Infection Control Policies and Hospital-Associated Infections Among Surgical Patients: Variability and Associations in a Multicenter Pediatric Setting

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ABSTRACT. Background. Hospital-associated infections are an important cause of patient morbidity and death. Little is known about the variability of infection rates and infection control practices among pediatric hospitals.

Methods. This cross-sectional study was performed with the Pediatric Health Information System database, which includes demographic and diagnostic data for 35 freestanding, noncompeting, children’s hospitals, and with data from a survey of the hospitals, which yielded additional information on infection control policies and practices. Patients undergoing elective surgical procedures were included in this study.

Results. Of the 35 eligible hospitals, 31 (89%) chose to participate in the survey component of this study. A total of 48,278 patients met the inclusion criteria for the study; 2.3% of these patients had respiratory infections and 0.8% had gastrointestinal infections. The frequency of patients diagnosed with respiratory or gastrointestinal infections varied considerably among the hospitals and ranged from <1% to 6%. Certain infection control processes also varied among the hospitals during the study period. For instance, of the 31 hospitals, 12 monitored hand hygiene, 19 had administrative support of hand hygiene, and 16 had alcohol hand gel present for the entire study period. The presence of alcohol hand gel for the entire study was strongly and independently associated with lower odds of gastrointestinal infections (adjusted odds ratio: 0.64; 95% confidence interval: 0.49-0.85).


ABBREVIATIONS. ICD-9, International Classification of Diseases, Ninth Revision; PHIS, Pediatric Health Information System; OR, odds ratio; CI, confidence interval; CDC, Centers for Disease Control and Prevention.
to both respiratory and gastrointestinal infections. The study protocol was reviewed and approved by the Children’s Hospital and Regional Medical Center institutional review board.

Patients

Our study included pediatric patients (through age 18) with discharge dates between October 1, 2001, and September 30, 2003. Because the PHIS database does not include dates of medical diagnoses, we could not use relative dates of medical diagnoses and procedures to determine hospital-associated infections. Instead, we restricted the analysis to patients hospitalized for procedures that were considered highly likely to have been elective or semielective, under the hypothesis that these patients were least likely to have been admitted with preexisting respiratory or gastrointestinal infections, because elective procedures are typically postponed in the presence of an intercurrent illness. In determining which patients met these criteria, we began with a list of the most commonly performed, primary surgical procedures in the pediatric hospital setting, and clinicians ascertained by consensus which of these would be considered both an elective procedure and the primary reason for admission in the majority of cases (the list included age category (<1, 1–2, or >2 years), gender, Medicaid status, month of admission, hospital bed size, coded medical or surgical complications, comorbid diagnoses (including cancer, diabetes mellitus, immunodeficiencies, sickle cell anemia, cardiovascular disorders, asthma, inflammatory bowel disease, autoimmune rheumatologic disorders, craniofacial disorders, burns, and disorders of prematurity), and type of elective surgical procedure performed (neurologic, ophthalmologic, otorhinolaryngologic, cardiologic, genitourinary, orthopedic, or involving cutaneous tissue). The PHIS database identifies a primary procedure for each patient who has any procedures coded, and these results were matched against our list of included procedures to determine study inclusion. Approximately 80% of these patients underwent their primary procedures within the first 24 hours after admission. If an individual met the study criteria more than once during the time period, then only the first hospitalization was included in the analysis. In addition, only patients from hospitals that participated in the survey could be included in the analysis.

Outcomes

The outcomes we evaluated were hospital-associated respiratory and gastrointestinal infections, defined by the presence of a diagnostic code for an acute respiratory (ICD-9 code 079.6x, 460–462.xx, 464–466.xx, or 480–487.xx) or gastrointestinal (ICD-9 code 500.1.xx–009.xx or 787.91) infection at discharge. For the purposes of the study, we assumed that these infections were the result of hospital transmission, given the elective nature of the admission.

