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Occupational Exposures Of Healthcare Workers To Pertussis Within A Large Pediatric Care Network: A Retrospective Study

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Occupational Exposures of Healthcare Workers to Pertussis within a Large Pediatric Care Network: A Retrospective Study

Thesis for a Master of Public Health

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May 1st, 2012

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Abstract

Background

Infection control policies have a significant impact on the risk for disease transmission in healthcare settings, and adherence to guidelines dictates their effectiveness. Healthcare worker (HCW) exposure to communicable diseases can occur when guidelines have not been consistently implemented, placing the HCW at risk for infection with subsequent transmission to patients and co-workers. Respiratory pathogens are a common source of healthcare-associated infection, especially in pediatric settings and pertussis has emerged as a particularly important agent that is associated with an increasing number of both community and healthcare-associated outbreaks despite the availability of an effective vaccine. Adults, including HCWs, are at high risk to be key reservoirs for transmission. We therefore aimed to describe the epidemiology and prevalence of HCW exposures to pertussis and related infection control measures in place for their prevention.

Methods

Data were collected as part of a retrospective cross-sectional study of occupational exposures of HCWs to four pathogens (pertussis, tuberculosis, meningococcus and varicella) at a large quaternary pediatric care network from January 1st, 2002 to July 18th, 2011. We reviewed occupational health and infection control records for all reported cases of pertussis to measure the frequency of potential and confirmed exposures, the associated index case and HCW characteristics, and subsequent occupational health interventions. We reviewed electronic health record data to identify all laboratory-confirmed pertussis cases during the study period and measure the frequency of potential missed exposures to pertussis.

Results

During the study period, there were 219 index cases of pertussis identified from occupational health records associated with 1193 confirmed employee exposures. 322 exposures (27%) occurred despite documentation of infection control precautions being in place for the patient. Of the 448 laboratory-confirmed pertussis cases identified through the EHR, 50% (N=224) were not investigated, indicating potential missed HCW exposures. The majority of uninvestigated cases were patients from ambulatory sites.

Conclusions

Pertussis results in a significant number of occupational exposures among HCWs. The true magnitude of exposures may be even greater than measured and thus many exposed HCWs may not receive appropriate interventions to prevent infection and subsequent transmission to co-workers and vulnerable patients. Interventions are needed to improve identification and reporting of pertussis as well as consistent implementation of infection control practices to prevent exposure.

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Thank you all!

Introduction

Healthcare settings are an important source of exposure to infectious pathogens for both patients and healthcare workers (HCWs).^[1, 2] Pediatric care environments, in particular, have unique features that can contribute to risk of infection from community pathogens including an increased exposure to secretions during patient care activities, prolonged shedding of pathogens among young children, and exposure to contaminated surfaces from extended and close contact with infectious children.^[3] Infection control policies are implemented to prevent healthcare-associated infection.^[4-7] In order to ensure effective infection control policies, it is important to understand the impact that the implementation of guidelines may have on the incidence of healthcare-associated infection.

Healthcare-associated infections in pediatric settings are frequently due to community pathogens^[3], and pertussis is a highly communicable acute respiratory illness that remains endemic, despite widespread availability of an effective vaccine.^[8, 9] The incidence of pertussis has steadily increased in the past few decades, especially among adults and adolescents across the United States.^[8-10] Pertussis is also a common cause of hospital-associated outbreaks^[1, 2, 5, 11-13] due to a higher prevalence of patients who cannot be vaccinated or who are immunocompromised as well as HCWs who are unvaccinated or have waning immunity.^[7, 12, 14, 15] Infected HCWs can then serve as an important transmission vector for susceptible individuals.^[2, 3, 14, 16] Adults are more likely to have mild or atypical symptoms and thus infected HCWs may continue to work with unrecognized illness.^[2, 8, 13] HCWs also tend to have high occupational mobility in pediatric facilities, aiding the spread of acquired pathogens.^[15, 17] Lastly, HCW attitudes towards perceived risk of infection and disease severity may impact use of infection control interventions.^[6, 18, 19] HCWs can therefore be an important source of pertussis transmission within healthcare settings.

Given the significant morbidity and mortality associated with pertussis infection, especially within the pediatric population, it is crucial to identify exposed HCWs to prevent the development of infection and subsequent transmission to co-workers and patients. Occupational exposures are regularly documented and investigated as an important part of infection control strategy.^[1, 7, 10, 17] This, however, requires identification and timely reporting of cases. Missed exposures may subsequently occur, especially where infection control infrastructure is less developed.^[5-7] Additionally, exposure investigations and subsequent intervention execution result in substantial disruption and significant cost for infection control and occupational health staff.^[13, 14, 17, 20] Prevention of exposures should also be prioritized to not only minimize infection risk, but also to minimize the resulting costs associated with

case investigations. There are well-defined infection control guidelines to prevent the transmission of respiratory pathogens, including pertussis, and the Centers for Disease Control and Prevention (CDC) recommends all HCWs receive the Tdap booster vaccine^[8]. Adherence to this and other infection control guidelines, however, are known to be inconsistent^[14, 21]

The objective of this study, therefore, was to determine the epidemiology of occupational exposures to pertussis in a large pediatric healthcare network from 2002-2011 and to estimate the associated frequency of adherence to infection control guidelines. Additionally, to determine whether current reporting methods completely capture all pertussis cases and to estimate the frequency of missed exposures, we identified index cases for whom there was no documented investigation. Results from this work will inform efforts to refine and improve adherence to current infection control guidelines, preventing occupational exposures and the resulting potential for subsequent transmission to vulnerable patients.

