

Haemophilus influenzae Type b Disease Among Amish Children in Pennsylvania: Reasons for Persistent Disease

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ABSTRACT. *Objective.* To identify reservoirs of *Haemophilus influenzae* type b (Hib) pharyngeal carriage and assess barriers to vaccination among 2 Amish communities in Pennsylvania.

Methods. We investigated recent cases, performed community surveys for Hib vaccination coverage and pharyngeal carriage, and administered a questionnaire assessing vaccination knowledge and attitudes to 298 members of 2 Amish communities (A and B) in Pennsylvania and, as a comparison group, 136 non-Amish family members who participated in state immunization clinics. From December 1999 to February 2000, 8 cases of invasive Hib disease occurred among children who were 5 years of age or younger in Pennsylvania. Six of the case-patients were from Amish communities. None of the children had been vaccinated.

Results. Among children who were 5 years of age or younger, Hib vaccine coverage was low in the 2 Amish communities: A (9 [28%] of 32) and B (3 [7%] of 41) compared with the non-Amish group (19 [95%] of 20). Hib carriage prevalence was higher in both Amish communities than in the non-Amish group (A: 3%; B: 8%; non-Amish: 0%). More households in community B had 1 or more Hib carriers than in community A (8 [28%] of 29 vs 3 [9%] of 32). Among Amish parents who did not vaccinate their children, only 25% (13 of 51) identified either religious or philosophical objections as a factor; 51% (26 of 51) reported that vaccinating was not a priority compared with other activities of daily life. Seventy-three percent (36 of 49) would vaccinate their children if vaccination were offered locally.

Conclusions. Undervaccinated communities in the United States still exist and allow circulation of Hib strains, resulting in disease among susceptible children. Identification of undervaccinated populations, such as the Amish, and targeted education and vaccination campaigns are essential to achieving elimination of Hib disease. *Pediatrics* 2001;108(4). URL: <http://www.pediatrics.org/cgi/content/full/108/4/e60>; *Hib vaccine, Amish.*

ABBREVIATIONS. Hib, *Haemophilus influenzae* type b; PFGE, pulsed-field gel electrophoresis; PADOH, Pennsylvania Department of Health; CDC, Centers for Disease Control and Prevention.

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Before the introduction of *Haemophilus influenzae* type b (Hib) conjugate vaccines, the incidence of invasive Hib disease in children who were 5 years of age or younger was 46 to 100 per 100 000 annually in the United States, and nearly 20 000 cases of Hib meningitis occurred each year.^{1,2} Since the licensure of the first conjugate vaccines in December 1987, incidence has declined by >95%.¹ The dramatic decline in Hib disease in children, even when vaccine coverage was <70%, was attributable to the effectiveness of the conjugate vaccines at decreasing both invasive Hib disease and pharyngeal carriage.³ Because carriage of the bacterium in the community is decreased, incidence of disease is reduced even among unvaccinated children (herd immunity).⁴

Vaccine coverage with Hib conjugate vaccines is estimated to be 90% in the United States, although coverage varies by location and community.¹ Despite high vaccine coverage, Hib continues to cause illness in approximately 100 to 200 children who are 5 years of age or younger each year.⁵ In 1998, 42% of these children were too young to have completed a primary vaccination series, and 56% were not vaccinated appropriately for age.⁶ Efforts to eliminate Hib disease have concentrated on improving vaccination levels by identifying and removing risk factors for undervaccination.⁷ However, we have an incomplete understanding of Hib reservoirs and patterns of transmission, which put undervaccinated children at risk for disease.

Between December 1999 and February 2000, 8 cases of invasive Hib disease in children who were 5 years of age or younger were identified in Pennsylvania. None of the case-patients had been vaccinated. Six of the 8 cases occurred in Amish communities. During each of the previous 3 years, only 1 to 3 cases of Hib disease in children who were 5 years of age or younger were reported in Pennsylvania. Clusters of Hib disease, or increased numbers of cases in concentrated periods of time, rarely have been reported.

