential barriers to full implementation. We did not attempt to validate the accuracy of data collection on either process measures or urinary catheter-days, both measures that were collected by unit staff and thus subject to bias. Similarly, because our CAUTI prevention interventions were simultaneously introduced as a single bundle, we were unable to determine the relative contribution of individual activities to CAUTI prevention. Finally, we did not capture costs associated with this work.

CONCLUSIONS

Hospitalized children with urinary catheters have a significant risk of developing a CAUTI. We noted a significant reduction in CAUTIs associated with a multidisciplinary, hospital-wide QI initiative that developed and implemented a pediatric CAUTI prevention bundle. Future work is needed to assess the capacity to implement a similar CAUTI prevention bundle in other pediatric settings and to determine whether implementation is consistently associated with reduced pediatric CAUTI.

ACKNOWLEDGMENTS

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REFERENCES


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