Methods

The objectives of this study were to describe the frequency and characteristics of healthcare worker exposure to pertussis and to measure the frequency of missed exposures to pertussis. This was part of a larger study investigating occupational exposures to four communicable diseases: pertussis, meningococcus, tuberculosis, and varicella zoster virus. We performed a retrospective review of infection control and occupational health records from a large quaternary care pediatric center to identify all investigated HCW exposures to pertussis between January 1, 2002 and July 18th, 2011. For the second objective, we utilized electronic health record data to identify all cases of pertussis diagnosed within the healthcare network during the same time period and compared them with the list of those identified through occupational exposure investigations. All cases identified through the electronic health record (EHR) that did not have an occupational exposure record were considered a source of potential missed exposures. This study was approved by the Children's Hospital of Philadelphia's Institutional Review Board.

The study site is a pediatric healthcare network that includes a tertiary care hospital, a 29-practice primary care network, and multiple subspecialties and surgical care centers throughout the five county metropolitan Philadelphia region and Southern New Jersey. The Infection Prevention and Control Department (IPCD) monitors laboratory confirmed instances of various communicable diseases within the healthcare network, including the four pathogens targeted in this study. The IPCD initiates an investigation for each positive laboratory confirmed case of a monitored communicable disease, to identify all HCWs who were potentially exposed during the patient's time of care. The results of this initial investigation are forwarded to the Occupational Health Department (OHD) who follows up with all identified HCWs, confirms whether an exposure occurred, and initiates any interventions indicated to prevent the development of diseases (i.e. confirmation of immune status or administration of post-exposure prophylaxis (PEP)). IPCD records do not indicate whether any clinic staff may have initiated post-exposure interventions without the oversight of occupational health.

For this study, an index case was defined as any patient who had a laboratory-confirmed diagnosis of pertussis that also resulted in a HCW exposure. Potential exposures were defined as HCWs involved in the care of the index case prior to investigation. A confirmed exposure was defined as any HCW who participated in the care of an index case and fulfilled the criteria for exposure distinguished by the infection control investigation. An exposure was deemed to occur when there was sufficient

contact between the index case and health care worker to result in transmission. This may occur before implementation of infection control precautions such as the use of personal protective equipment or as a result of incomplete adherence to infection control guidelines. The study site has a well-established infection control and occupational health program with clear guidelines for the prevention of HCW exposure, which are based upon recommendations from the CDC. [5, 7]

Data Elements

Data for all documented 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 HCW occupational health records. Specific data elements included age, gender, and select clinical information on each index case, information about employee-patient contact, employee vaccination history, infection control precautions in place at the time of exposure, the OHD recommended intervention, and actual action taken by the exposed HCWs. 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. It offers rapid access to patient-specific data, routing of orders and results, structured data in key fields, legible documentation, and the ability to manage data from across the patient population. Using the EHR, we performed a query for all PCR-positive *Bordetella pertussis* cases during the same study period. We compared those index cases identified through the occupational health record review to those identified through EPIC, using birthdates and encounter date. Any pertussis case identified through EPIC that was not listed in infection control and occupational investigation records was considered an uninvestigated case and a source of potential missed exposures. A sample of missed cases was further investigated by chart review using the electronic medical record system Chartmaxx[®] (MedPlus, Inc., Cincinnati, OH). This system contains full medical record information for an encounter including patient intake, discharge, care, associated personnel, and laboratory orders and results. The chart review provided illness and treatment information for the missed cases and identified the number of HCWs associated with their care.

