A Pertussis Outbreak Associated with Social Isolation among Elderly Nuns in a Convent

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The pertussis incidence during an outbreak in a convent in The Netherlands in 1992 was higher among 75 retired (unvaccinated) nuns (60%) than among 24 staff members (8%) and was higher among 9 nuns with only a convent career (100%) than among 66 nuns who had a career outside of the convent (55%). The pertussis incidence increased with duration of social isolation but not with age.

A decline in pertussis incidence was seen starting at the beginning of the 20th century; it became more pronounced in the 1940s, when pertussis vaccine became available [1]. Despite vaccination, pertussis resurged; the resurgence occurred first among children and was related to a decrease in vaccination coverage as a result of opposition, in the 1970s, to the use of whole-cell vaccine. In the 1990s, pertussis was increasingly seen in adults; this was related to waning vaccine-induced immunity in countries with high and uninterrupted vaccination coverage among children [2, 3]. The proposed explanations for this reemergence are genetic changes in Bordetella pertussis that make vaccines less effective, lessened potency of vaccines, waning of vaccine-induced immunity, greater pertussis awareness, and general availability of better laboratory tests [4]. In addition, a decreased incidence of natural immunity-boosting infections with B. pertussis, as a result of the high coverage of national vaccination programs, might explain the reemergence of pertussis [5].

The importance of natural B. pertussis infections is not well understood. In this report, we describe an outbreak of pertussis in a convent of retired and unvaccinated nuns. Some had only limited exposure to society during their working life, whereas others had careers outside the convent, in The Netherlands and in the tropics. We aimed to study the role of natural infection by determining the relationship between incidence of pertussis and duration of isolation from society.

Methods. To evaluate the association between pertussis incidence and age, isolation from society, and a career in society, the clinical outcomes and laboratory findings of a previously described pertussis epidemic in a convent were used [6]. The convent population consisted of 75 resident nuns and 24 nonresident staff members. The cohort study started in week 9 of the epidemic, when pertussis was diagnosed by culture, PCR, and serum IgG serological tests, and other causes of respiratory tract infections (e.g., tuberculosis and influenza) were excluded. From week 10 onward, outbreak management with antibiotics was focused on pertussis. The onset of clinical symptoms, such as coughing, was established retrospectively through interviews.

Nasopharyngeal swab samples for culture and PCR in charcoal medium were processed as described elsewhere [7]. Titors of IgG antibody to pertussis toxin were determined by ELISA [8] at the National Institute for Public Health and the Environment, Bilthoven, The Netherlands. Antibody binding activities were quantitatively expressed in “local” units per milliliter, which can be converted to US Food and Drug Administration international units [9]. The detection level of the assay was 5 U/mL.

Pertussis infection was defined as the presence of 1 of the following laboratory findings: (1) a B. pertussis strain isolated from the nasopharynx; (2) a reactive PCR result; (3) a significant (at least 3-fold) increase or decrease in IgG antibody titers between serum samples obtained at weeks 9, 13, and 60 of the epidemic; or (4) a single IgG titer of $\geq$100 U/mL [8]. Clinical pertussis was defined as a persistent cough for at least 10 days, starting after the appearance of the first case of laboratory-confirmed pertussis infection. Pertussis was defined as pertussis infection and clinical pertussis combined.

The career files of all 75 nuns in the convent archive and of the 24 staff members were examined, by use of a structured questionnaire, to assess date of entrance into the convent, duration of isolation in the convent, duration of a career in Dutch society or as a missionary in the tropics, and duration of isolation after retirement in the convent up to the start of the outbreak in June 1992.

Statistical associations between pertussis incidence and age and career type were analyzed by use of a Yates-corrected $\chi^2$ test. The relationship between pertussis incidence and age and the total duration of isolation before and after retirement in

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the convent and after retirement only were analyzed by $\chi^2$ test for linear trend (Epi Info, version 6.04d; Centers for Disease Control and Prevention). Age adjustment was performed by logistic regression analysis (SAS, version 8.2; SAS Institute). The statistical association between median duration of cough and age and duration of isolation was calculated by linear regression analysis with cough duration as outcome (S-PLUS, version 6.0; Insightful).

**Results.** Since entry into the convent (the first of the nuns entered in 1922), all 75 nuns had been based in the same convent of the congregation of the Sisters Servants of the Holy Ghost in The Netherlands. Nine of the 75 nuns stayed in the convent for the rest of their lives after entry. Nuns slept in separate rooms, shared their meals in the dining hall, and only seldom left the convent or received visitors. The other 66 nuns interrupted their isolation in the convent; 38 had a career in The Netherlands as a nursery or primary school teacher or a hospital nurse, 22 had a career as a missionary in the tropics, and 6 had a career in both The Netherlands and the tropics. The missionaries had worked in Asia, Africa, and South America. By the start of the outbreak, the convent had become a nursing home for the 9 nuns who never left and for the 66 career nuns who had retired into the convent. The nuns had daily common social and religious activities and were supported by 24 staff members living outside the convent.

