Health Care Worker Exposures to Pertussis: Missed Opportunities for Prevention

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KEY WORDS
infection control, pertussis, occupational exposure, health care worker, ambulatory care

ABBREVIATIONS
ED—emergency department
EHR—electronic health record
HCW—health care worker
IPC—infection prevention and control
IPD—infection Prevention and Control Department
OH—occupational health
OHD—Occupational Health Department
PEP—postexposure prophylaxis
PPE—personal protective equipment
Tdap—tetanus, diphtheria, and pertussis

Ms Kuncio contributed to study design, performed data collection and analyses, and produced the first draft of and reviewed and revised the manuscript; Ms Middleton aided in data cleaning and analyses and reviewed and revised the manuscript; Ms Cooney contributed to study design and implementation and reviewed and revised the manuscript; Mr Ramos contributed to data collection and study execution and reviewed and revised the manuscript; Dr Coffin contributed to study design, actively directed data analyses, and reviewed and revised the manuscript; Dr Feemster conceptualized the study design, supervised data analyses and study implementation, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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Pertussis is a highly communicable acute respiratory illness that remains endemic, despite the availability of an effective vaccine. The incidence of pertussis has steadily increased in the past few decades, especially among adults and adolescents, and is a cause of hospital-associated outbreaks. Infected health care workers (HCWs) can serve as an important transmission vector for susceptible people, particularly young infants. Adults are more likely to have mild or atypical symptoms, and therefore infected HCWs may continue to work with unrecognized illness. HCWs often have high occupational mobility in pediatric facilities, promoting the spread of acquired pathogens. Lastly, HCW attitudes toward perceived risk of infection and disease severity may affect the use of IPC interventions.

Occupational exposures to critical pathogens are regularly documented and investigated as an important part of IPC strategy. Given the significant morbidity and mortality associated with pertussis infection, especially in the pediatric population, it is crucial to identify exposed HCWs to prevent infection and subsequent transmission to co-workers and patients. Prevention of secondary cases of pertussis among exposed pediatric HCWs requires timely reporting of index cases and investigating for possible exposures so that affected HCWs can receive postexposure prophylaxis (PEP). This requires the presence of a reporting mechanism and knowledge of reporting requirements. Exposure investigations and subsequent interventions therefore result in substantial work and significant cost for the Infection Prevention and Control Department (IPCD) and Occupational Health Department (OHD) staff.

The objective of this study was to determine the epidemiology of occupational exposures to pertussis in a large pediatric health care network and to determine whether current reporting methods completely capture all pertussis cases. Results from this work will inform efforts to improve HCW adherence to appropriate precautions, especially in ambulatory settings, and to ensure that pediatric HCWs do not develop pertussis.

**METHODS**

**Study Design**

This cross-sectional study of occupational exposures to pertussis was performed through a retrospective review of IPCD and OHD records from a large quaternary pediatric care network. We identified all investigated HCW exposures to pertussis between January 1, 2002 and July 18, 2011. We also used electronic health record (EHR) data to identify all laboratory-confirmed cases diagnosed within the health care network during the same time period and compared them with the list of those identified through occupational exposure investigations. All cases identified through the EHR that did not have documentation of an occupational exposure investigation were considered a source of potential missed exposures.

This study was approved by the Children's Hospital of Philadelphia's Institutional Review Board.

**Study Site and Subjects**

The study site is a pediatric health care network that includes a tertiary care hospital, a 29-practice primary care network, and multiple subspecialty and surgical care centers throughout the 5-county metropolitan Philadelphia region and southern New Jersey. The study site has a well-established IPC and OHD program with clear guidelines for the prevention of HCW exposure based on recommendations from the Centers for Disease Control and Prevention. Ambulatory sites within the network are covered by the same IPC guidelines and reporting systems as the inpatient units and emergency departments (EDs), yet their use varies greatly between sites.