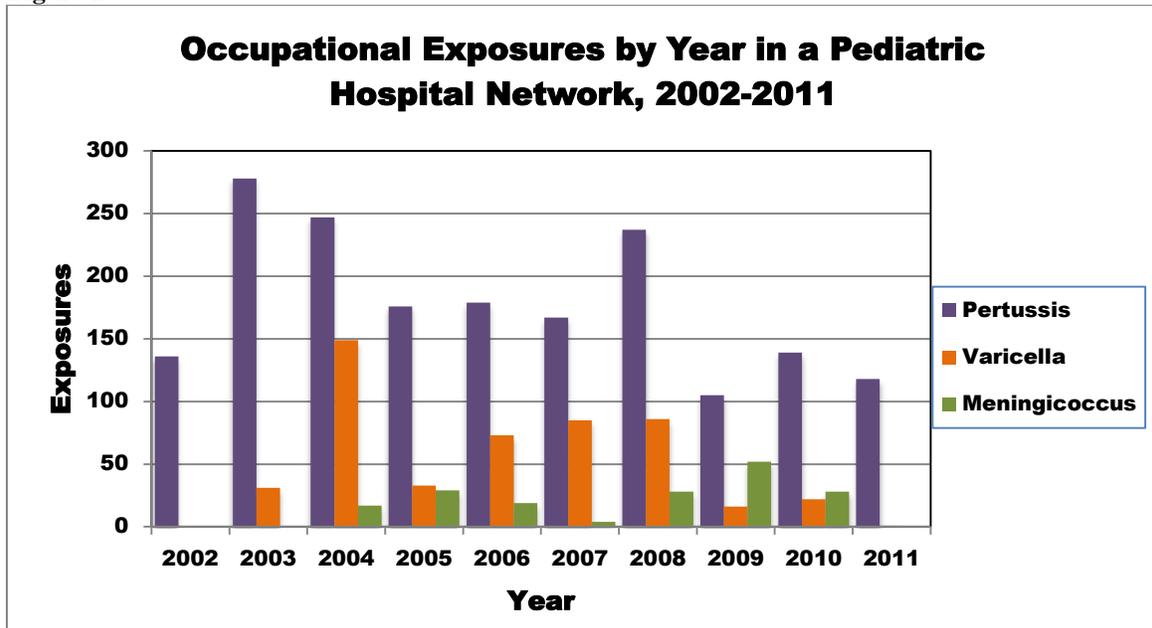
Statistical Analyses

Statistical analyses were performed to indicate any trends in the data when stratifying for explanatory variables. For descriptive analyses, categorical variables such as the site of care, were summarized by frequencies while continuous variables such as age, were summarized using medians. For the primary study objective we utilized Chi Squares to identify any significant characteristics of index cases and their related occupational exposures. For the secondary analysis of missed and captured cases, we performed univariable and multivariate logistic regression for the likelihood of being missed by infection control case-capture using the covariates of site, age of index case, and the time period of encounter. Specifically, we compared data between two time periods, before and after an official institutional recommendation for Tdap vaccination of all new employees, which was released in 2008. All statistical analyses were performed using SAS software, version 9.2 (SAS Institute; Cary, NC). Some graphics were produced using Excel (Microsoft® Office System, 2010).

Results

There were a total of 271 index cases of the four study pathogens during the study period resulting in 1816 confirmed exposures (Table 1). Of these, there were 219 (80.8%) index cases of pertussis and 1193 (65.7%) confirmed pertussis exposures. The median age of pertussis index cases was 0.5 years, resulting in a median of 3.0 confirmed exposures among HCWs. Seven pertussis index cases (3%) were HCWs who worked during their illness and exposed other staff, accounting for 175 (15%) exposures in total.

Figure 1



Across all four pathogens, there was a median of 4 confirmed exposures for each index case (Range: 3–28), and the median age of index cases was 1 year and ranged widely from 0.5 years for pertussis to 11.0 years for meningococcus. Pertussis cases and correlated exposures displayed different annual prevalence, but seemingly periodic time trends over the study period (Figures 1 and 2). Varicella and meningococcus also showed increasing trends over time for several years, followed by sudden decreases during the study period.

Table 1: Characteristics of HCWs and Index Cases resulting in a confirmed exposure to *N. meningitis*, *B. pertussis*, active tuberculosis, or Varicella Zoster virus. (N=number of HCWs included in the exposure investigation for each case)

	Meningococcal Disease N(%)	Pertussis N(%)	Tuberculosis N(%)	Varicella Zoster Virus N(%)	Total N(%)
Total Index Cases	13	219	1	38	271
# HCW Exposed/Index Case					
1-5 HCWs	6(46%)	159(73%)	0	9(24%)	174(64%)
6-15 HCWs	5(38%)	48(22%)	0	19(50%)	72(27%)
16-25 HCWs	2(13%)	7(3%)	0	7(18%)	16(6%)
25+ HCWs	0	5(3%)	1(100%)	3(8%)	9(3%)
Median # HCW Exposed /Index Case	8.0	3.0	28	9.5	4.0
Age Group of Index Case					
6 months or less	4(31%)	85(39%)	0	0	89(33%)
6-23 months	1(8%)	20(9%)	0	4(11%)	25(9%)
2-6 years	0	11(5%)	0	8(21%)	19(7%)
7-11 years	1(8%)	28(13%)	0	4(11%)	33(12%)
11+ years	5(38%)	23(11%)	1	6(16%)	35(13%)
HCW as Index	0	7(3%)	0	6(16%)	13(5%)
Unavailable	2(15%)	45(21%)	0	10(18%)	57(21%)
Median Age (years)	11.0	0.5	14.9	6.1	1.0
Total # Potential Exposures	183	1793	28	514	2518
Total # Confirmed Exposures	109	1193	28	486**	1816
Site*					
Main Hospital	55(50%)	214(18%)	0	298(61%)	567(31%)
ER	54(50%)	538(45%)	0	50(10%)	642(35%)
Ambulatory Sites	0	387(32%)	28(100%)	100(21%)	515(28%)
Unavailable	0	54(5%)	0	38(8%)	92(5%)
Job*					
MD, DO, PhD, Nurse Practitioner	28(26%)	334(28%)	8(29%)	103(21%)	473(26%)
Nursing	21(19%)	329(28%)	9(32%)	167(34%)	526(29%)
Ancillary Staff	1(1%)	66(6%)	0	37(8%)	104(6%)
Radiology	6(6%)	50(4%)	0	22(5%)	78(4%)
Respiratory Therapist	9(8%)	26(2%)	0	2(>1%)	37(2%)
Other Clinical Services	0	22(2%)	0	24(5%)	46(3%)
Non-Clinical Hospital Staff	1(1%)	17(1%)	10(36%)	28(6%)	56(3%)
Unavailable	43(40%)	349(29%)	1(4%)	103(21%)	496(27%)