Since 1922, no other outbreak of coughing had been reported by the nuns or in the convent archives. At the start of the epidemic, the mean age of the nuns was 75 years (range, 59–91 years), and that of the staff was 26 years (range, 21–47 years). The incidence of pertussis was higher among the 75 nuns in the convent (45 of 75; 60%) than among the 24 staff members living outside the convent (2 of 24; 8%) ($P = .0003$). All 75 nuns and 3 of the 24 staff members were not vaccinated against pertussis. The 3 unvaccinated staff members did not have pertussis. The duration of cough among nuns with pertussis was 11–268 days (mean duration, 55 days). Four of the nuns had pertussis when they died.

The pertussis incidence was higher among nuns with a lifelong career in the convent ($n = 9$) than among nuns with a career outside the convent ($n = 66$) (100% vs. 55%, respectively; $P = .007$). The pertussis incidence among nuns who had worked in Dutch society only ($n = 38$) was 74%; in those who had worked in the tropics only ($n = 22$), it was 35%; and in those who had worked in both the Dutch society and the tropics ($n = 6$), it was 17% ($\chi^2$ for linear trend in proportions, $\geq 19.8$; $P < .0001$).

The pertussis incidence among all 75 nuns was not statistically significantly related to age ($P = .31$) (table 1). Pertussis incidence also did not increase with increasing total duration of isolation (before and after a career outside the convent) ($P = .08$), but it did increase with increasing duration of isolation after a career outside the convent ($P = .005$) (table 1). In the logistic regression model, duration of isolation after a career outside the convent remained associated with pertussis incidence ($P = .01$) after adjustment for age.

Severity of illness, expressed as duration of cough, was not associated with age group or duration of isolation. Three of 4 deaths among nuns with pertussis were in the oldest age group (85–94 years) (table 1). **Discussion.** The risk of pertussis in nuns during the pertussis

### Table 1. Relationship between pertussis incidence, age, and duration of isolation from society among 75 nuns with ($n = 66$) and nuns without ($n = 9$) a career outside the convent.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pertussis incidence</th>
<th>Duration of cough</th>
<th>No. of deaths among nuns with pertussis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. with pertussis/total</td>
<td>Percentage</td>
<td>$P$ for linear trend in proportions</td>
</tr>
<tr>
<td>Age group, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55–64</td>
<td>8/16a</td>
<td>50</td>
<td>.31</td>
</tr>
<tr>
<td>65–74</td>
<td>13/21</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>75–84</td>
<td>16/27</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>85–94</td>
<td>8/11a</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Duration of isolation from society, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–6</td>
<td>5/15</td>
<td>33</td>
<td>.005</td>
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<tr>
<td>7–13</td>
<td>9/17</td>
<td>53</td>
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<tr>
<td>14–20</td>
<td>10/16</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>21–34</td>
<td>9/12</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>35–70</td>
<td>12/15</td>
<td>80</td>
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</tbody>
</table>

* No significant difference between the incidence of pertussis in the youngest and oldest age group ($P = .21$, Fisher’s exact test).

* No significant difference between the median duration of cough in the youngest and oldest age group ($P = .08$), but it did increase with increasing duration of isolation ($P = .01$).

* Duration of isolation of the 9 nuns without a career outside the convent and the duration of isolation since retirement of the 66 nuns with a career outside the convent.
outbreak in this convent was associated with duration of isolation from society and was independent of age. A career outside the convent protected against pertussis. A stay of up to 70 years in the convent—partly interrupted by careers in The Netherlands (an area with lower pertussis endemicity) and/or the tropics (an area with higher pertussis endemicity)—followed by a pertussis outbreak can be seen as a natural experiment.

We assume that social isolation in the convent protected against immunity through natural B. pertussis infection and explain the epidemic as being the result of an increase in susceptibility once B. pertussis was introduced into the convent. The nuns were never vaccinated against pertussis as children, and, if they had been vaccinated, the effect of the vaccination would have waned. Indeed, the 1992 epidemic was the first reported in the history of the convent, according to the well-kept archive of the convent and the long-term common memory of the nuns. Moreover, the epidemic occurred after the convent had changed from a closed congregation into an open nursing facility for elderly nuns aided by civil staff. Also, the 100% pertussis incidence among the 9 nuns isolated since their entry into the convent and the overall pertussis incidence of 60% (with a case-fatality rate of 9%) indicate a first epidemic.

It could be argued that, in this epidemic, the nuns experienced the first cases of pertussis in their lives. This is unlikely, because the nuns entered the convent at 18–34 years of age and were born in the prevaccination era, between 1898 and 1936, when B. pertussis infections were prevalent and everyone experienced pertussis before the age of 15 years [10]. It is estimated that infection-acquired immunity wanes after 4–20 years and that vaccine-acquired immunity wanes after 4–12 years [11].

Some nuns developed serious pertussis with a high mortality rate, comparable to pertussis in very young children without completed immunization. Natural infection with B. pertussis contracted in society effectively protected others against pertussis. Indeed, in The Netherlands in 1995–1996, the estimated incidence of infection was 6.6% per year among individuals 3–79 years of age, up to 10.8% among individuals 20–24 years of age, and higher than the incidence of notified cases (0.01%) [12]. However, both infection-acquired immunity and vaccine-acquired immunity wane over time. We conclude that booster doses of pertussis vaccines may be a valuable strategy to control pertussis in populations with national childhood vaccination programs.

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References