Statistical Analyses

Descriptive analyses and logistic regressions were performed, evaluating respiratory and gastrointestinal infection outcomes separately. We chose not to combine these into a single outcome measure because we hypothesized that there could be differences in the factors associated significantly with each, given the differences in the causative pathogens and the associated differences in modes of transmission. The predictors of interest were derived from the survey. Additional covariates were also evaluated and included age category (<1, 1–2, or >2 years), gender, Medicaid status, month of admission, hospital bed size, coded medical or surgical complications, comorbid diagnoses (including cancer, diabetes mellitus, immunodeficiencies, sickle cell anemia, cardiovascular disorders, asthma, inflammatory bowel disease, autoimmune rheumatologic disorders, craniofacial disorders, burns, and disorders of prematurity), and type of elective surgical procedure performed (neurologic, ophthalmologic, otorhinolaryngologic, cardiologic, genitourinary, orthopedic, or involving cutaneous tissue). Logistic regression analyses were used to evaluate associations between individual predictors of interest and outcomes, with adjustment for the covariates listed above. We then manually built forward, stepwise, multivariate (ie, multiple predictors of interest), regression models that examined which of the predictors of interest had the greatest impact on infection, with control for the other covariates.
covariates. The $P$ values for the odds ratios (ORs) for the predictors of interest from univariate logistic regression analyses determined the order in which predictors of interest were added to the multivariate models. Predictors of interest with $P$ values of $<.25$ were allowed to remain in the final multivariate model.

The regression analyses were clustered with respect to hospital, to account for the decreased variability within hospitals, compared with between hospitals. To protect the anonymity of the participating hospitals, all results are presented with the hospitals not identified. All analyses were conducted with Stata 8.0 software (Stata Corp, College Station, TX).

RESULTS

A total of 48,278 patients met the inclusion criteria for the study. Overall, 59% of the included patients were male, 45% were $\leq 2$ years of age, and 35% were recipients of Medicaid (Table 1). Of the 48,278 patients, 2.3% had respiratory infections and 0.8% had gastrointestinal infections. Among the 1,487 patients with infections, 51 (3%) had both respiratory and gastrointestinal infections. Among the respiratory infections, 45% were pneumonia, 9% were bronchiolitis or respiratory syncytial virus, 14% were croup, tracheitis, laryngitis, or epiglottitis, and 25% were an upper respiratory infection not otherwise specified. Among the gastrointestinal infections, 51% were diarrhea not otherwise specified, 24% were *Clostridium difficile*, and 10% were rotavirus. The frequency of patients being diagnosed with respiratory or gastrointestinal infections varied considerably among the hospitals, ranging from almost 1% to 6% (Fig 1); this variation was statistically significant ($P < .001$). Compared with patients without infections, patients with respiratory and gastrointestinal infections were younger, more likely to receive Medicaid, more likely to have a comorbid diagnosis, and more likely to have experienced a medical or surgical complication and had longer lengths of stay (both total and before surgery) ($\chi^2$ test, $P$ values all $<.05$; data not shown) (Table 1).

Of the 35 eligible hospitals, 31 (89%) chose to participate in the survey component of this study. The mean number of infection control practitioners per 100 beds was 0.71 (SD: 0.26), and 30 of the 31 institutions queried had infectious disease physician support (Table 2). Most institutions isolated patients with respiratory ($n = 30$) or gastrointestinal ($n = 29$) symptoms, performed surveillance for respiratory ($n = 27$) and gastrointestinal ($n = 23$) infections, used personal protective equipment with these patients ($n = 29$ and 28, respectively), and performed viral testing for patients with such symptoms ($n = 26$ and 25, respectively), whereas relatively few centers cohort-assigned symptomatic patients to staff members ($n = 8$ and 5, respectively). More variability was seen regarding policies on visitor screening for communicable illnesses and hand hygiene monitoring and support. Twenty-one institutions had a policy to screen all visitors, whereas 5 had a policy to screen children only and 5 had no policy. Of the 26 institutions that screened visitors, the policies of 25 called for restricting visitation of those who screened positive for communicable illness. Only 12 institutions monitored hand hygiene practices, whereas 19 received administrative resources and support for hand hygiene-related efforts. Alcohol hand gel was available during the study period in all except 2