Several outbreaks of vaccine-preventable diseases were described previously among undervaccinated Amish communities, including polio, rubella, and measles.⁸⁻¹¹ In the United States, several communities or groups do not vaccinate their children against many preventable childhood diseases, including Hib, some for religious or philosophical reasons.^{12,13} Although vaccination is not prohibited by Amish religious doctrine and several Amish communities

have participated in mass vaccination campaigns after outbreaks, levels of vaccination for routine childhood vaccines remain low in many Amish communities.^{8,14,15} In the course of investigating the cluster of Hib disease among Amish children in Pennsylvania, we examined factors that might explain the unusually high number of Hib cases in this population, including Hib vaccination levels, pulsed-field gel electrophoresis (PFGE) patterns of causative strains, and prevalence of Hib carriage. In addition, we examined community knowledge and attitudes about Hib vaccination to identify potential barriers that have prevented successful implementation of vaccination programs. Investigations of Hib disease and attitudes toward vaccination in communities that are resistant to routine community outreach programs may increase our understanding of Hib reservoirs and transmission and identify potential barriers to vaccination that could be removed with targeted efforts.

METHODS

Surveillance

We reviewed surveillance records of the Pennsylvania Department of Health (PADOH) for cases of Hib disease that occurred in Pennsylvania from January 1999 to June 2000. A case was defined as isolation of Hib from a normally sterile site in a child who was 5 years of age or younger. Information about each patient was collected by review of medical records and family interviews. All case isolates were sent to PADOH and Centers for Disease Control and Prevention (CDC) laboratories for confirmation and further testing. PFGE was performed on the isolates from each case as described previously, except for digestion of DNA with *Sma*I.¹⁶

Regional public health nurses from the PADOH interviewed households of case-patients to identify those that had children who were 48 months of age or younger so that appropriate chemoprophylaxis could be administered.

Information about each community was collected from the regional PADOH departments and from interviews with community leaders, such as bishops and midwives. Data from the PADOH National Electronic Telecommunications System for Surveillance database and PADOH records were reviewed to estimate the yearly incidence of invasive Hib disease in Pennsylvania. Because information about religious groups is not collected by the US Census Bureau, a gross estimate of the 1999 Amish population in the state of Pennsylvania was made from information at local and county clinic sites (S. Miller, PADOH, personal communication). To estimate the number of Amish children who were younger than 5 years, we applied age-group proportions determined from the 2 Amish community surveys. An estimate of the population of non-Amish children who were younger than 5 years in Pennsylvania was obtained from 1999 US Census Bureau data.¹⁷

Hib Pharyngeal Carriage Survey

We measured the prevalence of Hib pharyngeal carriage in 2 Amish communities in Pennsylvania (A and B) with recent cases. Each community consisted of a group of 31 to 33 families that attend religious services together every other Sunday, rotating the location of the services among district member homes. Children who were 7 years of age or older attended the community Amish school, where there are no immunization requirements. Younger children were cared for at home.

For a comparison group, we also assessed Hib pharyngeal carriage among non-Amish families that attended immunization clinics at 3 state health departments in south-central Pennsylvania. Each clinic was visited for 1 day. Only family members who attended the clinic participated in the Hib carriage survey. Informed consent was obtained for all participants. After obtaining parental permission, we collected oropharyngeal cultures from all members of each household by swabbing the posterior tonsils and pharynx with a Dacron-tipped swab.

A questionnaire that inquired about demographic information, social interactions, tobacco use, antibiotic use, breastfeeding, Hib vaccination, and polio vaccination was administered to a parent of each participating household. In the 2 Amish communities, Hib vaccination status was verified by vaccination card or regional PADOH immunization clinic records. In the non-Amish group from the immunization clinics, parental confirmation of vaccination status was accepted when vaccination records were not available in the clinic or from the parent or guardian. People who were taking antibiotics or had an unknown vaccine status were excluded from the analysis.

Hib antisera agar plates were inoculated immediately with individual swabs.¹⁸ Each plate was streaked and incubated at 37°C in 5% CO₂ for 48 hours. Colonies that had a precipitin halo around them, or resembled *H influenzae* morphologically, were picked and subcultured onto chocolate agar plates. Hib isolates were confirmed by growth factor requirements, and serotype was identified by slide agglutination. PFGE was performed as described above on survey isolates.

