Pertussis—The Case for Universal Vaccination

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PURPOSE. Does the literature support universal vaccination of adolescents and adults, reducing disease incidence in infants and young children?

DESIGN & METHODS. An extensive literature review and a meta-analysis of four case-control studies, evaluating effects of missed or late vaccine doses, was conducted.

RESULTS. The literature confirms (a) increasing pertussis rates; (b) adults and adolescents are the primary carriers; (c) vaccine effectiveness wanes over time; and (d) pertussis persists despite disease control efforts.

PRACTICE IMPLICATIONS. Missed or late doses mean an increase in likelihood of contracting pertussis, supporting full vaccination for children and boosters for adolescents/adults.

Search terms: Adolescents, adults, case-control studies, epidemiology, history, immunology, late doses, missing doses, pertussis, pertussis diagnosis, prevention and control, universal vaccination, vaccine

In working with many public health immunization patients and surveying available literature for several years, I noted an increasing incidence in pertussis. Each year, it seems, the news reports a number of small and large pertussis outbreaks scattered throughout Pennsylvania. On occasion, one hears of the death of an infant, usually too young to have received any pertussis vaccine immunizations. In 2005 the Centers for Disease Control and Prevention (CDC) announced the availability of Tdap (a new booster vaccine for adolescents and adults containing tetanus, diphtheria, and acellular pertussis antigens that was approved by the Food and Drug Administration; CDC, 2005).

The introduction of Tdap vaccine was the motivation for this project. Why is a pertussis booster needed when having the disease or being vaccinated should provide lifelong immunity? Why does the literature document an ever-rising incidence in pertussis if all children are receiving the required five doses of pertussis vaccine prior to entering school? Is vaccine effectiveness waning? Are primary care providers doing all they can to ensure children and their families are protected from this disease? Do providers have the knowledge and understanding of pertussis to educate families and the community? Do parents and schools understand what they must do to control outbreaks once pertussis has been documented in the community?

To address these concerns, this meta-analysis looked at the epidemiology of pertussis, the prevalence of the disease, the role that waning vaccine effectiveness seems to have on the spread of disease, and how universal vaccination of adolescents (a booster dose of pertussis vaccine for those 10–18 years of age) and adults (a booster dose for those 19–64 years of age) can help to minimize the spread of disease and protect the most vulnerable—our very young
infants and children. In addition, four studies were reviewed to determine if there was any increase in disease because of children receiving immunizations late or missing doses completely.

**A Review of the Relevant Literature and Evidence Supporting Practice Change**

**The Epidemiology of Pertussis**

Pertussis, commonly known as whooping cough, is caused by the bacterium *Bordetella pertussis* (Atkinson, Wolfe, Hamborsky, & McIntyre, 2009). *B. pertussis* is a small, aerobic gram-negative rod bacterium that causes “highly contagious infection with 80% attack rates in susceptible close contacts” (Judelsohn & Koslap-Petraco, 2007, p. 422). When discussing the pathogenesis of pertussis, Atkinson and colleagues (2009) stated,

> Pertussis is primarily a toxin-mediated disease. The bacteria attach to the cilia of the respiratory epithelial cells, produce toxins that paralyze the cilia, and cause inflammation of the respiratory tract, which interferes with the clearance of pulmonary secretions. Pertussis antigens appear to allow the organism to evade host defenses. (p. 199)

Davis (2005) reported that pertussis typically resides in older individuals and is responsible for the cyclical outbreaks and epidemics that spread to susceptible children, with projections estimating the number of cases in the United States at approximately 1 million per year.

**Clinical Features and Stages of Pertussis**

Pertussis can cause serious illness in children and adults and typically presents in three stages (Judelsohn & Koslap-Petraco, 2007). According to Broder and colleagues (2006), the incubation period is typically 7–10 days with a range of 5–21 days. The disease starts like the common cold with symptoms of runny nose, congestion, sneezing, and maybe a mild cough or fever—this is the first or catarrhal stage (Atkinson et al., 2009).

