

BEST-PRACTICE GUIDELINES TO DECREASE PERTUSSIS TRANSMISSION DURING
THE FIRST SIX MONTHS OF LIFE

By

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Abstract

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Pertussis is a highly contagious respiratory illness that has been on the rise for the last decade, and in 2011 levels of infected individuals reached its highest levels since the 1950's in the United States. Infants under the age of six months of age are the most vulnerable population to this infection. This cohort is the most susceptible to contracting this illness and most prone to significant consequences including high rates of hospitalization, respiratory complications and mortality from the disease. Due to the increased risk to infants less than six months of age, efforts to decrease the transmission of pertussis within this age group are necessary. This paper reviews the current practice guidelines to minimize the transmission of pertussis to infants less than six months of age and as well as evidence describing ways to decrease the risk to these infants. The current recommendations include initiating and following the Center of Disease Control and Prevention childhood immunization schedule; vaccinating women after the twentieth week of pregnancy to support passive immunity to newborn; encouraging cocooning of infants through immunizing persons who are in close contact with the infant; and promoting herd immunity within communities to decrease transmission.

Keywords: pertussis, transmission, prevention, infant and immunization

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Introduction

Rates of pertussis have risen steadily in the United States in the last decade. In 2012, there were nearly twenty-four million cases of pertussis worldwide, and approximately 200,000 to 400,000 childhood deaths related to pertussis (Gall, 2012). Paddock et al. (2008) noted pertussis as one of the top ten causes of childhood mortality worldwide. Rates of pertussis infection in the United States have increased from 1,010 cases in 1976 to 11,647 cases in 2003. The increase is particularly startling among infants younger than six months, with 63.4 per 100,000 diagnosed in the 1980's compared to 98.2 per 100,000 diagnosed in 2003 (Stiller, 2011). Rates continue to climb and in 2010, the number of pertussis cases in the United States, reached over 27,000 (Clark, Messonnier, & Hadler, 2012). The highest incidence of pertussis since the 1950's was reported in the U.S. during 2011, while reaching an epidemic level in Ohio, Michigan, California and Washington. Statistics from the Center of Disease Control and Prevention (CDC) note a 1300% increase in pertussis cases from 2011 to 2012 in Washington State. The trends for 2012 are on course to surpass previous years in record number of cases (CDC, 2012).

The vulnerability of infants younger than six months of age has been well documented. Infants are found to have higher susceptibility to contracting pertussis, have higher rates of complications and have a higher mortality rate (Zastrow, 2011; Paddock et al., 2008). Infants that are too young to be immunized are the most susceptible to contracting pertussis and suffering poor outcomes. To better protect this vulnerable population, a decrease in the transmission of pertussis within communities is a priority.

The purpose of this paper is to exam and to summarize current evidence focusing on reducing pertussis transmission among infants less than six months of age. The increasing rates of pertussis within the United States and the high risk for mortality this illness presents for infants less than six months of age, necessitates a thorough review of best practice standards. This paper outlines a set of strategies to assist diminution of pertussis transmission within communities and reduce mortality and morbidity in the most vulnerable age cohort.

Background

Pertussis is a highly contagious respiratory infection caused by the bacteria *Bordetella pertussis* with humans as the only known reservoir (Zastrow, 2011). The bacteria attach to the cilia that line the upper respiratory system and releases toxins that cause inflammation and damage within the respiratory tract. Pertussis infections are characterized by paroxysmal coughing and ending in a prolonged crowing intake of breath. The illness has an incubation period of seven to ten days and is separated into three phases: the catarrhal, paroxysmal and convalescent. The catarrhal phase is categorized by mild respiratory symptoms and low-grade fever that typically last one to two weeks and is the time period that the infection is most contagious and transmittable. The paroxysmal phase is characterized by a worsening cough, which lasts one to six weeks. Finally, the convalescent phase, which is distinguished by episodes of spasmodic coughing on expiration and labored inspiration that result in the high pitched whooping (Center for Disease Control and Prevention [CDC], 2012). Infants are most vulnerable during the paroxysmal phase when exacerbated respiratory issues increase the incidence of hospitalization and mortality.