Survey of Community Attitudes Toward Vaccination

In conjunction with the carriage studies, parents from the Amish communities were asked about their attitudes toward and use of childhood vaccines and other preventive health measures (eg, prenatal care). We also asked parents whether they planned to vaccinate their children in the future and whether they knew of methods to improve vaccination in their community. We attempted to interview separately both the mother and the father from each household. Questions about attitudes toward vaccination were asked initially as unprompted, open-ended questions, with potentially multiple replies, and then as prompted yes-no questions. The questionnaire concerning attitudes toward vaccination was not administered to the non-Amish comparison group.

Statistical Analysis

We used univariate analysis to compare Amish communities with the non-Amish comparison group and with each other. Fisher 2-sided *t* tests and χ^2 analysis were generated in Epi Info computer software, version 6, and SAS (version 6.12 for Windows; SAS Institute, Cary, NC).

RESULTS

Surveillance

From December 2, 1999, to February 28, 2000, 8 cases of Hib disease in children who were 5 years of age or younger were identified in Pennsylvania (Fig 1). All cases occurred in children who were younger than 3 years, and each case occurred in a different county. None of the patients had received the Hib conjugate vaccine. Four of the children had Hib isolated from cerebrospinal fluid, 3 from blood cultures, and 1 from both. One death occurred, for a case-fatality ratio of 12.5%. No patient had an underlying illness that put him or her at higher risk for Hib disease. The 8 Hib case isolates had 5 different PFGE patterns; the cases from Amish communities A and B had indistinguishable patterns. No epidemiologic links were identified between the case-patients from communities A and B.

Six of the 8 cases occurred in Amish communities (Fig 1). The median age of the Amish case-patients was 1 year (range: 6 months–3 years). One of the Amish case-patients lived in Maryland but had spent the 4 days before hospital admission at an uncle's house in Pennsylvania. The case-patients in Amish communities A and B were both 1 year of age and Pennsylvania residents. Both non-Amish case-patients were 2 months of age or younger; 1 was 10 days old and lived in a household with 2 children, ages 3 and 5 years, neither of whom had been vac-

↓ investigation initiated

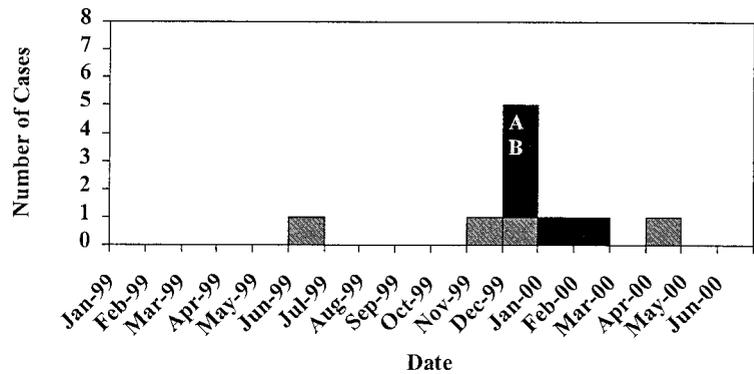


Fig 1. Number of cases of invasive Hib disease in children who were 5 years of age or younger in Pennsylvania, 1999 to 2000. Gray bars represent non-Amish children; black bars represent Amish children; A and B represent cases from Amish communities A and B.

inated with conjugate Hib vaccine. All households that met requirements for antimicrobial chemoprophylaxis were offered a 4-day course of rifampin^{19,20}; all but 1 household accepted. In total, 47 people received chemoprophylaxis with rifampin.

Between 1995 and 1999, the total number of Hib cases in Pennsylvania decreased (1995: 61 cases; 1999: 18 cases); however, the number of invasive Hib cases in children who were 5 years of age or younger was higher in 1999 than in the 3 previous years (1996: 2 cases; 1997: 3 cases; 1998: 1 case; 1999: 7 cases). The 1999 Amish population in Pennsylvania was estimated to be approximately 46 300 with 10 640 children who were younger than 5 years. In 1999, the estimated incidence of Hib disease among Amish children who were younger than 5 years in Pennsylvania was 38 cases per 100 000. The estimated 1999 incidence of Hib disease among non-Amish children who were younger than 5 years in Pennsylvania was 0.43 cases per 100 000. In previous years, at least 2 Hib cases occurred in unvaccinated Amish children who were younger than 5 years, 1 each in 1997 and 1998.