Severe coughing begins after 1–2 weeks—the paroxysmal stage (stage 2). “Children with pertussis have a decreased ability to expectorate respiratory secretions and develop a thick glue-like mucus in the windpipe” (National Network for Immunization Information, 2008 [para. 2]). Children with the disease typically cough violently and rapidly, resulting from difficulty in expelling thick productive mucus. At the end of the attack they are forced to inhale with a loud inspiratory “whooping” sound, with vomiting common after the attack (Hewlett & Edwards, 2005). Atkinson and colleagues (2009) reported the patient may show signs of cyanosis during the attack. Broder and colleagues (2006) described the paroxysmal stage as usually lasting 4–6 weeks. While Atkinson and colleagues reported that the paroxysmal stage may last up to 10 weeks, they also described how children and infants may appear seriously ill and in distress but may not show symptoms between attack periods.

The final or convalescent stage is gradual recovery with the cough gradually disappearing over 2–3 weeks (Atkinson et al., 2009) or may continue for 3 months or longer (Judelsohn & Koslap-Petraco, 2007). It is common that paroxysms can continue because of future respiratory infections for many months after the initial disease (Atkinson et al., 2009).

**The Transmission and Resurgence of Pertussis**

People with pertussis usually spread the disease via poor social etiquette—by coughing or sneezing around others, who then breathe in the droplet spray containing the pertussis bacteria; often the source for infection in young children and infants are their asymptomatic siblings and parents (CDC, 2010).

Atkinson and colleagues (2009) noted three key points concerning the spread of pertussis. First, transmission does not occur frequently by contact with freshly contaminated articles. Second, pertussis is highly communicable—secondary attack rates of 80% among nonimmune household contacts are very common. Third, the period of maximum communicability is during the catarrhal stage and the first 2 weeks after onset of cough (Atkinson et al., 2009).

Many adults think that pertussis, as a childhood disease, is a thing of the past. However, pertussis is rebounding in the United States. Since 1976, when a reported low of 1,060 cases were reported, pertussis rose to a reported 40-year high of more than 25,000 cases in 2004, with an estimated one third of all cases diagnosed in adolescents (Mitka, 2006). In recent years, the number of reported cases in the United States was 21,003 in 2005, 13,144 in 2006, 8,739 in 2007, 9,499 in 2008, and 13,506 in 2009 (CDC, n.d.). This trend indicates that there are still spikes in disease and pertussis continues to present a significant number of cases every year.

Formerly, it was believed that after the childhood immunization series of five vaccinations was complete, the child had lifelong immunity from pertussis. The 40-year rise in pertussis incidence has caused scientists to study the problem to determine the cause of the increasing incidence. Mitka (2006) reported (p. 871), “Twenty years ago, it was thought that either getting the disease or being vaccinated led to lifelong protection, so we did not recognize pertussis as a disease in older people.”
Seasonality of Pertussis

Atkinson and colleagues (2009) stated that pertussis may increase in the summer and fall. This coincides with study findings. Rendi-Wagner, Paulke-Korinek, Stanek, Khanakah, and Kollaritsch (2007) found disease peaks in January, May, October, and December. Sotir and colleagues (2008) described small clusters from June to August with most cases in October to December. Schafer, Gillette, Hedberg, and Cieslak (2006) identified cases from March through December with a peak in May, then another peak from late August through early August. Borchardt, Polyak, and Dworkin (2007) recorded cases from late August through September, and the Yavapai County school outbreak (CDC, 2004) listed cases from September through November. Mancuso and colleagues (2007) reported the exception; cases were reported from April through June. In general, the literature shows that most cases occur in the summer and fall months.