*Among the total number of confirmed exposures

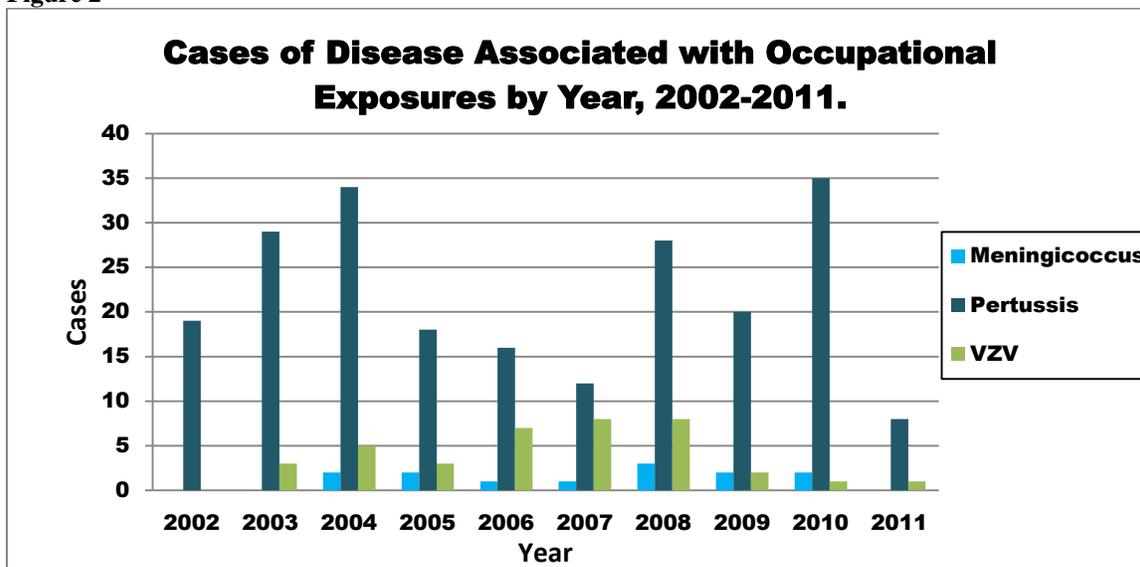
** Confirmation of a VZV exposure required determination of HCW immunity- HCWs who had documented immunity to VZV were considered exposed but not susceptible to infection.

Note: Percentages may not total to 100% due to rounding.

Pertussis Cases/Exposures

We focused our analyses upon pertussis due to the high prevalence of exposures to this pathogen during the study period (Table 2). Sixty-four percent of confirmed exposures to pertussis were reported between January 1st, 2002 and the end of 2007 (the year HCW vaccination with Tdap was recommended by the study site), while 36% of exposures were confirmed from January 1st, 2008 to July 18th, 2011. The median number of exposures per case did not differ between the year groups, though there was variation in the year to year distributions of exposures per case (Figure 3). The median age of the index cases increased from 0.35 years to 1 year. While most exposures occurred in the Emergency Department (ED) and in ambulatory sites (77%) during both time periods, a greater majority of exposures shifted to the ED in 2008-11. Front-line clinical staff (physicians, nurses, and nurse practitioners) continued to comprise the majority of exposed staff during both time periods at all sites (data not shown).

