# A point prevalence survey of health care–associated infections in pediatric populations in major Canadian acute care hospitals

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***Objective:*** To estimate the prevalence of pediatric health care–associated infections (HAI) in Canadian acute care hospitals.
***Methods:*** A point-prevalence study conducted in February 2002 in 25 hospitals across Canada. Information on HAI, utilization of antimicrobial agents and invasive devices, isolation precautions, and microbial etiology was collected.
***Results:*** Nine hundred ninety-seven children were surveyed. Ninety-one HAI were detected in 80 patients for a prevalence of 91 per 1000 patients surveyed. Bloodstream infections were the most common HAI (3% of patients; 34% of all HAI). The prevalence of patients with HAI was 8%, ranging from 0% in trauma/bum units to 19% in the pediatric intensive care units, and 27% in transplant units. By multivariate logistic regression analysis, having a central venous catheter (OR, 2.54; 95% CI, 1.46-4.40) or endotracheal tube with mechanical ventilation (OR, 2.59; 95% CI, 1.16-5.76) were independently associated with an HAI, as were being in isolation (OR, 2.90; 95% CI, 1.54-5.45), and receiving antimicrobial agents (OR, 9.27; 95% CI, 4.71-18.52).
***Conclusion:*** In this first national point-prevalence study in Canada, the prevalence of HAI was similar to that reported in other industrialized countries. These data will also be useful to provide an estimate of the health burden of pediatric HAI in Canada.
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Nosocomial infections, or health care-associated infections (HAI), are a significant cause of morbidity and mortality.[1,2] Surveillance for HAIs is an important and recommended component of a comprehensive infection prevention and control program at a hospital level and has been widely accepted as a primary step toward the prevention of HAI.[3] The majority of reported prevalence studies in pediatric institutions has focused either on specialized populations (such as pediatric intensive care,[4,5] neonatal intensive care,[6,7] and hematology/oncology patients[8,9]) or on specific types of pathogens or infections, such as methicillin-resistant *Staphylococcus aureus*[6] and bloodstream infections.[9,10] A recent national prevalence study in Switzerland reported pediatric HAI rates.[11] There remains, however, a paucity of information on the prevalence and relative distribution of all types of HAI in all pediatric populations.

We performed a cross-sectional national point prevalence survey of patients of all ages admitted to Canadian institutions participating in the Canadian Nosocomial Infection Surveillance Program (CNISP) to determine the prevalence, associated factors, and microbiology of HAI. We also assessed patterns of antimicrobial and device utilization within these institutions. In this article, we report our results for pediatric patients.

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## METHODS

Twenty-five acute care hospitals that are members of the CNISP participated in a 1-day HAI point prevalence survey between February 5 and 8, 2002. Nineteen of the CNISP hospitals had pediatric patients, defined as children 18 years of age and younger, and contributed data to the study. CNISP is a collaborative effort of the Canadian Hospital Epidemiology Committee (CHEC), a subcommittee of the Association of Medical Microbiology and Infectious Diseases-Canada (formerly the Canadian Infectious Diseases Society), and the Centre for Infectious Diseases Prevention and Control of the Public Health Agency of Canada (PHAC). All CNISP hospitals have university affiliations and provide primary, secondary, and tertiary care to adult and/or pediatric patients.

Eligible children were identified at each hospital from ward census lists obtained at 08:00 on the day the surveillance was to be conducted. Wards were surveyed over a full 24-hour period starting at 08:00 on the census day and finishing at 08:00 the following day. Children admitted after 08:00 were not included, and no child was enrolled more than once during the surveillance period. Data were collected on the status of the child during a full 24-hour period starting at 08:00 on the census day and finishing at 08:00 the following day, and collection began 24 hours after the census to allow sufficient time to have complete medical/nursing entries in the patients' hospitals charts.