Prevalence of Pertussis in Adolescents and Adults

Much of the literature addresses the prevalence of pertussis in adolescents and adults and identifies them as the primary carriers. In a national study, Davis (2005) reported that the 10–19-year-old age group experienced 38% of all cases, by far the most of any age group. Rendi-Wagner and colleagues (2007) found in Austria that 69% of patients were equal to or greater than 16 years of age. (Note: Austria requires vaccinations at 3, 4.5, and 6 months of age and recommends a booster at 2 years of age.) In Wisconsin, Sotir and colleagues (2008) reported that most cases occurred in children between the ages of 10 and 14 years. In Oregon, Schafer and colleagues (2006) reported that older children and teens, ages 10–17 years, accounted for 28% of all cases, and adults accounted for 39% of cases. In the study conducted by Mancuso and colleagues (2007) in a U.S. military community in Germany, 52% of cases occurred in children 5–14 years of age and 24% of cases occurred in adults more than 20 years of age. Pascual and colleagues (2006) studied an outbreak in a hospital where all patients were adults. In Yavapai County, Arizona, in 2002–2003 the CDC reported that 42% (203 out of 485) of cases were associated with schools. Of these cases, 56% were students (113), 4% (8) were school staff, and 40% (82) were family members (CDC, 2004). Of the students, the eighth graders experienced the highest attack rates and comprised 20% of the population (CDC, 2004). Khan and colleagues (2006), in Missouri, reported that the majority of outbreak patients were adolescents (50%) and adults 20 years or older (22%). Forsyth and colleagues (2004), in the Global Pertussis Initiative report, described adolescents and adults as being commonly and regularly infected with \( B. \) pertussis and were therefore potentially a major source of pediatric infection. All of these studies indicated that adolescents and adults were the primary carriers of the pertussis bacterium. Cherry (2005) attributed most of the increase in pertussis since 1984 to the "increased awareness of \( B. \) pertussis illness and also the use of many vaccines that were less efficacious than DTP vaccines of the past" (p. 1426).

From a historical perspective, DPT vaccines were introduced in the 1940s and were associated with significantly higher incidences of swelling and induration (odds ratio [OR] 11.67, 95% confidence interval [CI] 8.83–15.44, fever [OR for fever > 39°C 3.36, 95% CI 2.06–5.49] and crying for more than 2 hr (OR 4.72, 95% CI 2.94–7.59; Jefferson, Rudin, & DiPietrantonj, 2003). In response to those adverse effects, acellular vaccines were developed in the 1970s that had an adverse event profile considerably better than the DPT vaccines (Jefferson et al. 2003).

When comparing the efficacy of the DTP vaccines with the efficacy of the acellular vaccines, Jefferson and colleagues (2003) found that efficacy varied with the type of vaccine. While the efficacy of DTP (a whole-cell pertussis vaccine) was higher (varying from 37% to 92%), the multicomponent acellular pertussis vaccines exhibited less overall efficacy (from 67% to 70% efficacy for 1–2 component vaccines to 80–84% efficacy with 3+ component vaccines). Absolute efficacy of whole-cell DTP varied from 37% to 92%. One- and two-component acellular vaccines had lower absolute efficacy (67–70%) than vaccines with greater than or equal to three components (80–84%). Therefore, providers have switched from a more efficacious whole-cell DTP vaccine associated with many adverse events to a less efficacious acellular vaccine with a less severe adverse event profile (Jefferson et al., 2003). Cherry (2005) also suggested that a "universal program with adolescent and adult boosters would decrease the circulation of \( B. \) pertussis in these age groups and possibly could lead to the elimination of the organism from the population" (p. 1422).

The Case for Universal Vaccination of Adolescents and Adults

Universal Vaccination Against Pertussis

The literature studied, most notably Atkinson and colleagues (2009), Forsyth, Tan, von Konig, Caro, and Plotkin (2005), and the Global Pertussis Initiative (Forsyth, von Konig, Tan, Caro, & Plotkin, 2007), suggested that the most effective method for reducing the incidence of pertussis is universal vaccination. This means not only ensuring that all children are fully vaccinated with DTaP but that all adolescents (10–18 years of age) and adults (19–64 years of age) receive a booster dose of Tdap, either Boostrix (licensed for
those ages 10 through 64) or Adacel (licensed for those ages 11 through 64; Atkinson et al., 2009).

The Global Pertussis Initiative, in addition to universal vaccination of children, adolescents, and adults, also recommends the "cocoon strategy"—the immunization of new mothers and family members/close contacts of newborns. In fact, Forsyth and colleagues (2007) detailed "that although the cocoon strategy leads to only a 9–17% reduction in typical adult cases, there is a strong indirect effect on infants and young children: a decrease by 70%, 65%, and 69% was noted in cases among 0–3-month-old, 4–23-month-old, and 2–4-year-old groups" (p. 2638). Other target groups of the report include healthcare workers and childcare workers—all adults in close contact with children on a regular basis.