An index case was defined as any patient who had a laboratory-confirmed diagnosis of pertussis that also resulted in an HCW exposure. Potential exposures were defined as HCWs involved in the care of the index case before investigation. A confirmed exposure was defined as any HCW who had direct face-to-face contact within 3 feet of an index case regardless of the length of contact time and the vaccination status of the exposed person. Fulfillment of these criteria was confirmed by the OHD through interviews with each potentially exposed person. An exposure was deemed to occur when an HCW reported direct contact with an index case without the use of IPC precautions. This may occur before implementation of IPC precautions such as personal protective equipment (PPE) use or as a result of incomplete adherence to IPC guidelines.

**Pertussis Investigations**

IPCD receives notification of all laboratory-confirmed cases of pertussis within the network and initiates an investigation for each case to identify all HCWs who were potentially exposed during the patient's episode of care. Results of the initial investigation are forwarded to the OHD, which follows up with all identified HCWs, confirms whether an exposure occurred, and initiates any interventions indicated to prevent the development of disease (ie, administration of PEP). IPCD records document only postexposure interventions initiated by OHD.

**Data Collection**

Data for all confirmed occupational exposures were abstracted from the Employee Exposure Investigation forms.
maintained by the OHD. Forms included information from HCW interviews, review of the index case's medical chart, and review of OHD records. Specific data elements included age, gender, and select clinical information on each index case, information about employee–patient contact, employee vaccination history, IPC precautions in place at the time of exposure, the OHD recommended intervention, and actual action taken by the exposed HCWs.

**Missed Cases**

To determine the frequency of uninvestigated pertussis cases, we reviewed laboratory data from the study site’s EHR. The EHR includes the Epic suite of clinical and administrative products (EpicCare, Epic Systems Corporation, Verona, WI) and is used for all aspects of clinical care at the study site. Using Epic, we performed a query for all polymerase chain reaction–positive *Bordetella pertussis* cases during the same study period. We compared the cases identified through the OHD record review with those identified through Epic, using birthdates and encounter date. Any pertussis case identified through Epic that was not listed in IPCD and OHD investigation records was considered an uninvestigated case and a potential source of missed HCW exposures.

**Chart Review**

A sample of missed cases was investigated by chart review using the EHR system Chartmaxx (MedPlus, Inc., Cincinnati, OH). This system contains full medical record information for an encounter. The chart review provided illness and treatment information for the missed cases and identified the number of HCWs associated with their care.

**Statistical Analyses**

Statistical analyses were performed to indicate any trends in the data while stratifying for explanatory variables. For descriptive analyses, categorical variables, such as the care site, were summarized by frequencies, and continuous variables, such as age, were summarized using medians. For the primary study objective we used $\chi^2$ tests of association to identify any significant relationships between index case, site, and HCW characteristics and frequency of exposure.

For the secondary analysis of missed and captured cases, we performed univariable and multivariate logistic regression for the likelihood of being missed by IPCD case capture while adjusting for site, age of index case, and the time period of encounter. Specifically, we compared data between 2 time periods, before and after an institutional requirement for tetanus, diphtheria, and pertussis (Tdap) vaccination of all newly hired HCWs, which began in 2008. We hypothesized that this policy change would increase awareness about occupational exposures to pertussis and result in more vigilant use of PPE. All statistical analyses were performed by using SAS software, version 9.2 (SAS Institute, Inc, Cary, NC). Graphics were produced by using Excel (Microsoft Office System, 2010).

**RESULTS**

A total of 226 pertussis cases were reviewed by IPCD and OHD. Of these, 219 (96.9%) resulted in 1193 confirmed HCW exposures and were considered index cases. The median age of pertussis index cases was 0.5 years, and the median number of associated confirmed HCW exposures was 3.0. Seven pertussis index cases (3.1%) were HCWs who had exposed co-workers and patients. HCW index cases accounted for a disproportionate number of HCW exposures (175 [14.7%]).