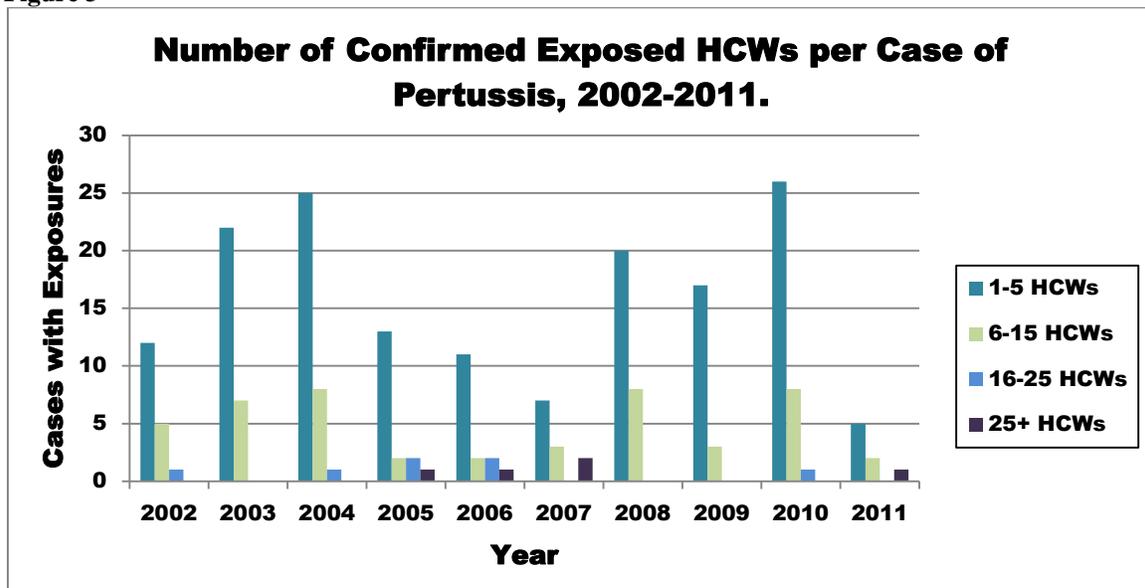
Figure 2



The primary reason for exposures to pertussis was an absence of timely initiation of infection control precautions indicated for the care of an index case (i.e. precautions were either not initiated until after the HCW exposure occurred or there was no documentation that precautions were ever initiated for the index case). This occurred in approximately half (47%) of all exposure events. Twenty seven percent of exposures occurred despite documentation of appropriate infection control precautions; this occurred

less frequently in 2008-11 compared to 2002-07 (19% vs 32% respectively). The ED had the highest proportion (65%, N=258) of pertussis exposures occurring before any droplet precautions were initiated, as compared to the other sites (data not shown). Seventy-one percent (N=848) of exposures occurred when caring for an index case who had respiratory symptoms noted on their chart. The frequency of the index case having documentation of respiratory symptoms was significantly higher in 2008-11 compared to 2002-07 (90% vs. 60%, $p < .0001$).

Figure 3



The OHD recommended chemoprophylaxis for the majority of confirmed exposures to pertussis. 91% of exposures to pertussis (N=1081) were given and filled a post-exposure prophylaxis (PEP) prescription, almost always for azithromycin. Three percent of exposed HCWs declined to follow OH recommendations, most frequently due to previously prescribed medication, pregnancy, or other medical contra-indications to antibiotic use. Furlough was recommended in three instances during the study period: once for a HCW who developed laboratory-confirmed pertussis and two who developed symptoms consistent with pertussis after exposure to an index case.

Table 2: Documented Cases of Pertussis resulting in Confirmed Occupational Exposures (N=number of cases of infection for which an exposure investigation was completed)

	2002-2007 N(%)	2008-2011* N(%)	Totals N(%)	p-value ****
Total # Index Cases	128	91	219	
Age Group of Index Case				<0.0001
6 months or less	49(39%)	36(40%)	85(39%)	
6-23 months	7(5%)	13(14%)	20(9%)	
2-6 years	4(3%)	7(8%)	11(5%)	
7-11 years	7(6%)	21(23%)	28(13%)	
11+ years	13(10%)	10(11%)	23(11%)	
HCW as Index	5(4%)	2(2%)	7(3%)	
Unavailable	43(34%)	2(2%)	45(21%)	
Median Age (years)	0.35	1.0	0.5	
# HCW Exposed/Index Case				0.3994
1-5 HCWs	91(71%)	68(74%)	159(72%)	
6-15 HCWs	27(21%)	21(23%)	48(22%)	
16-25 HCWs	6(5%)	1(1%)	7(3%)	
25+ HCWs	4(3%)	1(1%)	5(2%)	
Median # HCW Exposed / Index Case	3.0	3.0	3.0	
Total # Potential Exposures	1187	606	1793	
Total # Confirmed Exposures	759	434	1193	
Site				<.0001
Main Hospital	143(19%)	71(16%)	214(18%)	
ER	307(40%)	231(53%)	538(45%)	
Ambulatory Sites	260(34%)	127(29%)	387(32%)	
Unavailable	49(6%)	5(1%)	54(6%)	
Job				<0.0001
MD, DO, PhD, Nurse Practitioner	194(26%)	140(32%)	334(28%)	
Nursing	173(23%)	156(36%)	329(28%)	
Ancillary Staff	33(4%)	33(8%)	66(6%)	
Radiology	21(3%)	29(7%)	50(4%)	
Respiratory Therapist	14(2%)	12(3%)	26(2%)	
Other Clinical Services	15(2%)	7(2%)	22(2%)	
Non-Clinical Hospital Staff	15(2%)	2(>1%)	17(1%)	
Unavailable	294(39%)	55(13%)	366(31%)	
No Precautions in Place at Time of Exposure**				0.0010
Yes	333(44%)	226(52%)	559(47%)	
No	241(32%)	81(19%)	322(27%)	
Unavailable	185(24%)	127(29%)	312(26%)	
Index Case had Respiratory Symptoms				<.0001
Yes	457(60%)	391(90%)	848(71%)	
No	242(32%)	36(8%)	278(23%)	
Unavailable	60(8%)	7(2%)	67(6%)	
Intervention Performed				<.0001
Prophylaxis	664(87%)	417(96%)	1081(91%)	
Furlough	3(<1%)	0	3(>1%)	
Other	6(1%)	1(<1%)	7(1%)	
Declined Recommendations	21(3%)	10(2%)	31(3%)	
None***	59(8%)	5(1%)	64(5%)	
Unavailable	6(1%)	1(<1%)	7(1%)	

Note: Percentages may not total to 100% due to rounding.