These programs are all designed with the goal of universal vaccination in mind. The target areas are recommended programs designed to vaccinate those who are most likely to be the reservoir of disease and who may be in a position to pass the disease on to susceptible children.

Waning of Pertussis Vaccine Efficacy

Even with 100% compliance with vaccination recommendations, there is evidence that vaccine effectiveness wanes over time. Atkinson and colleagues (2009) stated that vaccine efficacy for DTaP (the 5-dose diphtheria-tetanus-acellular pertussis vaccine provided to children under the age of 7 years old) ranged from 80% to 85%. This means there would still be some level of disease in the community.

Edwards (2005) found the most dramatic increase in pertussis incidence has been among adolescents and young adults and indicated that this was due to the effects of a waning of vaccine-induced immunity effectiveness. Dempsey and colleagues (2009) also reported that waning immunity following childhood vaccination contributes to adolescent susceptibility to pertussis.

A 2006 study by Khan and colleagues reported some interesting data about vaccine effectiveness. This study noted that students missing at least one dose of the vaccine had a higher risk for pertussis than those who received all five doses (OR, 2.36; 95% CI, 1.17–4.77). Another interesting finding by Khan and colleagues is that early administration of the fifth dose of the vaccine at the age of 4 years was significantly associated with a risk for pertussis compared with vaccination at the age of 5 years (adjusted OR, 2.45; 95% CI, 1.16–5.16).

Other studies have shown that the period over which vaccine efficacy wanes varies according to the study. Lambert (1965) only reported that the increased incidence of pertussis in vaccinated persons was directly related to the interval since the last injection of pertussis vaccine. de Greef, Mooi, Schellekens, and de Melker (2008) described the waning period as 5–7 years after the last vaccination. Pascual and colleagues (2006) reported the vaccine waning period as 5–10 years, and the CDC (2004), describing Yavapai County, Arizona, reported the waning period as 5–15 years. Raguckas, VandenBussche, Jacobs, and Klepser (2007) reported that protection waned with time, resulting in little or no immunologic protection 5–10 years after the last dose in the primary series.

A 1988 study by Jenkinson to evaluate the duration of effectiveness of pertussis vaccine in the United Kingdom reported that the efficacy of pertussis vaccine is complete only for the first year after immunization and falls gradually over the next 3 years, although by the fourth year it is still 84% effective. During the next three years efficacy is around 50%, which is probably not adequate (p. 614).

Finally, Bamberger and Srugo (2008) reported that when individuals do contract pertussis after the waning of their immunity, the manifestations of their disease are frequently atypical and their illness is often underdiagnosed—posing a significant public health risk to the community.

Review of Current Statistics

A review of the Morbidity and Mortality Weekly Report Tables (CDC, n.d.) and the Pennsylvania Department of Health’s Vital Statistics (2007) is described in Table 1. Of significant note is the dramatic change in rates from the years 1996 to 2003 to the most recent 5-year period, 2004–2008. The rates for 2004, 2005, 2006, and 2008 were all significantly higher than the preceding 8-year period. The only exception in the period 2004–2008 was 2007—a year that was higher than the preceding period (1996–2003). The cause of this dramatic increase in pertussis incidence rates merits additional review.

When the incidence rates for pertussis in the years 1996–2008 are displayed graphically (see Figure 1), the significance of the 2007 incidence rate is easily seen. For the 5-year period of 2004–2008 the incidence rate for 2007 (386, 95% CI, 3.41–2.79) shows no overlap with the intervals of the other 4 years, indicating a significant change in that 1 year. But it does not tell why the change occurred.

Looking at the annual figures shown in 5-year trends is revealing (Table 1). The 1999–2003 average is 250 reported cases per year. In contrast, the 2004–2008 average is 511 reported cases per year. Statistical analysis of this comparison shows that a Pennsylvania citizen would be 2.015 times more likely to contract pertussis in the period 2004–2008 ($\chi^2 = 85.84, p < .001$).