![Fig 1. Distribution of presumed hospital-associated respiratory and gastrointestinal infections among hospitals. Each bar represents a different hospital (for both infection types, $P < .001$, multiple analysis of variance).](http://pediatrics.aappublications.org/doi/figure/10.1542/peds.2004-2014)
After adjustment for covariates, the presence of alcohol hand gel for the entire study was strongly associated with decreased risk of hospital-associated gastrointestinal infections (adjusted OR: 0.66; 95% confidence interval [CI]: 0.49–0.88; \( P < .01 \)) (Table 3).

The discussion section is not fully visible in the image but it mentions the importance of infection control programs in hospitals and highlights the findings of a multicenter study of 31 freestanding pediatric centers that showed novel findings regarding infection control practices and hospital-associated infections. The study found that (1) the frequency of hospital-associated gastrointestinal and respiratory infections among patients undergoing elective surgical procedures varied considerably among hospitals, (2) infection control practices varied among hospitals, and (3) the presence of alcohol hand gel for the entire period of the study was strongly and independently associated with decreased risk of hospital-associated gastrointestinal infections among patients undergoing elective surgical procedures. The importance of infection control programs in hospitals but was present for the entire study in only 16.

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The addition of other infection control variables (including those in Table 2) to the model including the presence of alcohol hand gel for the entire study and covariates did not change the relationship between the presence of gel and hospital-associated gastrointestinal infections or improve the overall significance of the model. There were no predictors of interest that were associated with respiratory infections after adjustment for covariates.

### Discussion
This multicenter study of 31 freestanding pediatric centers yielded novel findings regarding infection control practices and hospital-associated infections. We found that (1) the frequency of hospital-associated gastrointestinal and respiratory infections among patients undergoing elective surgical procedures varied considerably among hospitals, (2) infection control practices varied among hospitals, and (3) the presence of alcohol hand gel for the entire period of the study was strongly and independently associated with decreased risk of hospital-associated gastrointestinal infections among patients undergoing elective surgical procedures.

The importance of infection control programs in
decreasing hospital-associated infections is well recognized. The Joint Commission on Accreditation of Healthcare Organizations created accreditation standards for infection control in 1976, providing additional stimulus for hospitals to supply administrative and financial support for infection control. The CDC-initiated Study on the Efficacy of Nosocomial Infection Control in the 1970s and 1980s identified 4 infection control components important in reducing hospital-associated infection rates. The 4 elements included the presence of (1) a trained, effectual, infection control physician, (2) an infection control practitioner for every 250 beds, (3) organized surveillance and control mechanisms, and (4) a system for reporting infection rates to practicing surgeons. Although we could not duplicate the complexity of the Study on the Efficacy of Nosocomial Infection Control to confirm this, most if not all of the hospitals involved in our study likely met these basic criteria, given current Joint Commission on Accreditation of Healthcare Organizations standards and the information from the questionnaire demonstrating infectious disease physician involvement in infection control, relatively large numbers of infection control practitioners, and evidence of organized surveillance and control activities. The fact that our study identified few specific components of infection control practice associated with hospital-associated infections may reflect the lack of variation in many of the practices but also may be an indication that having the basic components of an infection control department is more important than the specific policies and procedures adopted.