An effective pertussis vaccine was first utilized in the 1940's and had significant impact on reducing pertussis death rate in children over the following decades from the tens of

thousands to under a hundred (Clark, Messonnier, & Hadler, 2012). However, pertussis continues to circulate and the resurgence of pertussis in the United States to epidemic levels not seen since the 1950's requires a thorough review of the current best practice guidelines to minimize the transmission of the infection. A review of current literature that examined the transmission and prevention of pertussis was analyzed to determine best practice guidelines. The guidelines focus on preventing transmission of pertussis through immunization, cocooning and herd immunity.

Literature Review

The literature search was initiated using the health science databases CINAHL, the Cochrane Library and PubMed through searching the key words “pertussis”, “prevention”, “transmission”, “infant” and “immunization”. Eight hundred and two articles were retrieved. The filters “peer reviewed articles” and “articles published in the last five years” narrowed the literature to 96 articles. These articles were scrutinized and searches of the references pages produced more sources that had not appeared in the original literature search. The review was narrowed to 23 articles based on their use of current research data to support evidenced based practice for current best practice guidelines. The review of articles demonstrated three general areas including: infant protection, current recommendations to decrease the transmission of pertussis to infants and physiological response by infant to maternal immunization.

Infant Protection

Risk to Infants. The World Health Organization (WHO) has described pertussis as a significant cause of infant mortality worldwide, even in developed nations, where having high rates of immunization is supported. Research has found that about 24% of infants less than six months of age have substantial complications from pertussis (WHO, 2010; Zastrow, 2011). The

rates of significant complications in underdeveloped nations are believed to be considerable higher (Zastrow). In 2005, the annual rates of pertussis infections in the general U.S. population were reported at 8.7 cases per 100,000 people in comparison to 97 cases per 100,000 in the infant under the age of one (Hanson et al., 2011). This demonstrates the significant risk that infants face in contracting pertussis. Moreover, statistically speaking infants have a higher rate of serious complications from pertussis that can lead to higher rates of hospitalization and death (Paddock et al., 2008).

The pertussis bacteria has catastrophic consequences for infants, as they are less able to tolerate the illness, thus, increasing their probability of suffering poor outcomes. Winters et al. (2012) noted that of the number of patients hospitalized with pertussis in California, 72% were less than six months of ages and the median age of hospitalized patients was 2.6 months of age. In the first six months of 2012, the CDC reported that of the 155 cases of pertussis in infants under age one in Washington State, 21% required hospitalization in comparison to only 0.6% requiring hospitalization of children older than one year of age. Of the hospitalized infants less than one year of age in Washington State, 41.2% were under two months of age (Pertussis epidemic- washington 2012," 2012).

Immunity of Infants. The infant population often has significant complications from pertussis such as apnea, cyanosis bronchopneumonia, encephalopathy, and death (Shah, & Davis, 2009). Catagnini, Flor and Munoz (2010) report neonates who contract pertussis during the first months of life require longer hospital stays; have higher rates of severe pulmonary hypertension; and substantially higher rates of mechanical ventilation in comparison to other respiratory illnesses. The CDC found that up to 20% of hospitalized infants with pertussis develop pneumonia, 50% demonstrate apnea and up to 1% may die (CDC, 2008).

The lack of acquired immunity prior to completing the primary immunization at six months of age is responsible for the increase risk of neonates contracting pertussis and suffering poor outcome from the infection. A 2010 study found that only 25% of infants were born with potentially protective levels of pertussis antibodies and that by six weeks of age the number of naturally protected infants fell to 10% (Shakib et al., 2010). This leaves approximately 90% of infants susceptible to contracting a pertussis infection (Shakib et al.). With the high rate of infants who develop pertussis infections and the high rates of deaths in infants younger than six months of age, the necessity to effectively lower the transmission of the pertussis illness is a priority (Shah, & Davis, 2009).

Transmission and Prevention. There is a significant amount of research on pertussis transmission and prevention. Rittle's (2010) literature review of the current evidenced based research determined that in the United States there is currently,

“(a) an increasing pertussis rate; (b) that adults and adolescents are the primary carriers; (c) vaccines effectiveness wanes over time; and (d) pertussis persists despite disease control efforts” (pg. 282).