Table 2 shows an analysis of data for 5 years (2004–2008) only. Most significantly, patients in 2008 were 1.316 times more likely to contract pertussis than in 2007 ($\chi^2 = 16.65, p < .001$).
There can be many reasons for this increase in the incidence of pertussis. Judelsohn and Koslap-Petraco (2007) suggested any of the following: an increased diagnosis by providers; underimmunization of infants, toddlers, adolescents, and adults; the effects of waning immunity from previous immunization efforts; a large reservoir of pertussis-susceptible adolescents; the high contagiousness of pertussis; and nosocomial spread in hospitals and doctor’s offices. The determination of the actual reasons for the change in incidence of pertussis between 2007 and 2008 will be left to future study.

A Meta-Analysis of Four Studies

A literature search was conducted in MEDLINE, Academic Search Elite, Health Business, Cochrane Central Register of Controlled Trials, CINAHL Plus, Cochrane Database of Systematic Reviews, and Biological Abstracts. Subject areas included pertussis diagnosis, epidemiology, outbreaks, history, immunology, prevention and control, health knowledge, attitudes, practice, vaccine-therapeutic use, and vaccination. Articles found dated from 1965 through mid-2009. Bibliographies of retrieved articles were searched, as were CDC

Table 1. Pennsylvania Pertussis Incidence Rates 1996–2008

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
<th>Population</th>
<th>Rate</th>
<th>Confidence Interval Upper Limit</th>
<th>Confidence Interval Lower Limit</th>
<th>Confidence Interval Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>508</td>
<td>12432792</td>
<td>4.09</td>
<td>4.44</td>
<td>3.73</td>
<td>0.71</td>
</tr>
<tr>
<td>2007</td>
<td>386</td>
<td>12432792</td>
<td>3.10</td>
<td>3.41</td>
<td>2.79</td>
<td>0.62</td>
</tr>
<tr>
<td>2006</td>
<td>587</td>
<td>12440621</td>
<td>4.72</td>
<td>5.10</td>
<td>4.34</td>
<td>0.76</td>
</tr>
<tr>
<td>2005</td>
<td>514</td>
<td>12429616</td>
<td>4.14</td>
<td>4.49</td>
<td>3.78</td>
<td>0.72</td>
</tr>
<tr>
<td>2004</td>
<td>560</td>
<td>12406292</td>
<td>4.51</td>
<td>4.89</td>
<td>4.14</td>
<td>0.75</td>
</tr>
<tr>
<td>2003</td>
<td>352</td>
<td>12365455</td>
<td>2.85</td>
<td>3.14</td>
<td>2.55</td>
<td>0.59</td>
</tr>
<tr>
<td>2002</td>
<td>194</td>
<td>12335091</td>
<td>1.57</td>
<td>1.79</td>
<td>1.35</td>
<td>0.44</td>
</tr>
<tr>
<td>2001</td>
<td>198</td>
<td>12287150</td>
<td>1.61</td>
<td>1.84</td>
<td>1.39</td>
<td>0.45</td>
</tr>
<tr>
<td>2000</td>
<td>288</td>
<td>12281054</td>
<td>2.35</td>
<td>2.62</td>
<td>2.07</td>
<td>0.54</td>
</tr>
<tr>
<td>1999</td>
<td>219</td>
<td>11994016</td>
<td>1.83</td>
<td>2.07</td>
<td>1.58</td>
<td>0.48</td>
</tr>
<tr>
<td>1998</td>
<td>260</td>
<td>12001451</td>
<td>2.17</td>
<td>2.43</td>
<td>1.90</td>
<td>0.53</td>
</tr>
<tr>
<td>1997</td>
<td>197</td>
<td>12019661</td>
<td>1.64</td>
<td>1.87</td>
<td>1.41</td>
<td>0.46</td>
</tr>
<tr>
<td>1996</td>
<td>327</td>
<td>12056112</td>
<td>2.71</td>
<td>3.01</td>
<td>2.42</td>
<td>0.59</td>
</tr>
</tbody>
</table>
reports addressing pertussis and vaccines containing pertussis antigens. A total of 27 studies were found relating to pertussis or whooping cough. This meta-analysis focused on four of the studies that evaluated pertussis in the community and the role of vaccine effectiveness and low vaccine coverage. All four were case-control studies: Torm and colleagues (2005) in Estonia, Grant and colleagues (2003) in New Zealand, Bisgard and colleagues (2004) with children 6–59 months of age in four areas of the United States, and Khan and colleagues (2006) in Cass County, Missouri. A summary of the details of these studies is provided in Table 3.