Between January 1, 2002 and the end of 2007 (the time period before the institutional requirement for Tdap vaccination of all newly hired HCWs), 64% of confirmed exposures to pertussis were reported, and 36.3% of exposures were confirmed between January 1, 2008 and July 18, 2011 (Table 1). Most exposures occurred in the ED and in ambulatory sites (77.5%) during both time periods. Front-line clinical staff (physicians, nurses, and nurse practitioners) made up the majority of exposed staff during both time periods at all sites. Approximately half (46.9%) of HCW pertussis exposure events resulted from a delay in the implementation of respiratory precautions. The ED had the highest proportion (65.0%, $N = 258$) of pertussis exposures because of the delayed initiation of droplet precautions, as compared with the other sites (data not shown). Twenty-seven percent of exposures occurred after documented initiation of appropriate precautions; this occurred less frequently in 2008 through 2011 compared with 2002 through 2007 (18.7% and 31.8%, respectively). The majority of HCW exposures (71.1%, $N = 848$) occurred while the HCW was providing care for an index case who had the presence of respiratory symptoms clearly documented in his or her chart.

**Occupational Health Interventions**

The OHD recommended chemoprophylaxis for the majority of confirmed exposures to pertussis. Therefore, 90.6% of HCWs exposed to pertussis ($N = 1081$) were given and filled a PEP prescription, most commonly for azithromycin. Of the exposed HCWs, 3% declined to follow OHD recommendations because of previously prescribed medication, pregnancy, or other medical contraindications to antibiotic use. Furlough was recommended in 3 instances during the study period: 1 HCW developed laboratory-confirmed pertussis, and 2 HCWs developed symptoms consistent with pertussis within 21 days after exposure to an index case.
TABLE 1  Documented Cases of Pertussis Resulting in Confirmed Occupational Exposures

<table>
<thead>
<tr>
<th>Age group of index case, N (%)</th>
<th>2002–2007</th>
<th>2008–2011*</th>
<th>Total</th>
<th>$p^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤6 mo</td>
<td>49 (39)</td>
<td>36 (40)</td>
<td>85 (39)</td>
<td></td>
</tr>
<tr>
<td>6–23 mo</td>
<td>7 (5)</td>
<td>13 (14)</td>
<td>20 (8)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>2–6 y</td>
<td>4 (3)</td>
<td>7 (8)</td>
<td>11 (5)</td>
<td></td>
</tr>
<tr>
<td>7–11 y</td>
<td>7 (6)</td>
<td>21 (23)</td>
<td>28 (13)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>&gt;11 y</td>
<td>13 (10)</td>
<td>10 (11)</td>
<td>23 (11)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>HCW as index</td>
<td>5 (4)</td>
<td>2 (2)</td>
<td>7 (3)</td>
<td></td>
</tr>
<tr>
<td>Unavailable</td>
<td>43 (34)</td>
<td>2 (2)</td>
<td>45 (21)</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

No. HCWs exposed/index case, N (%)

| 1–5 HCWs                      | 91 (71)   | 68 (74)    | 159 (72)| A |
| 6–15 HCWs                     | 27 (21)   | 21 (23)    | 48 (22)| |
| ≥16 HCWs                      | 10 (8)    | 2 (2)      | 12 (5) | |

Total potential exposures 1187 606 1793

Total confirmed exposures 759 434 1193

Site, N (%)

| Main hospital                 | 143 (19)  | 71 (16)    | 214 (18)| |
| ED                            | 307 (40)  | 231 (53)   | 538 (45)| |
| Ambulatory sites              | 260 (34)  | 127 (29)   | 387 (22)| |
| Unavailable                   | 49 (6)    | 5 (1)      | 54 (6)  | |

Job, N (%)

| MD, DO, PhD, nurse practitioner| 194 (26)  | 140 (32)   | 334 (28)| |
| Nursing                       | 173 (23)  | 156 (36)   | 329 (28)| |
| Ancillary staff or other clinical services | 83 (11) | 81 (19) | 164 (14) |
| Nonclinical hospital staff    | 15 (2)    | 2 (>1)     | 17 (1)  | |
| Unavailable                   | 294 (39)  | 55 (13)    | 349 (29)| |