The primary outcome was the occurrence of an HAI. HAI was identified as an infection not present on admission and with onset at least 72 hours after admission. All children who had been admitted to participating hospitals on the day of the survey were included in the denominator, although only children admitted for 48 hours or more at the time of the census were surveyed to meet the case definition for HAI. The study was limited to the following infections: pneumonia, urinary tract infections (UTI), bloodstream infections (BSI), surgical site infections (SSI), C*lostridium difficile*-associated diarrhea (CDAD), necrotizing enterocolitis (NE), viral gastroenteritis (VGI), and viral respiratory infections (VRI). The Centers for Disease Control and Prevention (CDC) definitions for nosocomial infections were used for all HAI except central venous catheter-associated BSI.[12] The Canadian Surveillance definitions for central venous catheter-associated BSI were used and are as follows: (1) confirmation of septic thrombophlebitis with a single positive blood culture; or (2) a single positive blood culture and a positive culture of the catheter segment with the identical organism, or a greater than 10-fold colony count difference in the blood cultures drawn from the device and the peripheral blood; or (3) a single positive blood culture and a positive culture from the discharge or aspirate from the exit site, tunnel or pocket, with the identical organism.[13] An infection was considered to be present if a child was symptomatic during the 24-hour surveillance period or was receiving antimicrobial therapy for treatment of an HAI at the time of the survey.

For each child, the following were collected: basic demographic information including date of admission; the admitting medical or surgical service; antimicrobial agents received on the day of the survey; the presence of indwelling devices including urinary catheters, central venous catheters, and endotracheal tubes with or without mechanical ventilation; and isolation precautions. Patients were classified into the following age categories: neonate (0 to <1 month), infant (1 month to <2 years), child (2 to <12 years), or adolescent (12-18 years). Information regarding causative organisms, if available, was also collected. Patients with HAI were identified through chart review, medical rounds, and/or discussions with nursing staff. All patient units and wards were surveyed except for the following: psychiatry, rehabilitation, and day or overnight surgery.

Data were reviewed, and a diagnosis of HAI was made according to study definitions by experienced infection control professionals or trained research personnel associated with each hospital using standard protocol and data collection forms. Conference calls were done before the study began to clarify definitions, and hospital visits were made by the investigators to address local concerns. In addition, PHAC epidemiologists were available by telephone on the survey days to address all questions regarding patient eligibility. There was, however, no formal test of interrater reliability. Methodology had been tested in a pilot study conducted 8 months prior to the survey at one of the CNISP pediatric hospitals.

Data were collected on manually completed patient data collection forms and forwarded to the PHAC for data entry and analysis. Two measures of prevalence were calculated: (1) the prevalence of HAI, defined as the ratio of the number of HAIs to the total number of patients, and (2) the prevalence of patients with HAI, defined as the ratio of the number of patients with 1 or more HAI to the total number of patients.

To assess differences between infected and noninfected children, we used a Wald test for categorical variables and a Student $t$ test for continuous variables. All tests were 2-tailed, and a $P$ value of less than .05 was considered significant. Odds ratios with corresponding 95% confidence intervals were calculated. Data analysis was performed using Microsoft Excel 2000 (Microsoft Corp, Redmond, WA) and SAS version 8.1 (SAS Institute, Cary, NC).

## RESULTS

A total of 997 pediatric patients was surveyed in 19 hospitals. Four facilities were stand-alone pediatric hospitals. The additional 15 hospitals were combined adult-pediatric hospitals. The mean age of the children was 4.3 years (range, 0-18 years). Of these, 249 (25%) were neonates, 356 (36%) infants, 215 (22%) children, and 177 (18%) teens; 447 (45%) were female. There were 420 (42%) children in critical care units (pediatric or neonatal ICU); 345 (35%) on medical pediatric units; 142 (14%) on surgical units; 46 (5%) on hematology/