*2011 data only includes cases encountered between January 1st and July 18th of that year.

** Includes No Mask use specifically noted, precautions noted as being initiated after exposure, or precautions being noted as never being initiated

*** No Intervention performed either due to medical conflict, previous prescription, or refusal to take prophylaxis.

**** P-Value is for the Chi-Square statistic determined for the variable in question.

Missed Exposures

We identified 450 laboratory-confirmed cases of pertussis from the study site's EHR during the study period (Table 3). One hundred and ninety (42%) of these cases of pertussis were diagnosed in 2002-2007 with a mean of 32 cases per year, while 260 (58%) were diagnosed in 2008-2011 with a mean of 74 cases per year. Of these 450 cases, 226 (50%) matched the list of index cases documented in the OHD records and 224 (50%) did not have documentation of an exposure investigation. The proportion of missed cases increased substantially between 2002-07 and 2008-11 (30% vs. 65%). 80% of ED and 78% of Main Hospital cases were investigated, while only 26% of ambulatory cases were reported and subsequently investigated.

Table 3: Pertussis index cases with and without an exposure investigation, 2002-2011 (as indicated from positive PCR results from the network's EMR)

	Investigated cases N(%)	Cases without an Investigation N(%)	Total Pertussis Index Cases N(%)
Totals from EPIC	226 (50%)	224 (50%)	450
Age Group of Case			
6 months or less	121(54%)	28(13%)	149(33%)
6-23 months	33(15%)	21(9%)	54(12%)
2-6 years	16(7%)	64(29%)	80(18%)
7-11 years	27(12%)	76(34%)	103(23%)
11+ years	20(9%)	34(15%)	54(12%)
HCW Index Case	5(2%)	0	5(1%)
Unavailable	4(2%)	1(<1%)	5(1%)
Year Group			
2002-2007	135(60%)	55(27%)	190(42%)
2008-2011	91(40%)	169(73%)	260(58%)
Site			
Main Hospital	103(46%)	27(12%)	130(29%)
ER	62(27%)	18(8%)	80(18%)
Ambulatory Sites	60(27%)	173(77%)	233(52%)
Unavailable	1(<1%)	6(3%)	7(2%)

Note: Percentages may not total to 100% due to rounding.

We identified characteristics associated with the likelihood of being an uninvestigated case of pertussis. Uninvestigated pertussis cases were significantly more likely to be 0-5 years of age, (OR=17.28, 95%CI: 8.71, 34.28) or 6-11 years of age (OR=12.16, 95%CI: 6.67-22.20), diagnosed at an ambulatory site (OR=11.00, 95%CI: 6.57, 18.42), and diagnosed during the 2008-11 period (OR 4.56, 95%CI: 3.04, 6.83). Due to the trend in age-group in univariable analysis we performed multivariate analysis to assess an association between age-group and site. When the variables were included in a

multivariable model, they all remained significantly associated with an increased likelihood of being an uninvestigated pertussis case (data not shown).

We performed a chart review of 24(11%) uninvestigated pertussis cases using EHR data from the encounter in which pertussis was diagnosed. In 92% (n=22) of these charts, there was no documentation of official infection control precautions having been initiated for the pertussis case, and for 12 (55%) of these cases, cough or respiratory infection was documented as the chief complaint. The only two cases (8%) for whom precautions were initiated were admitted patients in the Main Hospital. Encounters that took place at ambulatory sites listed one primary clinician who assessed the patient suggesting at least one 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 four pathogens over a ten-year period. To our knowledge, this is the largest retrospective study of occupational exposures to communicable diseases in a healthcare setting to date. Our results show that pertussis accounted for the vast majority of documented exposure events. We also found that a substantial proportion of pertussis cases were not reported to infection control and may have been associated with missed exposures. Therefore, the true magnitude of pertussis transmission within this healthcare network is likely much greater than the real-time infection control investigations indicated. We also identified characteristics associated with HCW exposures to pertussis, which may have important implications for infection control policies to protect both HCWs and patients.

Over a ten-year period, we found 219 pertussis cases that resulted in 1193 occupational exposures amongst HCWs. This demonstrates a significant risk for pertussis transmission within a pediatric healthcare system. Not only are patients subsequently at risk, but our finding that 5 pertussis index cases were HCWs illustrates the potential for disease transmission between coworkers.^[2] The frequency of pertussis exposures compared to the other pathogens of interest may be due to a higher prevalence of pertussis among pediatric patients. In particular, our findings indicated the most pertussis index cases were among infants (≤ 6 months), reflecting the increased disease severity experienced by young infants.^[9]

We found that the majority of pertussis exposures occurred in either the ED or in ambulatory settings and almost half of pertussis exposures occurred before the initiation of infection control measures (i.e. droplet precautions). Both emergency room and ambulatory settings often experience a high volume of patients, especially during the respiratory season^[3], and thus a significant proportion of pediatric patients may have respiratory symptoms. HCWs who perform triage activities may have contact with an infected patient before precautions have been initiated. This is suggested by our finding that the majority of exposures in the ED occurred before the initiation of droplet precautions. In an acute care environment, exposures may be likely to happen even when guidelines exist for infection control. Additionally, attitudes towards pertussis may impact the use of personal protective equipment. For example, previous studies have shown that HCWs do not perceive themselves to be at high risk for developing pertussis infection despite knowledge regarding pertussis transmission.^[13, 16, 18] Targeting work-site and HCW characteristics associated with implementation of respiratory-infection control protocols is key to the success of any practice change.