Zastrow (2011) examined current evidence regarding pertussis transmission and ascertained that the current CDC immunization protocols were advantageous to diminishing the rates of pertussis and concluded that infants, who completed the recommended three dose Diphtheria, Tetanus and Pertussis (DTaP) vaccine series on schedule, diminished their susceptibility to pertussis by six months of age.

Westra, De Vries, Tamminga, Sauboin and Postma (2010) evaluated the cost effectiveness of strategies including vaccinating infants immediately after delivery, and vaccinating both parents immediately post-partum. This approach has been labeled as a

“cocooning” method to minimize transmission of pertussis to newborns and also includes vaccinating women in the third trimester. This study found that both the interventions of immunizing parents during the postpartum period as well as maternal immunization during pregnancy were cost effective strategies to minimize pertussis transmission to infants (Westra et al., 2010). This study did note however, that there was a limitation to reviewing adequate data on maternal immunization in the third trimester of pregnancy and on neonatal immunization immediately after delivery, as there were no vaccines appropriately licensed to be utilized in these cohorts to provide adequate data of the topic at the time of this study (Westra et al.). The American College of Obstetricians and Gynecologists (ACOG) (2012) however, presented a committee opinion that promoted the use of Tdap in pregnancy as it found no evidence of adverse effects from use and reported a decrease in the pertussis burden off the neonates under six month of age (ACOG, 2012).

Gall (2012) reviewed past and current guidelines by the CDC’s Advisory Committee on Immunization Practices (ACIP) in regards to pertussis immunization and utilized a literature review from national and international medical journals focusing on reducing pertussis transmission. Evidence was presented that promoted the use of the Tdap vaccine during pregnancy, after the twentieth week of gestation (Gall, 2012). The use of DTaP in infants immediately after birth produced a poor immune response in the newborn, and was reported as a less effective method to produce fetal immunity then maternal immunization prior to delivery (Gall).

Gall (2012) further analyzed the ACIP’s current recommendations to use “cocooning” to protect infants from pertussis exposure. It was noted that there was a lack of sufficient research to provide an adequate review of the “cocooning” intervention to determine what implementation

barriers exist (Gall, 2012). Moreover, this research found that after a five-year period from the initiation of the intervention, the process was still not well implemented within the professional healthcare arena and was not being achieved in practice (Gall).

Hanson et al. (2011), however, determined that household members were the primary source of transmission in 70% of infant pertussis cases and that 50% of those household members were eligible to have an updated pertussis immunization. The common mode of infectious transmission through household member to infants was noted by Hanson et al. (2011) as a critical opportunity to decrease transmission of pertussis through updating pertussis vaccine in those who were in close contact with the infant.

Shah and Davis (2009) and Stiller (2011) explored that the use of Tdap in adolescents and adults to promote herd immunity, which is defined by the CDC as resistance to an infectious agent within the community by decreasing the number of susceptible members making transmission less likely (CDC, 2012). Plans (2010) research looked into developing a method to determine what critical levels of antibodies are necessary to establish herd immunity within a community. This research noted that both DTaP and Tdap needed to be administered to all appropriate age groups to produce herd immunity in the general population (Plans, 2010). Utilizing this intervention would provide a foundation that promotes herd immunity in communities, helping to decrease transmission risk to infants less six months of age.

Current Recommendations to Decrease the Transmission of Pertussis to Infants

Recommendations to decrease rate of transmission in the first six months of life include: (a) initiating and following the CDC childhood guidelines for a five dose DTaP schedule at 2, 4, 6, 15-18 months and 4-6 years of age; (b) vaccinating women with the Tdap vaccine after the twentieth week of pregnancy to promote passive immunity to the infant until full immunization

can be achieved with DTaP; (c) practice cocooning of infants through immunizing persons who are in close contact with the infant including family members, caregivers and healthcare workers; and (d) use of Tdap in adolescents and adults to promote herd immunity (CDC, 2012; Shah, & Davis, 2009; Stiller, 2011).