Hib Pharyngeal Carriage Survey

In Amish community A, 32 (97%) of 33 households participated in the survey; in community B, 30 (97%)

of 31 households participated. The case-patient in community A, who had just completed 10 days of ceftriaxone, was excluded; however, the parents of the child were included in the survey because they did not require chemoprophylaxis. The case-patient in community B and the patient's household ($n = 11$) were excluded from the carriage survey because they were receiving ceftriaxone and rifampin chemoprophylaxis, respectively. In the non-Amish comparison group, 60 (92%) of 65 non-Amish families with appointments at the immunization clinics participated in the survey.

In Amish community A, pharyngeal swabs were obtained from 144 (93%) of 155 residents in participating households. Five residents (3%) were carriers of Hib, and 3 households (9%) had 1 or more Hib carriers (Table 1). In Amish community B, pharyngeal swabs were obtained from 154 (86%) of 180 residents. Thirteen (8%) were Hib carriers, and 8 (28%) of 29 households had 1 or more Hib carriers. In the non-Amish comparison group, pharyngeal swabs were obtained from 136 (56%) of 242 total household members. None of the participants were carriers. Hib carriage was significantly higher in the Amish communities than in the non-Amish group. Community B had higher carriage than community A, although this was not statistically significant ($P =$

TABLE 1. Comparison of Hib Carriage and Vaccination Survey Results: Amish Communities A and B and Non-Amish Group

Characteristics	Amish Community A ($n = 144$)	Amish Community B ($n = 154$)	Non-Amish Group ($n = 136$)
Hib carriers (n [%])	5 (3)*	13 (8)*	0 (0)
Households with carrier (n [%])	3/32 (9)*	8/29 (28)*	0/60 (0)
Fully vaccinated for age, 6 mo–5 yrs (n [%])‡	9/32 (28)*	3/41 (7)*	19/20 (95)
Received polio vaccine: children ≤ 15 yrs (n [%])§	37/59 (62)*	11/81 (14)*	60/60 (100)
Living in household with >2 people/ room (n [%])	97 (67)	150 (97)*	100 (74)
Households with children ≤ 5 yrs (n [%])	20/32 (63)	21/29 (71)	35/60 (58)
Median number living in household (range)	6 (3–11)†	7 (3–11)†	4 (2–7)
Median age (y) (range)	18 (0–70)	12 (0–87)†	19 (0–56)

Number is depicted as number divided by total when denominator was different from sample size.

* $P \leq .05$ by χ^2 with non-Amish group as reference group.

† $P \leq .05$ by Wilcoxon 2-sample test with non-Amish group as reference group.

‡ Completed vaccination series for age group (17,18).

§ From parent recall or vaccination records (for people swabbed only), unknown vaccination status excluded.

.07). The prevalence of households with 1 or more Hib carriers was higher in community B than in community A ($P = .06$) and significantly higher in the Amish communities than in the non-Amish communities.

The 18 isolates obtained from the Hib antisera plates all were confirmed to be Hib by serotyping and growth factor requirements.

The median age of Hib carriers in communities A and B was 8 years and 9 years, respectively. No carriers were younger than 1 year or older than 30 years. Twenty-eight percent of carriers were older than 21 years. All adult carriers had young children in the household, and 2 had children who were Hib carriers. Crowding, smoking, breastfeeding, and attending social gatherings were not statistically associated with Hib carriage.

Children in community A were more likely to have been fully vaccinated for age with the Hib vaccine than were those in community B ($P = .01$; Table 1). Hib vaccine coverage among young children was significantly lower in both Amish communities compared with the non-Amish group. Sixty percent of Hib vaccinations were documented among the non-Amish children.