The frequency of pertussis exposures identified in our results suggest that interventions to ensure timely implementation of and adherence to infection control protocols are necessary. For confirmed exposures, the primary intervention is PEP, and needs to be administered to all exposed individuals to be most effective.^[1, 20] There are well-established guidelines to prevent both exposure and subsequent development of disease, but it is not clear how effective these guidelines are in different settings, particularly ambulatory settings.^[6, 7, 21, 22] The use of control measures is most effective if they are utilized by HCWs at the point of contact with an infected patient. Education programs targeting enhancement of precaution guideline adherence and the risk perception of pertussis have been shown to improve utilization of infection control practices.^[1, 6, 13] This approach of preemptively enhancing practitioner knowledge regarding the clinical features of pertussis, related infection risk, and the efficacy of droplet precautions could promote earlier initiation of and better adherence to infection control measures. HCW vaccination with Tdap is another strategy that offers pre-exposure prevention of infection. Vaccination of all HCWs with Tdap is now recommended by the Advisory Commission of Immunization Practices^[23] and has been found in several studies to be a cost-effective intervention.^[4, 13, 15, 17-19, 24]

Our study also found a substantial proportion of pertussis cases that were not reported and investigated. Case identification is the first step in ensuring that infection control guidelines are appropriately implemented. We were not able to establish the true magnitude of exposures resulting from these uninvestigated cases, but the chart review of a sample of uninvestigated cases showed that infection precautions were not initiated in the majority of cases and at least one and up to 12 HCW were potentially exposed for each case. Surveillance for pertussis is challenging due to the non-specific nature of many symptoms (eg. cough, runny nose), particularly in older children, adolescents, and adults.^[25] Pertussis infection therefore may not be initially recognized or reported in these groups.^[1, 13, 26] The majority of uninvestigated cases that we identified were children 2-11 years of age and the majority were patients from ambulatory sites. Ambulatory sites have unique features compared to inpatient and ED settings that may contribute to the frequency of both identified and missed exposures.^[5, 7] Access to masks and other supplies is frequently less widespread within ambulatory sites, decreasing compliance to indicated precautions.^[7] The substantial number of uninvestigated pertussis cases may also have been associated with the testing practices and the mechanisms in place for following-up and reporting test results to the IPCD. Many of the ambulatory practices within the study site network perform laboratory tests at out-of-network facilities. Results are sent to the ordering provider and uploaded into the EHR,

but this will not generate an automatic alert for the IPCD. The ordering clinician would then need to call to initiate an investigation. As evidence suggests that infection control practices in ambulatory sites are not uniformly implemented,^[5-7] there may be variable knowledge regarding reporting procedures. It is important to ensure that policies and procedures are communicated to HCWs and that the tools needed to follow guidelines are available at ambulatory sites.

It is important to note the significant resources that go into infection control of pertussis in a healthcare setting. Substantial costs to the hospital result from providing masks, PEP, furlough, and other tools to prevent infection. In addition, the numerous hours spent by the IPCD and the OHD investigating exposures and allocating appropriate interventions incurs a loss of productivity on the hospital. Thus, pertussis infection control in the healthcare setting requires significant resources for investigation, treatment, and prevention.^[14, 15, 17, 20, 24]

Strengths and Limitations

This study was a retrospective review of infection control and occupational health reports. While these reports used a standardized format, data were not collected for research purposes and available information was not uniform. This resulted in missing data, especially for exposures that occurred earlier in the study period. Additionally, IPCD and OHD reports did not provide information such as employee vaccination status, nor culture results from exposed HCWs that would aid in determining incidence of subsequent infection. The investigations and data collection by IPCD staff, however, 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.

Despite limitations, this study provides a comprehensive review of occupational exposures over nine and a half years within a large pediatric healthcare system that includes many types of care settings and a diverse HCW and patient population.

Conclusion

This extensive review of HCW exposures to pertussis and 3 other pathogens, exhibits the importance of infection control adherence to prevent occupational exposures in a pediatric care setting. Occupational exposures occur frequently among a wide range of HCWs in all care settings, not only resulting in risk of infection among HCWs and patients, but also in significant resource consumption among infection control and occupational health departments. The considerable number of uninvestigated cases suggests that we may underestimate the true magnitude of exposure. Without

comprehensive identification of pertussis cases, the implementation of PEP will not reliably prevent outbreaks of pertussis. Additional work is needed to identify the barriers to case identification and reporting for pertussis and the timely initiation of infection control precautions- this can inform the development of interventions to improve practice. Future work can also investigate the impact of strategies such as employee vaccination and education programs that may reduce the reliance on PEP and focus infection control practices on prevention strategies.