Vaccinating. The combination vaccine DTaP was approved in 1991 for use in the pediatric population in the United States. The pertussis vaccine used in the combination vaccine in the United States is the acellular pertussis (aP) vaccine. The current recommendation by ACIP is to complete a primary series of three doses of DTaP vaccine, which are administered at two, four and six months of age and then followed with two booster doses between the ages fifteen and eighteen months and again between four and six years of age (CDC, 2012). A literature and epidemiologic review of pertussis data determined that the use of the first two doses of the pertussis vaccine should be given as near to the recommended two and four months age to decrease infant susceptibility to pertussis (Wood, Quinn, McIntyre and Elliott, 2008). The protective immunity to pertussis is acquired by infants after the third dose of the DTaP vaccine is completed. Thus, the need to complete the series is vital for infants to gain protection from pertussis.

One contributing factor to the increased transmission of pertussis in the infant population may be the lack of adherence to the dosing schedule (Zastrow, 2011). A 2005 study by Luman et al. found that 48% of children in the United States under the age of thirty-six months were behind in one or more doses of the DTaP series, while 10-20% remained under-vaccinated for more than six months. The National Immunization Survey in 2009 documented that 25.8% children age twenty-four to thirty-five months had delayed immunization, 8.2% refused immunization, and 5.8% had both delayed and refused immunizations (Smith, 2011).

Refusing and delaying childhood vaccinations has risen to the highest rate in sixty years in the United States as missed childhood vaccinations surged from 22% in 2003 to 39.9% in 2009 (Smith, 2011). The consequence of not receiving the DTaP immunization can leave a child six times more likely to contract pertussis (Feikin et al., 2000).

WHO (World Health Organization) reports that the aP vaccine's protective efficacy is at 76-85% after the completion of the primary three shot series (WHO, 2010). A waning effectiveness of the primary series has been noted at approximately five to six years of age. Due to the reduction in antibodies noted in children at age five to six, the current recommendation is to follow the primary DTaP immunization series with two boosters (WHO). A one-dose booster is recommended in the second year of life. This is followed by a second one-dose booster at four to five years of age in order to maintain sufficient immunity when children begin school (CDC, 2012). Surveillance of pertussis in the United States has found that without the second DTaP booster the number of cases of pertussis rise in the seven to ten year old age range and further escalated the risk of transmission of the disease (WHO).

Vaccinating During Pregnancy. The 2012 ACIP (Advisory Committee on Immunization Practices) guidelines include the use of Tdap vaccine after the twentieth week of pregnancy in women who have not previously received a Tdap vaccine as an adult or those who have unknown immunization history (CDC, 2012; ACOG, 2012; Gall, 2011). There has been no evidence of any adverse effects on fetal development with the use of Tdap vaccine, and no contraindications have been reported with the use of any inactivated Tdap vaccine in pregnancy. ACOG does note that there is a theoretical risk to use of any vaccine, as with any medication in pregnancy, there is a possible potential that the vaccine could interfere with appropriate fetal

development. The risk to benefit ratio should be reviewed and discussed with all patients (ACOG).

Both the American College of Obstetrics and Gynecology (ACOG) and the American Academy of Pediatrics (AAP) support the recommendation to immunize against pertussis in pregnancy, as studies have demonstrated there is more efficient placental transfer of antibodies to newborns when women are fully immunized (Gall, 2012). Research finds that maternal immunization before or during pregnancy aids the creation of protective antibodies, which are transferred to the infant and provide passive immunity prior to delivery (Gall). Shakib et al. (2010) note that a booster dose of Tdap received in early adolescences can produce protective antibody level for about five years however, after time it will begin to wane and may no longer provide any substantial protection for a woman during pregnancy or for the newborn. The lack obtaining pertussis immunizations or incomplete immunization in mothers has correlated with low maternal antibody levels, which is associated with minimal placental transfer of passive antibodies and shortened passive protection for infants (Gall).