All four studies included significant odds ratios showing that if children missed any doses of pertussis vaccine or had any delay in any dose of the pertussis vaccine they were twice as likely to contract the disease as their on-time and fully-immunized peers. The results of these studies, cases, and controls were analyzed using MedCalc (version 11.1.1.0; 2009), a statistical analysis package. MedCalc uses the Mantel-Haenszel method for calculating the weighted summary OR and assessing the homogeneity of the four study populations. A test for heterogeneity ($Q = 7.184$, $p = .066$) showed that the populations of all four studies were homogenous and that the fixed effects model was therefore valid for meta-analytic calculations.

The pooled OR from all four studies was 2.13 (95% CI, 1.65–2.76). In interpreting these data, a person who was missing a dose of pertussis vaccine or received a dose of pertussis vaccine late would be 2.133 times more likely to contract the disease than a person who had all doses of vaccine on time. The confidence intervals of all four individual studies also overlap the overall CI obtained from the fixed effects model, another indicator of significance (see Figure 2).

**Limitations of the Meta-Analysis**

The MedCalc meta-analysis determined that the populations are fairly similar. However, the populations studied could be different. MedCalc uses a conventional parametric index, Hedges g, to calculate the standardized mean difference under the fixed effects model. According to Hogarty and Kromrey (2000), other effect size estimators such as gamma and trimmed d are more robust to violations of the assumptions of population normality and homogeneity of variance and can be more appropriate than conventional parametric indices. The usage of SAS or another statistical analysis package that incorporates these more robust effect size estimators could modify the results of this analysis.

If there were more studies available to include in the meta-analysis a more definitive conclusion might appear. The meta-analysis was conducted using crude odds ratios. Some
of the studies made adjustments for confounding factors. This meta-analysis made no such adjustments because the actual adjustments made to the four studies reviewed are not available.

The individual studies also noted some limitations. Grant and colleagues (2003) noted that a multivariate analysis showed increased risk when first, second, or third dose occurred. This meta-analysis only took into account if any dose was late. Torm and colleagues (2005) noted problems with delay in case of identification as well as high mobility of families—a factor leading to missed doses. Khan and colleagues (2006) noted that 83.2% of their cases were probable cases according to the CDC clinical case definition (coughing at least 2 weeks but no laboratory confirmation and no epidemiological link to a confirmed case). This could have resulted in misclassification of cases in their study. Finally, Bisgard and colleagues (2004) noted that their study was only designed to examine the timing of administration of the fourth dose of vaccine. They found it more effective when given at less than or equal to 14 months of age. Their data might be confounded if providers were more likely to vaccinate at 12 months of age.

There are two other limitations of note for this meta-analysis. First, none of the studies addressed the vaccine handling and storage practices in the various clinics or provider offices. If vaccines are frozen they can be destroyed, and if kept too warm they can be ineffective in producing desired immunity. Second, it would be interesting to determine whether whole cell or acellular pertussis vaccine was used in any or all of the studies and what were

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**Table 3. Summary of Four Studies Reviewed in Meta-Analysis**

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Study Location</th>
<th>Issue in Question</th>
<th>Number of cases</th>
<th>Number of controls</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torm et al. (2005)</td>
<td>Estonia</td>
<td>Fewer than 3 doses of vaccine vs. Fully vaccinated</td>
<td>54</td>
<td>77</td>
<td>2.10a</td>
<td>1.4–3.0</td>
</tr>
<tr>
<td>Grant et al. (2003)</td>
<td>New Zealand</td>
<td>Delay in any immunization vs. Fully vaccinated</td>
<td>70</td>
<td>71</td>
<td>2.66b</td>
<td>1.02–7.71</td>
</tr>
<tr>
<td>Bisgard et al. (2004)</td>
<td>4 selected U.S. states</td>
<td>Received 0–3 doses vaccine vs. 4 or more doses of vaccine</td>
<td>893</td>
<td>181</td>
<td>2.40c</td>
<td>1.1–5.2</td>
</tr>
<tr>
<td>Khan et al. (2006)</td>
<td>Cass County, MO</td>
<td>Missing at least 1 dose of vaccine vs. Receiving all 5 doses</td>
<td>158</td>
<td>79</td>
<td>2.36d</td>
<td>1.17–4.77</td>
</tr>
</tbody>
</table>