Precautions in place at time of exposure, N (%) | 0.001

| No                            | 333 (44)  | 226 (52)   | 559 (47)| |
| Yes                           | 241 (32)  | 81 (19)    | 322 (27)| |
| Unavailable                   | 185 (24)  | 127 (29)   | 312 (26)| |

Index case had respiratory symptoms, N (%) | <.0001

| Yes                           | 457 (60)  | 391 (90)   | 848 (71)| |
| No                            | 242 (32)  | 36 (8)     | 278 (23)| |
| Unavailable                   | 60 (8)    | 7 (2)      | 67 (6)  | |

Intervention performed, N (%) | <.0001

| Prophylaxis                   | 684 (87)  | 417 (90)   | 1081 (81)| |
| Furlough or other             | 9 (1)     | 1 (<1)     | 10 (1)  | |
| Declined recommendations      | 21 (3)    | 10 (2)     | 31 (3)  | |
| Nonea                         | 59 (8)    | 5 (1)      | 64 (5)  | |
| Unavailable                   | 6 (1)     | 1 (<1)     | 7 (1)   | |

N = number of cases of infection for which an exposure investigation was completed. Percentages may not total to 100% because of rounding.

* 2011 data include only cases encountered between January 1 and July 18 of that year.
* P is for the $\chi^2$ statistic determined for the variable in question.
* Includes no mask use specifically noted, precautions noted as being initiated after exposure, or precautions being noted as never being initiated.
* No intervention performed because of medical contraindication (eg, pregnancy), previous prescription, or refusal to take prophylaxis.

### Missed Exposures

We identified 450 laboratory-confirmed cases of pertussis from the site’s EHR during the study period, including 224 (49.8%) for which there was no evidence of an exposure investigation (Table 2). Fifty-five (24.5%) of these missed cases of pertussis were diagnosed in 2002 through 2007, with a mean of 9.2 (95% confidence interval, 6.2 to 12.2) cases per year, and 169 (75.4%) were diagnosed in 2008 through 2011, with a mean of 42.3 (95% confidence interval, −6.4 to 90.9) cases per year. The proportion of pertussis cases without an IPCD investigation increased substantially between 2002 through 2007 and 2008 through 2011 (38.9% and 65.0%, respectively). Only 25.7% of cases from an ambulatory site had a documented investigation, compared with 80% of ED and 78% of main hospital cases.

We performed a chart review of 24 (11%) randomly selected uninvestigated pertussis cases using EHR data from the encounter in which pertussis was diagnosed. In 22 (92%) of these charts, initiation of droplet precautions was not documented, although cough or respiratory infection was documented as the chief complaint for 12 (55%) of these cases. The 2 cases (8%) for whom precautions were initiated were admitted patients in the main hospital. The estimates for potential HCW exposures differed by site. Based on EHR review, encounters that took place at ambulatory sites noted 1 primary clinician involved in index case care, indicating at least 1 potentially exposed HCW per index case. Meanwhile, encounters at the main hospital or ED listed multiple physicians and nurses who assessed the patient, suggesting several potential exposures per uninvestigated case.

### DISCUSSION

In this study, we describe a large pediatric care network’s experience with HCW exposures to pertussis over a 10-year period. To our knowledge, this is the largest retrospective study of occupational exposures to pertussis in a health care setting to date. Our results show that pertussis accounts for most documented HCW exposure events to critical pathogens, and HCW exposure occurs even after initiation of appropriate precautions. We also found that a substantial proportion of laboratory-confirmed pertussis cases were not reported to IPC and may have been associated with missed HCW exposures. Therefore, the true magnitude of pertussis exposure in this health care network is probably much greater than the real-time IPCD investigations.
indicated. We also identified characteristics associated with HCW exposures to pertussis, which may have important implications for IPC policies to prevent pertussis transmission to both HCWs and patients. More effective IPC policies may help decrease the costs and the burden on the health care environment that results from disease outbreaks and occupational exposures.