**Table 1.** Description of the patients surveyed for health care-associated infections according to select characteristics

| | All patients | | Neonate | | Infant | | Child | | Adolescent | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Patient characteristics** | **N** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** |
| | 997 | 100.0 | 249 | 25.0 | 356 | 35.7 | 215 | 21.6 | 177 | 17.8 |
| Medical service | | | | | | | | | | |
| Medicine/pediatrics | 345 | 34.6 | 24 | 9.6 | 129 | 36.2 | 115 | 53.5 | 77 | 43.5 |
| Surgery | 142 | 14.2 | 3 | 1.2 | 43 | 12.1 | 43 | 20.0 | 53 | 29.9 |
| Intensive care units | 420 | 42.1 | 221 | 88.8 | 171 | 48.0 | 19 | 8.8 | 9 | 5.1 |
| Hematology/oncology | 46 | 4.6 | 0 | 0.0 | 5 | 1.4 | 26 | 12.1 | 15 | 8.5 |
| Transplant | 22 | 2.2 | 0 | 0.0 | 7 | 2.0 | 9 | 4.2 | 6 | 3.4 |
| Trauma/burn | 9 | 0.9 | 0 | 0.0 | 1 | 0.3 | 2 | 0.9 | 6 | 3.4 |
| Obstetrics/gynecology | 5 | 0.5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 5 | 2.8 |
| Other | 8 | 0.8 | 1 | 0.4 | 0 | 0.0 | 1 | 0.5 | 6 | 3.4 |
| Patients receiving antimicrobials | 385 | 38.6 | 64 | 25.7 | 126 | 35.4 | 115 | 53.5 | 80 | 45.2 |
| Patients on isolation precautions | 122 | 12.2 | 11 | 4.4 | 72 | 20.2 | 28 | 13.0 | 11 | 6.2 |
| Device utilization | | | | | | | | | | |
| Indwelling urinary catheter | 63 | 6.3 | 6 | 2.4 | 23 | 6.5 | 16 | 7.4 | 18 | 10.2 |
| Central venous catheter | 238 | 23.9 | 55 | 22.1 | 82 | 23.0 | 60 | 27.9 | 41 | 23.2 |
| ETT, no ventilation | 16 | 1.6 | 2 | 0.8 | 7 | 2.0 | 2 | 0.9 | 5 | 2.8 |
| ETT, with mechanical ventilation | 109 | 10.9 | 34 | 13.7 | 51 | 14.3 | 14 | 6.5 | 10 | 5.6 |
| All devices | 312 | 31.3 | 67 | 26.9 | 108 | 30.3 | 75 | 34.9 | 62 | 35.0 |

*ETT*, endotracheal tube.

oncology units; and 44 (4%) on other units including transplant, trauma, and gynecology. Among the total children surveyed, 312 (31%) had at least 1 indwelling device; 238 (24%) had a central venous catheter; 109 (11%) were mechanically ventilated, whereas an additional 16 (2%) had an endotracheal tube but were not mechanically ventilated; and 63 (6%) had an indwelling urinary catheter (Table 1).

Eighty children had a total of 91 HAI, for an overall prevalence of HAI and of infected patients of 9.1% and 8%, respectively. Eleven (1%) children had 2 HAI. The highest prevalence of HAI was in the neonate age group. Neonates were 1.5 times as likely to have an HAI than all other groups combined (9% vs 6%, respectively, $P < .0001$). The prevalence of infected patients ranged from 0% in trauma/burn units to 19% in pediatric intensive care units (PICU) and 27% in transplant units (data not shown). BSIs were the most frequent HAI, found in 30 (3%) of the patients surveyed and most commonly because of coagulase-negative staphylococci (Fig 1). Pneumonia was found in 21 (2%) of the patients; UTI, 10 (1%); SSI, 9 (1%); viral gastroenteritis, 15 (2%); viral respiratory infection, 1 (0.1%); and CDAD, 5 (0.5%). Twenty-five (83%) of the 30 BSI were central venous catheter related, and 13 (62%) of the 21 pneumonia cases were ventilator associated. There were no cases of necrotizing enterocolitis. Gram-negative organisms accounted for the majority of cases of pneumonia and UTI, whereas most SSI were caused by gram-positive cocci (staphylococci and enterococci).