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Appendix

Appendix 1. Employee Exposure Worksheet:

The Children's Hospital of Philadelphia
Infection Prevention & Control Department

Employee Exposure Worksheet

Completed by:

Beeper #:

Pertussis _____

Varicella _____

N meningitides _____

Other _____

Index case Information (include name, DOB/age, clinical status, date(s)/location(s) of exposure)

Manager/charge nurse contact

Employees Requiring Contact:

Nurses:

Physicians (indicate resident/fellow/attending):

Radiology – include contact name or n/a

Respiratory – include contact name or n/a

Other:

For Occupational Health use only

ee potentially exposed _____

exposed _____

outside window _____

treated _____

unable to contact _____

refused _____

T dap Y _____ T dap N _____

Appendix2: Study Data Collection Forms

Case Identifier _____

Study Aim 2 Form #1: Index Pertussis EMR Review

**This form is to be filled out for the study cohort.
It reflects inpatient information.
It is to be entered into the database for only those who meet all eligibility criteria.**

- 1. Age at Time of Stay _____ ₈₈ Unknown

- 2. Sex ₀₁ Male
₀₂ Female
₈₈ Unknown

- 3. Racial background (check all that apply)
₀₁ North American Indian/Northern Native
₀₂ Asian/Asian American
₀₃ Black/African American
₀₄ Native Hawaiian/Other Pacific Islander
₀₅ White/Caucasian
₀₆ Other [*Specify:* _____]
₀₇ Refused
₈₈ Unknown

- 4. Ethnicity ₀₁ Hispanic or Latino
₀₂ Not Hispanic or Latino
₈₈ Unknown

- 5. Hospital Site
₀₁ Main
₀₂ Emergency Room
₀₃ Ambulatory
₈₈ Other(please specify) _____
₉₈ N/A

- 5a. Unit _____

- 6. Admission Due to Infection ₀₀ No
₀₁ Yes
₈₈ Unknown
₉₈ N/A

- 7. History of Pertussis Vaccination ₀₀ No
₀₁ Yes
₈₈ Unknown
₈₈ Unknown
₉₈ N/A

- 8. Period of Hospital Stay
i. Admission Date (mm/dd/yyyy) _____ / _____ / _____
ii. Discharge Date (mm/dd/yyyy) _____ / _____ / _____

- 9. Date of Symptom Initiation (mm/dd/yyyy) _____ / _____ / _____

- 10. Infection Control Precautions Initiated ₀₀ No
₀₁ Yes
₈₈ Unknown

₉₈ N/A

10a. Initiation Date (mm/dd/yyyy)

___ / ___ / _____

10b. End Date (mm/dd/yyyy)

___ / ___ / _____

11. Caregivers For Patient _____ Days Prior to Infection Control Precautions

11a.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

11b.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

11c.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

11d.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

11e.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

11f.

i. Type of Caregiver

₀₁ MD

₀₂ RN

₀₃ Aid

₀₄ _____

₈₈ Other _____

₉₈ N/A

ii. Date(s) of Care _____

Index Case Identifier _____

Report Identifier Within Index Case Infection _____

Study Aim 2 Form #2: Occupational Health Review

Start Date for Exposure Search (mm/dd/yyyy) _____ / _____ / _____

End Date for Exposure Search (mm/dd/yyyy) _____ / _____ / _____

1. Demographics

a. Age at Time of Exposure _____ ₈₈ Unknown

b. Sex ₀₁ Male
₀₂ Female
₈₈ Unknown

c. Racial background (check all that apply)

₀₁ North American Indian/Northern Native
₀₂ Asian/Asian American
₀₃ Black/African American
₀₄ Native Hawaiian/Other Pacific Islander
₀₅ White/Caucasian
₀₆ Other [*Specify*: _____]
₀₇ Refused
₈₈ Unknown

d. Ethnicity ₀₁ Hispanic or Latino
₀₂ Not Hispanic or Latino
₈₈ Unknown

2. Report Information

a. Site ₀₁ Main
₀₂ Emergency Room
₀₃ Ambulatory
₈₈ Other (please specify) _____
₉₈ N/A

i. Unit _____

b. Type of Caregiver ₀₁ MD
₀₂ RN
₀₃ Respiratory Therapist
₀₄ OT/PT
₈₈ Other _____
₉₈ N/A

c. Date of Report (mm/dd/yyyy) _____ / _____ / _____

d. Date of Exposure (mm/dd/yyyy) _____ / _____ / _____

e. Reason for Belief of Exposure _____

f. Vaccination For Pertussis

- ₀₀ No
- ₀₁ Yes
- ₈₈ Unknown
- ₉₈ N/A

i. Date of Last Vaccine (mm/dd/yyyy) ____ / ____ / _____

ii. Type of Vaccine _____

g. Post-Report Actions Taken

- ₀₁ Prophylaxis
- ₀₂ Vaccination
- ₀₃ Diagnostic Testing
- ₀₄ Furlough
- ₀₅ Excused from Patient Care
- ₀₆ Treatment
- ₀₇ Nothing
- ₀₈ Other [*Specify:* _____]
- ₈₈ Unknown

h. Diagnosis of Pertussis Given

- ₀₀ No
- ₀₁ Yes
- ₈₈ Unknown
- ₉₈ N/A