Note: All odds ratios were adjusted in the studies cited. Estonia uses diphtheria, tetanus, whole-cell pertussis on a four-dose schedule of 3, 4.5, and 6 months then a booster at 2 years of age. New Zealand uses DTPH (diphtheria, tetanus, pertussis, Hib—Tetramune) on a three-dose schedule of 6 weeks, 3 months, and 5 months. Torm et al. appeared to have adjusted the quoted odds ratios but did not explain how they were adjusted. Grant et al. adjusted the odds ratios for age. Bisgard et al. adjusted via a conditional logistic regression. Khan et al. adjusted by controlling for age and via a conditional logistic regression.

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**Figure 2.** A presentation of the confidence intervals of the calculated odds ratios of all four studies. *Note: The “Total (fixed effects)” overlaps all four studies, an indicator of significance.*
the ages of the patients when these vaccines were administered. These questions could be the subjects of future research projects.

How Do I Apply This Evidence to Nursing Practice?

Based on the evidence, the best method to ensure a reduction of the incidence in pertussis is to promote universal vaccination not only for all children but also for all adolescents and adults. As vaccine immunity wanes over time, missing doses can reduce effectiveness of other doses already received.

There are some barriers that might directly lead to this lack of universal vaccination in children, adolescents, and adults. First, there is the question of insurance coverage for DTaP (the child formulation) and Tdap (the adolescent and adult booster). Not all insurance policies currently cover the costs of immunizations—a factor that can lead to disease-susceptible individuals in the community. Second, not all hospital emergency rooms currently administer Tdap as the standard tetanus booster. This can lead to adults and adolescents being carriers of pertussis and transmitting it to younger, underimmunized family members. Third, because Tdap is more costly than the older Td booster vaccine, cost may be a factor when facilities make decisions about which vaccine they will routinely provide to their patients. Finally, there are variations in the school immunization requirements among the states. Having consistent immunization requirements from state to state might help in achieving universal immunization and reducing the disease burden of pertussis in the community. It would be helpful if further research was conducted on these four barriers or on any other barrier identified to determine what might be done to further the goal of universal vaccination of the population against pertussis.

In the absence of a universal vaccination program, current programs for vaccinating adolescents will not sufficiently control B. pertussis transmission to infants. For an adult vaccination program to be successful, the program must include education to increase the awareness of both providers and the general public (Forsyth et al., 2007). Therefore, public health education, particularly for parents, will be an important factor in controlling the incidence of disease.

With this in mind, this report refers the reader to two Web sites for further information helpful in identifying pertussis and controlling outbreaks in the community as well as educating providers, families, school authorities, and the public at large. The Pertussis Fact Sheet, found at the Pennsylvania Department of Health (n.d.) Web site (http://www.portal.state.pa.us/portal/server.pt/community/diseases_and_conditions/11595), provides general information on the disease and its prevention in the community.

The second Web site—Guidelines for the Control of Pertussis Outbreaks—maintained by the CDC (2000; http://www.cdc.gov/vaccines/pubs/pertussis-guide/guide.htm) will assist several interested constituencies. Primary care providers will find up-to-date information about diagnosis, appropriate laboratory tests, and recommended antimicrobial agents for treatment and postexposure prophylaxis of pertussis. Other chapters will assist primary care providers in promoting the early exclusion of pertussis patients from schools and other community settings. Finally, information is provided to assist families and school authorities in recognizing outbreaks and identifying how to quickly implement steps to reduce the effects of pertussis in the community.

Through better education of the community, it is hoped that whenever pertussis is identified, the spread of disease can be minimized and that the most vulnerable, our very young children, can be protected from this disease.

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