Cord blood of newborns contains higher levels of pertussis when mothers received a Tdap immunization during pregnancy, or prior to pregnancy, in comparison to the cord blood of infants whose mothers were not immunized (Gall, 2011). Use of the Tdap vaccine provides maternal protection against pertussis and, decreases transmission rates to infants, which has been reported to provide infants with two to three months of passive immunity through the transplacental transfer of antibodies (Gall; Stiller, 2011). Immunization prior to or during pregnancy has been shown to produce higher antibody levels in infants during the first critical weeks of life. Infants who were born to mothers who had received the Tdap immunization in during pregnancy had antibody levels that were 2.6 times greater in comparison to the infants of

non-immunized mothers (Halperin et al., 2011; Gall, 2012). The higher antibody rates provide a higher level of protection for the infants until they can receive the primary DTaP immunization series. Katz, Capua, & Bocchini (2012) reported that Tdap immunization in pregnancy would prevent more cases of infant pertussis, hospitalizations and deaths than immunization received in the postpartum period.

Vaccinating During Post-Partum. Maternal immunization in the post-partum period is reported to produce an antibody response in approximately fourteen days from the date of vaccination, which is when the neonatal protection from maternal exposure would begin (Halperin et al., 2011). Murphy et al. (2008) noted that pertussis antibodies present in breast milk do not provide infants with protection from the illness. The antibodies that are found in breast milk are unable to enter the neonatal circulation in adequate amount from the intestines (Murphy et al., 2008). This limits the protection gained with maternal post-partum vaccination to the reduction of maternal susceptibility to pertussis, which limits the infant's exposure in the first weeks of life. Thus, the concern in waiting to immunize a woman until the post-partum period is that there is no placental antibody transfer to provide infant with early life protection. Further, maternal response to a post-partum vaccination is not rapid enough to provide adequate maternal protection from acquiring pertussis and passing it on to the infant in the first few weeks of life when they are most vulnerable. With the rising rates of pertussis found in the United States, ACIP has altered its Tdap recommendations to promote vaccination after the twentieth week of pregnancy as a delay in immunizing a mother until post-partum period can increase the risk of transmission to the infant in the susceptible period of life (CDC, 2012). Further, if the mother is not breastfeeding, pertussis antibodies will not be transmitted to the infant. The only protection

available to infants who are not breastfeeding is through minimizing the infant's exposure to pertussis.

Physiological Response by Infant to Maternal Immunization

Blunting. It has been suggested that the passive maternal antibodies an infant receive with maternal immunization in pregnancy may interfere with the infant's ability to independently produce pertussis -specific antibodies after they are directly vaccinated with DTaP. This has been termed "blunting" (Center for Disease Control and Prevention Morbidity and Mortality Weekly Report, 2012). Katz, Capua & Bocchini (2012) noted that infants whose mothers received a Tdap vaccine in pregnancy had higher circulating maternal antibodies during the first four to five months of life and were more likely to provide an infant with protection that decreases the risk of pertussis at the most vulnerable age. However, after about six months, it was found that those infants whose mothers had been vaccinated with Tdap had a slightly lower circulating antibody level and were at a slightly higher risk for contracting a pertussis infection as the immune response was blunted by the circulating maternal antibodies (Center for Disease Control and Prevention Morbidity and Mortality Weekly Report). Current evidence suggests that blunting is short lived because maternal antibodies decline quickly after delivery and are at a minimum shortly after the infant receives their first direct immunization dose (Shakib, Raissy, Stoddard, Edwards & Byington, 2010). ACIP has reviewed the duration of blunting and believes that the potential benefit of protection from maternal antibodies to a newborn outweighs the potential risk created by shifting the burden to later infancy (Morbidity and Mortality Weekly Report). The consequences of blunting does need further research to determine the clinical significance, if any, to an infant's immune response and to adjust current immunization guidelines.

Cocooning. “Cocooning” is a strategy developed to protect newborns against pertussis by insulating them from exposure to the pertussis bacteria. Minimization of transmission of pertussis to infants is provided with the protection of vaccinating families, caregivers and others who may have close contact with infants (CDC, 2012). Wendelboe et al. (2007) concluded that 76%-83% of the transmission of *Bordetella pertussis* to infants is through contact with household members. The high percentage of close contact transmission necessitates the use of immunization in those who are close to infants. Base –case analysis from the Netherlands found a reduction in overall number of pertussis cases by 26% with the use of cocooning (Zepp et al., 2011). Decreasing exposure risk is directly correlated to decrease pertussis rates.