Community A differed from community B by several other factors (Table 1). Community A had fewer people living in crowded households (>2 people per room), and the median number of people in the home was significantly less than in community B. More children in community A had received the polio vaccine than in community B. The majority of women in both communities received prenatal care (79 of 81) from a physician (41%), a midwife (89%), or both (32%). The midwife in community A was an advocate of vaccination who held a bimonthly immunization clinic in her home with the district PADOH nurse; the midwife in community B was not an advocate of vaccination. Most parents (81%) reported that they had sought medical care for 1 or more family members at least once in the past year.

The households in the Amish communities differed from the non-Amish group by several factors. The 2 Amish communities had larger households than the non-Amish comparison group, and the median age in Amish community B was significantly younger than in the comparison group (Table 1).

Survey of Community Attitudes Toward Vaccination

In the survey of community attitudes toward vaccination, 66 parents (30 in community A and 36 in community B) were interviewed. The sample included 26 fathers and 40 mothers, representing 51 families. Only 4 interviews were conducted with both parents simultaneously; the remainder were conducted separately. All community members knew about the recent Hib case in their community. Fifty-one (77%) of the 66 parents surveyed had not had all eligible children vaccinated with the Hib conjugate vaccine. When asked in an unprompted manner for specific reasons for not vaccinating with the Hib vaccine, no parent reported religious objections and 2 (4%) reported philosophical objections; 6 (11%) reported that they did not vaccinate because of

fear of vaccine side effects. When prompted to answer yes-or-no questions about specific reasons for not vaccinating, 3 (6%) of 51 parents reported religious objections and 11 (22%) reported philosophical objections; more than half of the parents reported that they did not think that vaccination was a priority compared with other activities in their daily life (Table 2). Responses from parents in communities A and B were combined; there was no statistical difference in the responses between parents in communities A and B.

In the assessment of changes in attitudes toward Hib vaccine, parents in community A were significantly more likely to report that they planned to vaccinate their children in the future than were parents in community B (11 [58%] of 19 vs 8 [25%] of 32; $P = .02$). We also inquired about alternative ways to deliver vaccine; most parents reported that they would vaccinate their children if a vaccination session were held in a local setting or if PADOH staff came to their home (Table 2).

We asked the 19 parents (11 in community A and 8 in community B) who had not vaccinated their children but planned to vaccinate in the future about their reasons for changing their minds. All or most of these parents in community B were influenced by the recent case of Hib disease, new knowledge about Hib and the Hib vaccine, and improved vaccine accessibility (8 [100%] of 8, 7 [88%] of 8, and 8 [100%] of 8, respectively). Although community A had more parents who planned to vaccinate their children in the future than community B, the recent case of Hib disease, new knowledge about Hib and the Hib vaccine, and the improved vaccine accessibility were less important reasons for their change in attitude (6 [55%] of 11, 2 [22%] of 11, and 6 [60%] of 11, respectively).

DISCUSSION

Because of widespread vaccination, Hib disease in the United States is relatively rare, and Hib has been targeted for elimination.²¹ For this to occur, each case should be a sentinel event and trigger additional

TABLE 2. Attitudes Regarding Vaccination Among 51 Parents From Communities A and B Who Did Not Vaccinate All Eligible Children With the Hib Vaccine

Attitudes	Parents (n [%])
Reasons for not vaccinating	
Religious objections	3 (6)
Philosophical objections	12 (24)
Vaccinating not a priority*	26 (51)
Too expensive	8 (16)
Too difficult to travel	15 (29)
Parents didn't know about Hib	19 (37)
Child not at risk for Hib	17 (33)
Would vaccinate with Hib vaccine in the future if	
Transportation easier	9 (18)
DOH clinic open evenings or weekends	9 (19)
Vaccination session at local setting	36 (73)
DOH came to home to vaccinate	37 (76)

DOH indicates Department of Health.

Unknown or undecided responses are excluded from analysis and >1 reply may apply.