Over a 10-year period, we found 219 pertussis cases that resulted in 1183 HCW exposures. This demonstrates a significant risk for pertussis transmission within a pediatric health care system. Not only are patients at risk for transmission from exposed HCWs who may become infected, but disease transmission may also occur between co-workers, as illustrated by the 7 HCW index cases identified in our results.4

The frequency of pertussis exposures may be influenced by the increasing prevalence of pertussis among pediatric patients. In particular, our findings indicated that the majority of pertussis index cases were among infants (≤6 months), who are at highest risk for developing severe disease.2 Exposure frequency may also reflect the challenge of diagnosing pertussis, especially among older children and adolescents, who are more likely to have atypical symptoms and for whom the diagnosis of pertussis may not be immediately suspected.

The frequency of pertussis exposures we identified suggests that interventions are needed to ensure timely implementation of and adherence to IPC protocols. In particular, our data indicate that a quarter of exposures happened after precautions were initiated, underscoring the challenges of implementing transmission-based precautions. There are well-established guidelines to prevent exposure and subsequent disease development, but it is unclear how effective these guidelines are in different settings, particularly in ambulatory settings.16,19,21,22

Ambulatory sites have unique features compared with inpatient and ED settings that may contribute to the frequency of both identified and missed exposures.7,19 Masks and other supplies may not be readily available in triage areas or examination rooms in ambulatory sites, decreasing compliance to precautions.19 Evidence suggests that IPC guidelines in ambulatory sites are not uniformly implemented,7,16,19 and therefore knowledge about effective prevention practices and reporting procedures may vary. It is crucial that HCWs be informed about policies and procedures and that the tools needed to follow guidelines be consistently available. Education programs targeting guideline adherence have been shown to improve IPC practices.8,9,16

Targeting work site and HCW characteristics associated with pertussis exposure is probably critical to the successful implementation of precautions designed to interrupt pertussis transmission in an ambulatory setting. We found that the majority of pertussis exposures occurred in the ED or in ambulatory settings, and almost half occurred before the initiation of droplet precautions. HCWs who perform triage activities may have elevated risk of exposure. Additionally, attitudes toward pertussis may affect the use of PPE. For example, previous studies have shown that HCWs do not perceive themselves to be at high risk for developing pertussis infection despite knowledge about pertussis transmission.8,13,17

Our study also found that a substantial proportion of pertussis cases were not reported and investigated by OHD and IPCD. Case identification is the first step in ensuring that IPC guidelines are implemented. These results suggest that reporting guidelines were not uniformly followed. The majority of identified uninvestigated cases were patients from ambulatory sites. We were not able to establish the true magnitude of exposures resulting from these uninvestigated cases, although our chart review indicated that at least 1 and up to 12 HCWs were potentially exposed for each case.

Case identification is a significant challenge for the prevention of pertussis exposure. This is suggested by

### Table 2: Laboratory-Confirmed Pertussis Cases With and Without an Exposure Investigation, 2002–2011

<table>
<thead>
<tr>
<th>Age group of case</th>
<th>Investigated Cases, N (%)</th>
<th>Cases Without an Investigation, N (%)</th>
<th>Total Pertussis Cases, N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mo or less</td>
<td>121 (54)</td>
<td>28 (13)</td>
<td>149 (33)</td>
</tr>
<tr>
<td>6–23 mo</td>
<td>33 (15)</td>
<td>21 (9)</td>
<td>54 (12)</td>
</tr>
<tr>
<td>2–6 y</td>
<td>16 (7)</td>
<td>64 (29)</td>
<td>80 (18)</td>
</tr>
<tr>
<td>7–11 y</td>
<td>27 (12)</td>
<td>76 (34)</td>
<td>103 (23)</td>
</tr>
<tr>
<td>11+ y</td>
<td>20 (9)</td>
<td>34 (15)</td>
<td>54 (12)</td>
</tr>
<tr>
<td>HCW index case</td>
<td>5 (2)</td>
<td>0</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Unavailable</td>
<td>4 (2)</td>
<td>1 (&lt;1)</td>
<td>5 (1)</td>
</tr>
<tr>
<td>Year group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002–2007</td>
<td>135 (60)</td>
<td>55 (25)</td>
<td>190 (42)</td>
</tr>
<tr>
<td>2008–2011</td>
<td>91 (40)</td>
<td>169 (75)</td>
<td>260 (58)</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main hospital</td>
<td>103 (46)</td>
<td>27 (12)</td>
<td>130 (29)</td>
</tr>
<tr>
<td>ER</td>
<td>62 (27)</td>
<td>18 (8)</td>
<td>80 (18)</td>
</tr>
<tr>
<td>Ambulatory site</td>
<td>80 (37)</td>
<td>175 (77)</td>
<td>253 (52)</td>
</tr>
<tr>
<td>Unavailable</td>
<td>1 (&lt;1)</td>
<td>6 (3)</td>
<td>7 (2)</td>
</tr>
</tbody>
</table>