ACIP has recommended cocooning infants to pertussis since 2005 (CDC, 2011). Recommendation include use of a single Tdap dose for all parents, siblings, extended family, child care providers and healthcare workers who are in contact with infant less than twelve months of age (Zepp et al., 2011). Zittle (2009) reported that a there is a strong indirect effect on infants with the use of cocooning strategy. A decrease of 70% of pertussis cases was noted in the 0-3 month age range and 65% in the 4-23 months when cocooning was implemented (Forsyth et al., 2005).

Multiple studies have found that cocooning is a cost effective intervention that did decrease pertussis cases in parents and thus, infants (Zepp et al., 2011; Westra et al., 2010). The high transmission rate from household members and the vulnerability of infants to serious complications from pertussis necessitates the use of immunization in those who are in close contact with infants to minimize transmission (Westra et al., 2010). Waning immunity in the community creates the need to protect infants through the use of routine Tdap vaccines for those in close contact with infants. Vaccinating healthcare workers who have close and routine

interactions with newborns is recommended to prevent pertussis transmission. Healthcare facilities are advised to create and follow policies that enforce updating Tdap vaccines in all persons who are in contact with newborns (Plans, 2010).

ACIP has stated that cocooning alone is not a sufficient strategy to prevent pertussis morbidity and mortality in newborns (CDC, 2012). Cocooning does not completely isolate an infant from all contact with pertussis. The 2006 study by Healy et al. found barriers to cocooning in the high risk populations included lack of family compliance due to limited vaccination hours in facilities and an inaccurate recollection of immunization history by adults (2011). The coverage of post-partum women has been reported as moderate, but immunizing fathers and other family members has been less effective (Katz, Capua, & Bocchini, 2012). To enhance vaccination coverage it is recommended that policies for standing order for Tdap vaccines be implemented and facilities should arrange for onsite immunizations. These recommendations are noted to increase coverage rates in the population of people in contact with infants, especially in high-risk populations.

Herd Immunity. Decreasing infectious disease within communities requires that a maximum number of people be protected from the disease to interrupt the transmission within a population (Plans, 2010). Herd immunity facilitates a reduction in the number of new cases of pertussis by disrupting the transmission. The necessary number of protected people needed to enable the disruption of the transmission of an infection within a community is called the herd immunity threshold (Plans). Pertussis has a high herd immunity threshold as it is an infection found in all age groups and requires universal vaccine coverage at frequent intervals to prevent its transmission.

Herd immunity is required to provide adequate protection from pertussis. The Tdap vaccine has been approved since 2005 for use in persons eleven to sixty-four years of age. Currently, there are two Tdap vaccines available in the United State for this age group: Boostrix and Adacel (CDC, 2012). The current ACIP guidelines are that the Tdap vaccine be administered as a single dose immunization in place of the tetanus and diphtheria (Td) vaccine in adolescents, if it has been greater than ten years since a person's last Td, or if they have never received a Tdap vaccine (CDC). Studies found that pertussis is circulating in all age groups within communities and universal vaccination, at frequent intervals and within all age cohorts are recommended (Cherry, 2012). The guidelines focus on use of vaccination to maintain both adolescent and adult immunity and to maximize control of the rates of pertussis in the community to limit infant exposure and minimize the threat to infant.

To promote herd immunity, ACIP's recommendations include the use of a single dose Tdap booster in all adolescents aged eleven through eighteen years of age, with the optimal timeframe for the adolescent booster recommended between the age of eleven and twelve (CDC, 2012). The Tdap is advised to replace the use of the Td vaccine that was previously used. Research found that immunity from the primary Tdap series delivered in early childhood immunizations wanes in adolescence and subsequent booster doses were needed to maintain immunity and prevent the spread of pertussis in the community (Zastrow, 2011). In the first six months of 2012 the CDC reported that in the highest incidences of pertussis was found among infants under age one year and in adolescents ages 10, 13 and 14 years of age (Pertussis epidemic- washington 2012, 2012). The rise in pertussis infections in the adolescent age group suggests that waning immunity is preventing herd immunity and necessitate a booster Tdap to

improve immunity and to decrease circulation of pertussis in both adolescents and adults, thereby, providing less exposure of pertussis to infants.