The one variable we did find to be protective against infections was the availability of alcohol hand gel, which supports the importance of hand hygiene in preventing hospital-associated infections. Multiple lines of evidence, from the work of Ignaz Semmelweis in mid-19th century Vienna to nursery-based studies correlating better hand hygiene with decreased *Staphylococcus aureus* transmission to infants and more recent studies demonstrating an association between the use of antiseptic soaps and decreased nosocomial infection rates, provide proof of the value of hand hygiene. The CDC and many other experts promote hand hygiene as the single most important measure in the prevention of hospital-associated infections. Despite the evidence and expert opinion supporting hand hygiene, many studies have shown that health care workers perform it <50% of the times they should. Commonly cited barriers to health care worker hand hygiene include lack of time and the skin damage that accompanies frequent washing with soap and water. Alcohol-based hand gels address these barriers, because they require a fraction of the time for effective hand hygiene and they are less damaging to skin than soap and water. In addition, alcohol hand gels appear to be more effective in killing many microorganisms and a few studies demonstrated increased frequency of hand hygiene and decreased frequency of hospital-associated infections with provision of alcohol hand gel in the context of institution-wide hand hygiene campaigns. Given the benefits of alcohol hand gel, the CDC now calls for its use as the primary mode of hand hygiene, except when hands are visibly soiled, in its guidelines on hand hygiene in health care settings. However, because of poor activity against bacterial spores, protozoan oocysts, and certain nonenveloped (nonlipophilic) viruses, such as hepatitis A, it is recognized that alcohol hand gel should not be used in outbreak situations involving these organisms.

We cannot state with certainty why alcohol hand gel use was associated inversely with gastrointestinal infections and not with respiratory infections in this study. The finding could be attributable to the fact that, although contact transmission is an important mode of spread for the pathogens of both gastrointestinal and respiratory infections, the agents of gastroenteritis appear to be even more dependent on contact transmission than the agents of respiratory infections.
infections. In addition, rotavirus is a common cause of hospital-associated gastroenteritis and is relatively resistant to common hand hygiene agents but appears to be more susceptible to alcohol hand gel.24,25 Therefore, alcohol hand gel may offer a greater relative benefit against the pathogens of gastroenteritis.

This study has several limitations. First, our data regarding infection control practices were collected through a retrospective survey. Most queries were about the presence of policies and were not necessarily a measure of practice. In addition, certain responses might have been biased according to the infection control practitioners’ knowledge base and their level of awareness with respect to hospital-associated infections within their institutions. However, for either of these factors to have confounded our associations, they would have had to be associated with hospital-associated infection rates. A number of the infection control policies and practices that we examined exhibited little variation among institutions, making it difficult for us to detect whether an association with infection rates existed. It is also possible that some of the infections we included were actually community-acquired infections rather than hospital-associated infections, despite our efforts to reduce misclassification. We do not think, however, that this would have introduced systematic bias. Finally, although we attempted to control for multiple sources of potential confounding in our analyses, it is possible that some residual confounding remained, because this was an observational study and not a randomized, controlled trial. Whether this systematically biased our results would depend on whether variations were associated with particular institutions, something we have no reason to suspect a priori.

Despite these limitations, our study resulted in important findings with respect to hospital-associated infections among patients undergoing elective surgery, as well as infection control practices in the pediatric setting. Hospitals should support the use of alcohol hand gel, with the aim of decreasing hospital-associated infection rates. A number of the infection control policies and practices that we examined exhibited little variation among institutions, making it difficult for us to detect whether an association with infection rates existed. It is also possible that some of the infections we included were actually community-acquired infections rather than hospital-associated infections, despite our efforts to reduce misclassification. We do not think, however, that this would have introduced systematic bias. Finally, although we attempted to control for multiple sources of potential confounding in our analyses, it is possible that some residual confounding remained, because this was an observational study and not a randomized, controlled trial. Whether this systematically biased our results would depend on whether variations were associated with particular institutions, something we have no reason to suspect a priori.

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REFERENCES

1. Haley RW, Culver DH, White J, et al. The efficacy of infection surveil-


5. Bower A, Donald A. Analysis of data arising from a stratified design with the cluster as unit of randomization. Stat Med. 1987;6:43–52

6. Neuhaus JM, Kalbfleisch JD, Hauck WW. A comparison of cluster-

7. Haley RW, Culver DH, White J, et al. The efficacy of infection surveil-

8. Joint Commission on Accreditation of Healthcare Organizations. Surve-


26. Aylin GA, Babb JR, Davies JG, Lilly HA. Hand disinfection: a com-

27. Ayliffe GA, Babb JR, Davies JG, Lilly HA. Hand disinfection: a com-

28. Ayliffe GA, Babb JR, Davies JG, Lilly HA. Hand disinfection: a com-


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