Validity of Interview Information in Estimating Community Immunization Levels

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THE INCREASING control of communicable diseases has been one of the striking health achievements of the present century. To a considerable extent, this advance has been achieved by immunization against specific disease agents. As a result of widespread immunization programs, a number of important killers and cripplers not only of children but all too often of adults as well have become rare throughout this and other developed nations. For this freedom, there is a price: constant vigilance in maintaining high levels of immunity in the population.

Because it is vitally important for health planners to know whether levels of immunization against communicable diseases are adequate, some type of surveillance is necessary. The simplest method is to compare the number of immunizations given with the numbers of eligible persons. Unfortunately, experience has shown that this method of estimation can be misleading (*1*). Even in the face of high overall immunization levels, subgroups of the community may be poorly covered (*2*). More reliable information can be obtained from surveys in which a representative sample of the community is queried about immunization and disease history (*3,4*). A major problem in this method of evaluation, however, is that only rarely has it been possible to validate historical information obtained from sample surveys.

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Although the ultimate criterion of the success of an immunization program is whether or not a disease is prevented, this is an unfortunate way to learn that immunity levels are too low. For many communicable diseases, measuring antibody levels is probably as accurate and much more practical. Occasional evaluation of historical information by checking antibody levels is a prudent procedure, even though the determination of titers of antibodies against a number of diseases in an adequate population sample is a major undertaking.

The present study was designed to evaluate immunization histories obtained from a sample of the population of Washington County, Md. The principal method of evaluation was the comparison of historical information from interviews with the results of serologic determinations.

Materials and Methods

Washington County is in western Maryland, lying mostly in the broad valley between the Blue Ridge and Allegheny Mountains of the Appalachian chain. In 1968, it had a population approaching 100,000 persons, divided almost equally between the city of Hagerstown, its suburbs, and the rest of the county. Its long and important contributions to health knowledge began with dental and morbidity surveys in the early 1920s, the latter being the forerunner of the present National Health Survey (*5*).

In the summer of 1968, a 1 percent systematic sample of the county population was drawn from a list of households obtained in a nonofficial census conducted in 1963 (*6*), supplemented by a similar sample of dwelling units added since that time. In cooperation with State and local health departments, a modification of an immunization questionnaire that had been widely used throughout the State was administered. (A copy of the questionnaire will be supplied on request.) All interviewers had been employed on previous immunization surveys. Historical information was obtained from each adult in the study population; information about children was supplied by a responsible adult in the household. Personal immunization records were consulted whenever they were available. Permission to obtain venous blood from all household members over age 3 was then requested; if granted, an appointment was made for a physician to collect approximately 10 ml. of blood. At this time, it was possible to interview persons who were not at home initially. Because few blood specimens were obtained from very young children, this analysis has been limited to persons over age 5.

The blood specimens were sent to the laboratory of the Maryland Department of Health and Mental Hygiene for a battery of tests. These included antibody determinations for measles, mumps, rubella, and the three types of poliovirus. Tetanus antitoxin levels were also measured when sufficient serum remained after the other procedures had been done.

Measles antibody levels were measured by the hemagglutination-inhibition (HAI) test according to the method of Rosen (*7*). Because HAI titers of 1:4 or greater correlate well with immunity to measles, these values were used to define serologic immunity (*8*).

Mumps antibody titers were determined by the Laboratory Branch's complement fixation procedure (*9*). A complement-fixing (CF) titer of 1:4 or greater was considered evidence of past infection and presumed immunity to reinfection. Serum dilutions less than 1:4 were not tested because of difficulty with anticomplementary activity. Serum neutralization tests were performed on all specimens for which mumps CF antibody was not detectable (*10*). A mumps neutralizing antibody titer of 1:2 or greater has been shown to provide protection against natural mumps in all but rare instances (*11*).

Poliovirus neutralizing antibody titers to all three prototypes of polioviruses were determined in rhesus monkey kidney cell cultures, using 100 $TCID_{50}$ of virus and an incubation period of 60 minutes at room temperature (*12*). A titer of 1:2 or greater was considered to be evidence of immunity.

Rubella antibodies were measured by the HAI procedure described by Stewart and co-workers (*13*). The lowest dilution at which antibody could be detected by this technique was 1:8. Persons who had HAI titers of less than 1:8 were presumed to be susceptible. Although recent studies have shown that approximately 3 to 4 percent of the persons who have low levels of HAI antibody as a result of natural infection can be reinfected during an outbreak of rubella, as evidenced by rises in antibody titers, in this study a HAI titer of 1:8 or greater was considered evidence of immunity to clinical rubella (*14*).