There was a notable trend toward developing an HAI among patients less than the mean age, although this was not statistically significant (3.1 vs 4.4 years of age, respectively, $P = .06$). In univariate analysis, the following factors were associated with infection: being in the neonate age category (OR, 2.1; 95% CI: 0.98-4.57, $P = .06$); being in a pediatric intensive care unit or a transplant unit (OR, 4.2; 95% CI: 1.97-8.91, $P = .0002$ and OR, 6.5; 95% CI: 2.30-18.48, $P = .0004$, respectively); having indwelling devices (OR, 4.7; 95% CI: 2.90-7.59, $P < .0001$) such as an indwelling urinary catheter, central vascular catheter, or

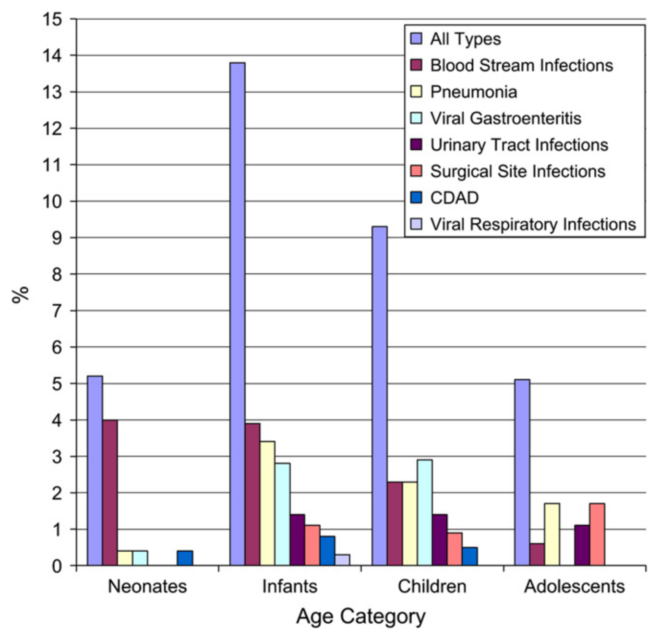


**Fig 1.** Prevalence rates of health care-associated infections by type of infection and age group.

**Table 2.** Comparison of characteristics of patients with and without health care-associated infections

| Article I. Patient characteristics, N = 997 | Infected patients, n = 80 | Noninfected patients, n = 917 | | |
|---|---|---|---|---|
| | No. (%) | No. (%) | OR (95% CI) | *P value** |
| Age group | | | | |
| Neonates | 46 (57) | 441 | 2.11 (0.98-4.57) | .06 |
| Infants | 8 (10) | 84 | 1.93 (0.70-5.32) | .20 |
| Children | 18 (22) | 230 | 1.59 (0.67-3.73) | .29 |
| Adolescents | 9 (11) | 180 | Reference | |
| Medical service | | | | |
| Transplant | 6 (8) | 16 (2) | 6.53 (2.30-18.48) | .0004 |
| Pediatric intensive care unit | 13 (16) | 55 (6) | 4.19 (1.97-8.91) | 0002 |
| Surgery | 12 (15) | 130 (14) | 1.61 (0.76-3.38) | .21 |
| Neonatal intensive care unit | 26 (33) | 326 (36) | 1.39 (0.76-2.53) | .29 |
| Hematology/oncology | 3 (4) | 43 (5) | 1.21 (0.35-4.26) | .76 |
| Medicine/pediatrics | 20 (25) | 325 (35) | Reference | |
| Patients receiving antimicrobials | 69 (86) | 316 (35) | 11.98 (6.22-22.87) | <.0001 |
| Patients not on antimicrobials | 11 (14) | 601 (65) | Reference | |
| Patients on isolation precautions | 24 (30) | 98 (11) | 3.58 (2.13-6.04) | <.0001 |
| Patients not on isolation precautions | 56 (70) | 819 (89) | Reference | |
| Indwelling devices | | | | |
| Indwelling urinary catheter | 12 (15) | 51 (6) | 3.00 (1.52-5.89) | .0002 |
| No indwelling urinary catheter | 68 (85) | 866 (94) | Reference | |
| Central venous catheter | 43 (54) | 195 (21) | 4.30 (2.70-6.86) | <.0001 |
| No central venous catheter | 37 (46) | 722 (79) | Reference | |
| ETT, with mechanical ventilation | 26 (33) | 83 (9) | 4.84 (2.88-8.13) | <.0001 |
| No mechanical ventilation | 54 (67) | 834 (91) | Reference | |
| All devices | 52 (65) | 260 (28) | 4.69 (2.90-7.59) | <.0001 |
| No devices | 28 (35) | 657 (72) | Reference | |