* Compared with other activities of daily life.

evaluation. This investigation, prompted by a series of cases, identified an underserved community that would benefit from targeted intervention. Each of the patients lived in a different county, no direct contact between them was detected, and most isolates had different PFGE patterns. The use of PFGE as a subtyping tool for Hib during outbreak investigations has not been evaluated fully; however, our data suggest that it is unlikely that these cases represented the introduction and transmission of a single strain of Hib. Instead, this investigation identified undervaccinated communities with a relatively high prevalence of carriage that served as a reservoir for the bacterium. The prevalence of carriage in the Amish communities was similar to prevaccination carriage surveys in the United States, and the incidence of Hib disease also similar to that of the prevaccine era.³ Low coverage with Hib vaccine put the children in these communities at risk for Hib disease, both because they were not protected by the vaccine and they did not benefit from herd immunity.

Hib vaccination decreases Hib carriage and transmission; however, the critical amount of vaccine coverage necessary to cause herd immunity is not well understood. We found no pharyngeal Hib carriage in the non-Amish comparison group, which had high vaccine coverage, similar to results from other studies.³ Hib vaccination levels of 20% to 30% in community A did not eliminate carriage but probably contributed to the lower carriage prevalence in this community compared with community B. Although most previous studies of Hib carriage have focused on children, in our carriage survey several adults were carriers, all parents with young children. Children who are 5 years of age or younger are at highest risk for disease and in most studies have the highest prevalence of carriage; however, the importance of adult carriage in ongoing Hib disease has not been assessed adequately.

Because it probably is not feasible to target adults in a Hib elimination strategy, routine childhood vaccination remains crucial. The reasons for undervaccination in these Amish communities likely are multifactorial. We found that lack of knowledge about Hib disease and the vaccine and an attitude that puts childhood vaccination as a lower priority compared with other daily activities probably contributed to low vaccination coverage. Philosophical and religious objections to vaccination seemed to play a minor role and should not be barriers to improving community vaccination levels. Although both Amish communities were able to gain access to health care, including prenatal care, these parents identified improving accessibility to Hib vaccines as the most important factor that would lead them to vaccinate their children.

Most of the parents who had not vaccinated their children with the Hib conjugate vaccine had sought medical care at least 1 time during the previous year. Visits by Amish parents to primary care practitioners may represent missed opportunities to offer age-appropriate vaccination. Several authors have suggested ways to improve primary care delivery to Amish communities, although no specific recom-

mendations have been made for improving vaccination.¹⁵ Coordinated efforts by practitioners and public health officials are necessary to improve vaccination levels in populations with large Amish communities.

As a result of this investigation, PADOH initiated a program to encourage vaccination and improve delivery of the Hib conjugate vaccine to all children who are 5 years of age and younger in Amish communities in Pennsylvania. Improvements in vaccination levels have been difficult, and 2 additional cases of Hib disease in unvaccinated Amish children, in different counties, occurred in November 2000 and February 2001. Identifying and understanding obstacles encountered during efforts to improve vaccination in communities that are insulated from traditional public health services and unaccustomed to the practice of childhood vaccination are important and represent a challenge for public health officials who work with these communities.

In our study, Amish community A, with a midwife actively encouraging vaccination, had a higher vaccination level and a higher percentage of parents who plan to vaccinate their children in the future. Furthermore, knowledge of the recent case and information about Hib disease and vaccine were important reasons for deciding to vaccinate, especially among community B parents. Efforts to determine effective educational messages and to optimize means for delivery are necessary to change attitudes regarding childhood vaccination and will be essential to establishing and maintaining a longitudinal program for the Hib vaccine, which requires 3 doses before 2 years of age.

Although the incidence of Hib disease among children in the United States is low, Hib cases do still occur, and, as this investigation demonstrates, some communities have high prevalence of Hib carriage and are poorly vaccinated. To reduce Hib disease in children further will require high vaccination levels of all US children, especially in pockets of continuing Hib transmission, such as the Amish communities identified in this study. The Amish and other undervaccinated communities represent challenges to current US vaccination programs and primary care health practitioners to improve community education and vaccine delivery in populations outside the mainstream. Besides putting an unvaccinated child at risk, undervaccinated communities may facilitate Hib transmission to a child by creating an ecological niche where the bacterium persists. In addition to improving vaccination levels, a better understanding of the reservoirs of Hib carriage and the interaction between vaccine coverage and Hib carriage is essential to eliminating Hib disease.

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