Serum antitoxin titrations for tetanus were performed by the passive hemagglutination procedure described by Levine and co-workers (*15*). The generally accepted value of 0.01 international unit

(IU) of antitoxin per ml. as the minimum protective level of tetanus antitoxin in the circulation is based on the evidence presented in the review by McComb (*16*) and was also used in this study.

Results

The selected sample comprised 286 households. Questionnaires were completed for 265 of these, representing 789 persons. Blood samples for antibody testing were taken from 504, or 70 percent of the 720 persons who were age 5 or older. There were no significant differences in the proportion of persons agreeing to venipuncture by race, sex, or place of residence. Age was the factor most closely associated with allowing blood specimens to be taken. Persons over age 60 were least likely to agree to venipuncture—56 percent of this group compared with 73 percent of younger persons. Persons in households in which the head of the household ranked low in occupation or income were less likely to give blood. No association could be found with education, except that those who had completed college were more likely to agree to venipuncture.

An attempt was made to verify immunization histories by checking medical records. This check was not feasible for mumps or rubella. Mumps vaccine had been used only rarely in the county at the time of this study, and rubella vaccine was not yet available. Both measles and poliovirus vaccines had been given in large-scale school and community programs for which no central records had been kept. Nor was it possible to check on tetanus immunizations for adults, who had received their immunizations from a wide variety of sources.

However, a search of pediatric sources located medical records with a definite indication that tetanus immunizations had been given to 94 persons. For 89 of them, a definite number of immunizations was also stated. On this item, there was complete agreement between information from the interviews and the medical records for 43 percent and a difference between the two sources of only one immunization for another 30 percent. The medical records showed two to five more immunizations than did the information from the interviews for 12 percent of this group; for these people the interview information was likely to be erroneous. Fifteen percent of the group stated that they had had two to four more immunizations than the records showed; in this instance, immunizations from other sources could account for at least some of the differences.

There were 53 persons who had a history of having received four or more tetanus immunizations and whose medical records showed the number of immunizations. The medical records corroborated the interview information for 36 (68 percent).

With respect to the age at which the most recent tetanus immunization was given, the interview data and medical records agreed within 1 year for 65 percent of the group. The medical records showed an age 2 to 11 years greater than the interview records for 16 persons, the median value being 3.5 years. For 15 persons, the age entered on the medical records was less than that given to the interviewer by a median value of 3 years (range 2 to 10 years). For this last group, of course, it is possible that the latest immunization was received elsewhere.

A total of 494 persons gave a definite history regarding past illness from measles or immunization against it, and also had their sera examined for HAI antibodies against measles. The results are shown in table 1. In all instances, the proportion of immune persons was somewhat understated by the interview results. The degree of underestimation was somewhat greater among young adults than any other subgroup. All persons over age 15 were serologically immune. The proportion of persons with a positive history of measles was greatest among older adults. Among 44 children with a history of immunization against measles but no illness, only one was not immune. All children with a history of disease were immune. Among 15 children with no history of either immunization or disease, three were not immune. All four susceptible children were rural residents.

Sera from 492 persons were tested for CF antibodies to mumps. Those with a CF titer lower than 1:4 were to be tested for neutralizing antibodies, but this test could not be made for 32 persons because no more serum remained. For the purposes of this analysis, it was assumed that the proportion positive to the neutralization test was the same among specimens with and without sufficient serum for the second test. Thus, the estimated number of persons with serologic evidence of immunity to mumps was the sum of those persons with positive reactions to the CF test, those with negative reactions to CF but with positive reactions to the neutralization test, and approximately 30 percent of the persons who had negative reactions for CF antibodies but who were not tested for neutralizing antibodies.

The prevalence of immunity against mumps is shown in table 2. The degree of underestimation by history was much more marked than for measles. Although 84 percent of the persons with a history of mumps were serologically immune, 70 percent of the persons who denied ever having mumps were also immune. The interview results were most likely to classify children correctly, but were almost useless among older adults. The predictive power of the history did not vary appreciably with place of residence or with socioeconomic status.