*ETT*, endotracheal tube; *OR*, odds ratio; *CI*, confidence interval.
*Wald or Pearson $\chi^2$ test where appropriate.

**Table 3.** Independent patient characteristics associated with an HAI: stepwise logistic regression model*

| Characteristic | OR | 95% CI | *P value* |
|---|---|---|---|
| Receiving antimicrobial agent | 9.37 | 4.71-18.52 | <.0001 |
| ETT with mechanical ventilation | 2.59 | 1.16-5.76 | .02 |
| Central venous catheter | 2.54 | 1.46-4.40 | .0009 |
| Being on isolation precautions | 2.90 | 1.54-5.45 | .0009 |

*ETT*, endotracheal tube; *OR*, odds ratio; *CI*, confidence interval.
*Adjusted for age, being in NICU or PICU.

endotracheal tube with mechanical ventilation; being in isolation precautions (OR, 3.6; 95% CI: 2.13-6.04, $P < .0001$); and receiving antimicrobials (OR, 11.9; 95% CI: 6.22-22.87, $P < .0001$), (Table 2). In the multivariate logistic regression model for HAI, the following characteristics were all independently associated with an HAI: having a central vascular catheter, having an endotracheal tube with mechanical ventilation, being in isolation and receiving antimicrobials (Table 3). Being in a PICU, NICU, or transplant unit was not independently associated with a HAI.

On the day of the survey, 385 (39%) children were receiving at least 1 systemic antimicrobial agent; 187 (19%) were receiving more than 1 agent. Those in the "child" age category were more often prescribed an agent than those in other age categories (54% vs 35%, respectively, $P < .0001$) and were 1.5 times more likely to be on more than 1 agent than the other age categories combined (27% vs 17%, respectively, $P = .02$). Among the children who had an HAI, 69 (86%) were prescribed antimicrobial agents, most commonly β-lactams (17%), cephalosporins (16%), and aminoglycosides (12%). Three hundred sixteen (82%) patients receiving antimicrobial agents did not have an HAI.

One hundred twenty-two (12%) of the patients surveyed were being managed under additional (transmission based) precautions, in addition to routine precautions.[14] Of these, 11 (4%) were neonates, 72 (20%) were infants, 28 (13%) were children, and 11 (6%) were adolescents. Infants were 2.5 times more likely to be on additional precautions compared with all other groups (20% vs 8%, respectively, $P < .0001$). The most common type of isolation precaution was contact (7%), followed by droplet (6%). Only 0.7% of the patients surveyed were on airborne isolation.

## DISCUSSION

This study is unique in that it examines the prevalence of HAI through hospital-wide surveillance in children hospitalized at multiple acute care hospitals across the country. It provides a robust estimate of burden of disease, distribution of infections, and resource consumption because of HAI in children in Canada. Our results demonstrate that an overall prevalence of infected children was 8%, with infections most common in neonates, and major associated factors as having indwelling devices, being in isolation, and receiving an antimicrobial agent. Contrary to other reported studies, being in a PICU or an NICU was not independently associated with HAI.[4,5,15]

As the first national study of the prevalence of HAI in pediatric patients in Canada, this study provides data that can be used as a baseline for future pediatric HAI prevalence studies, in Canada and elsewhere. Our data demonstrate that children are at a similar risk of HAI as are hospitalized adults. Large multicenter prevalence surveys focusing primarily on adults have shown an overall prevalence of HAI ranging from 4% to 10%[16-21] as compared with our overall prevalence of 9.1% in a pediatric population.