Percentages may not total to 100 because of rounding.
the high proportion of exposures that occurred before initiation of appropriate precautions. Surveillance for pertussis can be difficult because of the nonspecific nature of many symptoms (eg cough, runny nose), particularly in older children, adolescents, and adults. Pertussis infection therefore may not be initially recognized or reported in these groups.  

Particularly during periods of high transmission, heightened suspicion of pertussis in any child presenting with an afebrile cough illness is important, and mask use may be needed for both symptomatic patients and HCWs during health care encounters. Early implementation of droplet precautions is essential to prevent potential transmission, but this requires implementation before an exposure event can occur. If all HCWs wear masks for any patient with a cough or if all children who present with cough illnesses are given a mask on arrival until likelihood of pertussis can be better established through history and physical, many exposures could be prevented. Another preexposure prevention strategy is HCW Tdap vaccination, which may decrease the impact of missed and underreported cases. Vaccination of all HCWs with Tdap is recommended by the Advisory Commission of Immunization Practices and has been found in several studies to be a cost-effective intervention, and our study does have limitations. It was a retrospective review of IPCD and OHD reports, and although these reports were standardized, data were not systematically collected for research purposes. Confirmation of exposure was based primarily on self-report, which could result in recall biases that may underestimate or overestimate the number of occupational exposures. Additionally, there were missing data from exposure investigations, especially in 2002 through 2007 compared with 2008 through 2011. This may affect the comparability of results between these time periods. IPCD and OHD reports did not generally provide information such as employee vaccination status or testing results from exposed HCWs that may have enabled us to estimate the incidence of secondary infection. However, the IPCD investigations were performed in real time and included data gleaned from a variety of sources, including HCW interviews and medical chart review, which strengthened data reliability. Lastly, we were not able to determine the reasons for uninvestigated pertussis cases; an IPC investigation form is not generated for all pertussis cases if it is clear after preliminary review that there were no exposures. However, this is not likely to account for all the uninvestigated cases that we identified. Despite its limitations, this study provides a comprehensive review of occupational exposures over nine and a half years within a large pediatric health care system that includes both inpatient and ambulatory care settings and a diverse HCW and patient population.

CONCLUSIONS

This extensive review of HCW exposures to pertussis illustrates the importance of early case identification and uniform implementation of IPC transmission-based guidelines to prevent occupational exposures in a pediatric care setting. Occupational exposures to pertussis occur frequently among a wide range of HCWs in all care settings, resulting in risk of infection among HCWs, who can then expose patients and co-workers. The large number of uninvestigated cases suggests that the true number of exposures may be underestimated. To most effectively prevent pertussis exposure and subsequent transmission, thorough case ascertainment and prompt initiation of droplet precautions are essential. Additional work is needed to identify the barriers to case identification and reporting for pertussis and the timely implementation of IPC precautions; this work can inform the development of interventions to improve practice. Future work can also investigate the impact of strategies such as employee vaccination, universal use of droplet precautions, and education programs to promote appropriate PPE use.

REFERENCES


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