The analysis of immunization procedures against poliomyelitis is complicated because persons may have had more than one dose of three different products—Salk vaccine, oral monovalent vaccine, and oral trivalent vaccine. Fortunately, from the point of view of this presentation, there were no significant differences in the proportion serologically immune except between persons with no history of immunization and those who had had one or more doses of some poliovirus vaccine. As shown in table 3, the frequency of immunity in this population was highest against type 2 poliovirus and lowest against type 1. Only five persons under 15 years of age had had no poliovirus vaccine. Above that age, the proportion of immune persons ranged from 64 to 81 percent among persons who had not been vaccinated and from 83 to 92 percent among those who had. The proportion of immune persons was slightly lower among vaccinated children than among vaccinated adults. Historical information about vaccination overestimated the prevalence of immunity among children and markedly underestimated it among older adults. There were no significant differences by place of residence, but the underestimation of immune status by history was more marked among poorer families.

HAI antibody levels against rubella were determined for 504 persons. The results are shown in table 4. About half of the study group stated that they had had the disease; 89 percent of them were immune. Among the half without a history of rubella, 78 percent were immune. The difference in the proportion of persons who were immune was most marked under age 15: 71 percent of the persons in this age group with a positive history were immune, compared with 40 percent among those without a history of disease. Over age 15, the proportion of immune persons was almost 95 percent, with no significant differences according to history of disease. The historical information tended to underestimate the prevalence of immunity at all ages. There were no significant differences by place of residence or socioeconomic status.

The prevalence of serologic immunity affords a much better evaluation of histories of immunization against tetanus than against other diseases, because virtually all immunity against tetanus is artificially induced. Unfortunately, testing for tetanus antitoxin levels had to be given a low priority because of health department program interest in

Table 1. Prevalence of immunity against measles, by history of disease and of immunization, age, place of residence, and income of head of household

Age, residence, and income	Positive history of disease		Positive history of immunization only		Positive history of disease or immunization		Negative history of disease or immunization		Percent of population immune by—	
	Number tested	Percent immune [1]	Number tested	Percent immune [1]	Number tested	Percent immune [1]	Number tested	Percent immune [1]	History	Serology
Total	368	100.0	44	97.7	412	99.8	82	96.3	83.4	99.2
Age group:										
5–14	63	100.0	43	97.7	106	99.1	15	80.0	87.6	96.7
15–39	125	100.0	1	100.0	126	100.0	31	100.0	80.3	100.0
40 or over	180	100.0	0	....	180	100.0	36	100.0	83.3	100.0
Residence:										
Rural	176	100.0	21	95.2	197	99.5	46	93.5	81.1	98.4
Urban	192	100.0	23	100.0	215	100.0	36	100.0	85.7	100.0
Annual income of head of household:										
Less than $6,000	172	100.0	13	100.0	185	100.0	31	93.5	85.6	99.1
Over $6,000	196	100.0	31	96.8	227	99.6	51	98.0	81.7	99.3

[1] Hemagglutination inhibition titer 1:4 or more.

Table 2. Prevalence of immunity against mumps, by history of disease, age, place of residence, and income of head of household

Age, residence, and income	Positive history		Negative history		Proportion of population classed as immune by—	
	Number tested	Percent immune [1]	Number tested	Percent immune [1]	History	Serology
Total	295	83.6	197	69.7	60.0	78.0
Age group:						
5–14	48	91.7	74	64.6	39.3	75.2
15–39	101	89.9	57	77.7	63.9	85.5
40 or over	146	76.8	66	68.5	68.9	74.2
Residence:						
Rural	142	81.1	98	64.0	59.2	74.1
Urban	153	86.1	99	75.5	60.7	81.9
Annual income of head of household:						
Less than $6,000	129	78.6	86	64.0	60.0	72.7
Over $6,000	166	87.7	111	74.1	59.9	82.3

[1] Estimated as described in text.

the viral diseases. Antitoxin determinations were done only after all other tests had been completed. Among persons who gave adequate histories, only 157 had sufficient serum remaining for this determination. The results are shown in table 5.