In 2012, ACIP began recommending that any adult age 19 years and older, who have not yet received a dose of Tdap vaccine, should receive this immunization and that it may be administered regardless of interval since last tetanus or diphtheria toxoid (Td) vaccine (CDC, 2012). The guideline to use a booster immunization in this cohort was enacted to promote herd immunity by increasing the prevalence of the protect members in a community as adults have been found to be primary carriers (Rittle, 2009). A rise in the incidence in *B. pertussis* cases over the last forty years and the increase in those over age thirty-five indicate that for adults to maintain immunity the required booster vaccinations (Plans, 2010)

The current level of herd immunity to pertussis found in the United States is not completely protective for unvaccinated children (Glanz et al., 2009). Glanz et al. (2009) theorize that the updated immunization recommendations currently advised by the CDC will have a positive impact on herd immunity in the future. As the number of adolescents and adults obtaining booster vaccinations increases it is believed that the transmission of pertussis to infants will decrease. By improving vaccine coverage there will be an expansion in herd immunity, and thus, transmission of pertussis will diminish.

Refusal to vaccinate against pertussis in childhood has been shown to have a significant impact on herd immunity and contributes to the significant increase for the risk of contracting pertussis. Research found that over an eleven-year period that a person was twenty-three times more likely to contract pertussis if they were not immunized (Glanz et al., 2009). To minimize the risk of contracting pertussis and minimize the risk to infants strong and consistent herd immunity is a necessity.

Recommendations for Future Research

The utilization of pertussis vaccination has been shown to be an effective method to decrease the transmission rates of pertussis to infants. There is a need for further research on the effect of passive antibodies an infant receives during maternal immunization in pregnancy on the infant's ability to independently produce antibodies for primary protection after direct vaccination. Determining if the passive antibodies that the fetus receives from a maternal source are protective or detrimental in long-term protection from pertussis is vital to determine best practice guidelines. Randomized trials are needed to concretely determine the safety and efficiency in protecting infants from pertussis in the first six months of life when they are most vulnerable.

Further research is needed to determine the effectiveness of accelerating the first dose of DTaP from two months of age to six weeks of age along with evaluating if this intervention would promote faster primary immunization and reduced pertussis rates. A study by Shinall, Peters, Zhu, Chen & Poehling (2008) found that hospitalization was decreased by nine percent and decrease deaths attributed to pertussis by six percent in infants younger than three months of age. Additionally, Campbell et al. (2012) found that an accelerated pertussis vaccination schedule of infants in England produced sustained vaccine coverage rates, with fewer reported cases of pertussis among infants. The concern that has been raised is that the early initiation of the vaccine can have a rebound effect that lowers antibody rates and minimize effective coverage by six months of age. More in depth analysis is need to determine the most effective guidelines for DTaP schedule.

Conclusion

Pertussis is a highly contagious and potentially lethal respiratory infection, especially in infants under six months of age. Awareness of the risks pertussis poses to infants, and recognizing the current epidemic levels present in many communities is one step towards regaining control of the issue. Minimizing the risk of pertussis infections for infants requires increased protection to help decrease transmission rates. This will require the cooperation and diligence from both healthcare professionals and community members.

Eliminating pertussis in developed countries like the United States is a difficult task as the age cohort of infants less than six months of age are too young to be independently immunized, and are therefore, dependent on their surrounding family and community to fulfilling the immunization recommendations across the age spectrum to provide immunization protection.

As pertussis immunity wanes over time, repeated vaccination boosters are required to maintain immunity through life. This waning immunity increases the exposure risk for infants and further adds increased burden for individuals within the community to stay up-to-date on immunization requirements. Understanding the risk and susceptibility infants less than six months of age face and utilizing current guidelines to provide a foundation of prevention from pertussis exposure and using a proactive approach through the use of antibody transferred via maternal immunization, as well as encouraging herd immunity are the basis for best practice guidelines.

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