Other countries have reported rates of HAI in children as part of a national comprehensive point prevalence survey.[19,21-26] Four studies looking only at medical-surgical patients reported a prevalence of HAI between 4% and 7%.[19,22-24] These are similar to our findings of 6% for medical-surgical patients. The prevalence of pediatric HAI in Canada is therefore similar to that reported in other developed countries. A possible exception is the higher prevalence of HAI in PICU and a lower prevalence in NICU compared with the United States,[4,6] although, without a better understanding of the demographics of the ICU populations in both countries, it is difficult to make robust comparisons. Similarly, comparisons of HAI rates between countries (as between hospitals within 1 country) may be limited by differences in patient populations, surveillance methods, and definitions of infections. One study from Brazil found an overall prevalence rate of 27.2% in their pediatric population,[25] whereas a prevalence survey from France found an overall prevalence of 4%.[26] Again, comparisons with our findings are difficult to establish without understanding the differences in delivery of health care between these 2 countries.

The present study shows other important results. Infants (1 month to <2 years of age) had a higher prevalence of HAI (12%) than neonates (5%), children (7%), or adolescents (5%) (Table 2). The prevalence of patients with HAI in ICUs (19%) or transplant units (27%) was much higher than the overall prevalence of patients with HAI (8%). The acuity of illness on such units is obviously higher than that of patients on general units. Interestingly, neither ICUs nor transplant units were independently associated with an HAI on multivariate logistic regression. However, the study was not designed to identify causality of associated factors. For example, patients with an HAI were more likely to be receiving an antimicrobial agent than the patients who were not found to have an HAI, and this factor was independently associated with an HAI on logistic regression. However, the association is less likely to be a risk factor but a result of the infection.

There are limitations to our study primarily inherent to large multicenter point prevalence surveys. First, although data collection was conducted by experienced or trained infection control professionals using standardized definitions, the data collection remained unmonitored, and there may be inconsistencies among hospitals in identifying an HAI. Because the diagnosis of an HAI is frequently based on laboratory findings, there may be some variability in the microbiologic laboratory testing. However, all participating hospitals are affiliated with an academic health sciences center and have licensed laboratories that routinely undergo proficiency testing as well as utilizing the same laboratory protocols. Second, we may not have identified patients who were previously hospitalized and readmitted with an HAI, therefore underestimating the true prevalence of HAI. Third, seasonal variations will have influenced the results of this study, particularly for viral respiratory illnesses and viral gastrointestinal disease. Fourth, the populations examined in this study were in major teaching hospitals and so are likely not entirely representative of all hospitalized pediatric populations in Canada. We did not evaluate acuity of illness among hospitals and cannot, therefore, generalize our findings to the general patient population in Canada. In addition, we could expect differences in the acuity of the patients within the participating hospitals. This difference in the patient populations among the hospitals is likely insignificant, given that these hospitals have successfully worked together in the past on a variety of surveillance projects and the patient case mix has been found to be similar in those previous studies. However, because we did not evaluate the interreliability among hospitals, this remains a limitation to the study.

Last, prevalent infections likely differ somewhat in type from incident infections. Freeman and Hutchinson have demonstrated that prevalence studies have higher than comparable incidence rates and are inherently statistically less stable.[27] Ideally, prevalence surveys should be utilized for trend analysis over time.

Despite these limitations, the data presented in this study are an important contribution to understanding the prevalence of HAIs in a Canadian pediatric population. This approach remains a feasible method of evaluating the burden of HAI and increasing awareness of the importance of ongoing surveillance. The results are sufficiently robust to be used as baseline indicators for future comparisons.

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