Approximately one-third of the tested group were stated to have received four or more injections of tetanus toxoid either alone or in combination with diphtheria toxoid and pertussis vaccine. The number of injections was strongly related to age: 76 percent of the children but no adults over 40 had received at least four injections. The prevalence of immunity was in turn highly dependent on the number of immunizations that had been given. Among those who had received four or more doses, 94 percent were immune; all the susceptible persons in this group had received their last injection more than 10 years previously. A history of completed immunization within the past 10 years thus appeared to be a reliable indicator of immunity. Negative histories reflected the true situation less accurately. About one-third who were stated to be unimmunized were in fact immune and must have received some tetanus toxoid

Table 3. Prevalence of immunity to poliomyelitis, by history of immunization, age, residence, and income of head of household

Age, residence, and income	1 or more doses of poliovirus vaccine				No poliovirus vaccine				Proportion of population classed as immune by—			
	Number tested	Percent immune [1]			Number tested	Percent immune [1]			History	Serology		
		Type 1	Type 2	Type 3		Type 1	Type 2	Type 3		Type 1	Type 2	Type 3
Total	238	84.0	89.1	84.5	177	64.4	78.0	71.8	57.3	75.7	84.3	79.0
Age group:												
5–14	100	81.0	86.0	79.0	5	20.0	60.0	20.0	95.2	78.1	84.8	76.2
15–39	102	87.3	92.2	88.2	31	71.0	80.6	77.4	76.7	83.5	89.5	85.7
40 or over	36	83.3	88.9	88.9	141	64.5	78.0	72.3	20.3	68.4	80.2	75.7
Residence:												
Rural	109	81.7	88.1	81.7	87	64.4	77.0	70.1	55.6	74.0	83.2	76.5
Urban	129	86.0	89.9	86.8	90	64.4	78.8	73.3	58.9	77.2	85.4	81.3
Annual income of head of household:												
Less than $6,000	82	86.6	93.9	82.9	106	65.1	77.4	74.5	43.6	74.5	84.6	78.2
Over $6,000	156	82.7	86.5	85.3	71	63.4	78.9	67.6	68.7	76.7	84.1	79.7

[1] Neutralizing antibody titer of 1:2 or more.

in the past. The probability of this type of historical error was greatest among younger urban residents with above average incomes. But even though the interview results led to a marked underestimation of immunity levels at all ages and in all other subgroups, the epidemiologic pattern of immunity reflected by the interview and serologic methods was similar.

Discussion

Historical information has been widely used to assess the immune status of communities, and it is generally recognized that interview data have many shortcomings. The information about an entire household is often obtained from a single informant, and memory for distant events is notoriously unreliable. Even when the informant is asked to look up immunization records and to check with other members of the household, as was done in the present study, inaccuracies cannot be avoided.

A search of medical records will often produce additional information. Unfortunately, this supplementation is likely to produce biased results. Not only is medical information more readily obtainable for some groups than for others, but in most

Table 4. Prevalence of immunity against rubella, by history of disease, age, place of residence, and income of head of household

Age, residence, and income	History of disease		No history of disease		Proportion of population classed as immune by—	
	Number tested	Percent immune [1]	Number tested	Percent immune [1]	History	Serology
Total	257	88.7	247	78.5	51.0	83.7
Age group:						
5–14	49	71.4	74	40.5	39.8	52.8
15–39	97	90.7	64	92.2	60.2	91.3
40 or over	111	94.6	109	96.3	50.5	95.5
Residence:						
Rural	120	88.3	126	81.7	48.8	85.0
Urban	137	89.1	121	75.2	53.1	82.6
Annual income of head of household:						
Less than $6,000	104	87.5	117	81.2	47.1	84.2
Over $6,000	153	89.5	130	76.2	54.1	83.4

[1] Hemagglutination titer of 1:8 or more.

Table 5. Prevalence of immunity against tetanus, by number of immunizations, age, place of residence, and income of head of household

Age, residence, and income	4+ immunizations		1–3 immunizations		No immunizations		Proportion of population classed as immune by—	
	Number tested	Percent immune [1]	Number tested	Percent immune [1]	Number tested	Percent immune [1]	History	Serology
Total	50	94.0	69	69.6	38	34.2	31.8	68.8
Age group:								
5–14	37	97.3	11	90.9	1	100.0	75.5	95.9
15–39	13	84.6	25	84.0	8	37.5	28.3	76.1
40 or over	0	....	33	51.5	29	31.0	....	41.9
Residence:								
Rural	33	90.9	43	67.4	20	20.0	34.4	65.6
Urban	17	100.0	26	73.1	18	50.0	27.9	73.8
Annual income of head of household:								
Less than $6,000	10	90.0	35	62.3	22	22.7	14.9	53.7
Over $6,000	40	95.0	34	76.5	16	50.0	44.4	80.0

[1] 0.1 international unit or more per ml.

instances it can only correct understatements, leaving overstatements unchanged. Such one-sided corrections can lead to a false sense of security.

Other problems in estimating immunity from historical data are insoluble. Many disease agents produce a significant proportion of inapparent infections, leading to immunity with no evidence of disease. Clinical manifestations may be nondescript and not characteristic of any single disease entity, leading to a high proportion of misdiagnoses. These errors, however, are most likely to lead to conservative estimates of immunity levels in a population.

In the case of tetanus, the discrepancies between the historical and serologic methods of assessing the immune status of members of a community are largely attributable to memory defects and to the difficulties of knowing whether to class persons with incomplete courses of immunization as immune or susceptible. In this study, the historical information reflected the trends of immunity with age, place of residence, and socioeconomic status fairly well, even though the absolute frequency of immunity was understated in all instances.

For mumps and poliomyelitis, the high and remarkably uniform prevalence of inapparent infections in the study population was probably responsible for much of the failure of the interview information to reveal the true situation. A high percentage of children with no history of mumps had already had inapparent infections. A disconcerting finding was that in almost one-fifth of the surveyed children a high level of immunization against poliomyelitis by history was associated with a lack of adequate antibody levels. Furthermore, the probability of being immune was similar whether the person was said to have had one or several doses of vaccine. Much more predictable, of course, was the finding that the majority of older adults were immune to poliomyelitis with little history of immunization.

The findings of this study suggested that many infections with rubella were not recognized or remembered. Somewhat similar findings were reported by Lerman and co-workers (*17*). The persons studied were students of upper socioeconomic status or nurses with a median age of 20 years, groups that might be expected to have better than average recall about past illnesses. Among those with a positive history of rubella, 92 percent were serologically immune. On the other hand, 55 percent of those with negative histories were also immune. Because rubella often occurs without a rash, it is not necessary to invoke inapparent infections as a cause of immunity among persons with a negative history, although it is possible that inapparent infections may play a part. The historical information in this study provided only a fair estimate of the prevalence of immunity among children; it underestimated this situation for adults.

The validity of historical information about measles immunity could not be adequately tested. Virtually everyone was serologically immune regardless of the person's past history of measles or immunization against it. Children with negative histories who were serologically immune were few in number and could easily be accounted for by the inaccuracies inherent in interview data.

Although the interview method seems unsatisfactory in general as a means of estimating the immune status of a community, historical information may be useful in specific situations; this is notably true for tetanus. It appears that a carefully elicited history of the immunization completed within the previous 10 years virtually insures immunity, confirming again the wisdom of current recommendations on tetanus immunization (*18*).

Historical information may also be helpful in delineating groups of persons with an increased probability of being susceptible. This approach was suggested by Levine and co-workers (*19*) who, in a study of susceptibility to measles among elementary school children in Pittsburgh, Pa., found that information on history of disease and immunization could markedly increase the efficiency of a vaccination campaign. If all children in their study group had been vaccinated against measles, a total of 1,053 immunizations would have been required to protect the 60 who were found to be susceptible by serologic testing. If immunizations had been given only to those who denied having had measles or measles immunizations, only 149 would have had to be vaccinated to protect the 29 susceptibles—nearly half of the group in need of this protection. In the present study population, a followup measles vaccination campaign limited to persons with negative histories would have involved only 15 children and would have reached three of the four susceptibles.

A similar approach might be helpful with respect to rubella among children under 15 years of age. To protect all 58 susceptibles in this age group would have required a total of 123 vaccinations, or 2.1 vaccinations for every susceptible. Limited to children with no history of rubella, only 74 children would have to be vaccinated to protect 44 susceptibles, a ratio of 1.7 vaccinations for every susceptible. Under some circumstances, this modest saving might be worthwhile.

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In 1968, a representative sample of households in Washington County, Md., was selected for a historical and serologic survey of the immune status of the community. Ninety-three percent of the selected households were interviewed. Among the interviewed households, there were 720 persons over age 5, 70 percent of whom allowed blood samples to be taken. The prevalence of immunity according to history was compared with that shown by the serologic findings for measles, mumps, poliomyelitis, rubella, and tetanus.

The interview data revealed the general patterns of rubella and tetanus immunity in the community but understated the true levels more markedly for tetanus than for rubella. The comparison for measles was inconclusive because nearly everyone was serologically immune. Interview information for mumps and poliomyelitis correlated poorly with the serologic findings.