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Epidemiological Observations in the Halifax Epidemic*

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REPORTS of individual epidemics are apt to have little importance as epidemiological contributions unless certain features of the epidemic can be considered in terms of the general behavior of the disease being studied. Unusual opportunities were present in Halifax in the winter of 1940–1941 to study a simultaneous outbreak of *gravis* diphtheria, scarlet fever, and meningococcus meningitis. The common factors underlying this general increase in the prevalence of respiratory diseases were in large part the result of the impact of war on civilian life. Crowding and the rapid overturn of susceptibles in a population are well recognized as proper fuel for the flames of contagion. This is the inevitable result of mobilization and increased industrial activity. In such wartime conditions much can be learned concerning the dynamics of spread within the crowd and methods of control among civilians and troops.

Much of the material presented was taken from the records of the Dalhousie Public Health Clinic and the Halifax City Health Department. Considerable basic epidemiologic data had been collected by the late Dr. Allan MacLean, head of the Department of Preventive Medicine at the Dalhousie Medical School in Halifax. Dr. MacLean died in October, 1940, just after the start of the Halifax epidemics. Miss Jean Peabody who had assisted Dr. MacLean in his statistical studies gave invaluable assistance in gathering and analyzing data.

The Harvard group which worked in collaboration with the Halifax public health officials consisted of eleven persons of bacteriological, clinical, and epidemiological interests. It was headed by Professor J. Howard Mueller of Harvard who had visited Halifax early in the epidemic to collect strains of the *gravis* organisms for diphtheria toxin

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studies. Plans were laid for the larger expedition from Boston when word was received after Christmas that, not only had diphtheria started again to increase in prevalence after dropping off in mid-December, but that scarlet fever and meningitis had assumed epidemic proportions. It should be emphasized that the Harvard Group were in Halifax for only six weeks and the responsibility and credit for the control of epidemic spread and the reduction of mortality rests with the local and Provincial health officials and practitioners.

Before considering the epidemic diseases separately it will serve to bring them into focus by considering Halifax as a background before and after the onset of war, and the environmental factors present which influenced the spread of respiratory contagion.

The population of Halifax according to the Dominion Census of 1941 was 69,326. Even in normal times it has importance as the largest city and capital of a rather sparsely settled maritime province and as a year round open water harbor where large quantities of goods are shipped to and from European ports.

Medical services and hospital facilities in ordinary times may be regarded as adequate. There is a well organized system of clinics run in conjunction with the Dalhousie Medical School. A 45 bed contagious hospital is larger than necessary for the usual winter cases of diphtheria, scarlet fever, and other contagious diseases. Up to October 1, 1940, there was no full-time health commissioner, and campaigns for immunization against diphtheria and other diseases had not been stressed by public health officials. This was perhaps reflected in the rates for diphtheria in previous years which were higher (some 30 to 80 cases annually) than in communities where a larger percentage of children had received toxoid. Housing was sub-standard in certain sections of the city, notably along the waterfront. In 1938 some 300 buildings had been condemned as unsatisfactory domiciles but new building projects were not yet under way to replace these tenements. In fact, the housing situation in this city had never fully recovered from the disastrous effects of the explosion of 1917.[1]

As in the last war Halifax became in 1939 an important winter port for shipping war materials and troops. The civilian population increased under these needs and in addition there was a constantly shifting population of the military, naval, and air forces. Merchant sailors manning convoys from all over the world converged here in large numbers. Ample opportunities can be seen in such an environment for the introduction of infection and its rapid exchange.

After the epidemic had started a severe strain was put on local hospital and medical facilities. Two additional hospitals were opened up for the overflow from the contagious hospital and, in spite of its extra beds, at one time in the winter 73 patients were being taken care of in this 45 bed institution. At least one-fourth of the doctors with active practice were in uniform and, for the same reason, public health and bedside nurses were equally scarce. However, the reorganization of the health department with a full-time commissioner took place in time to allow for greater effect from public health activities. This was especially important in the coördination of military and civilian control measures.

In addition to the three epidemic diseases, diphtheria, scarlet fever, and meningitis, there were sharp epidemics of other respiratory diseases, notably influenza and measles, in the late fall and early winter. The influenza was mild and not followed to any extent by post-influenzal pneumonias and deaths. The diphtheria was the most interesting in that it is the first recorded extensive outbreak due to the *gravis* strains on this side of the Atlantic. Also, diphtheria with its specific treatment, prevention, and gauge of susceptibility is a rich field for epidemiological study and deserves consideration in greater detail.

The incidence among civilians in the 12 months from July, 1940, to July, 1941, was 649 cases of diphtheria with 24 deaths, 605 cases of scarlet fever with no deaths, and 114 cases of meningococcus meningitis with 16 deaths. Among these meningitis cases were individuals from elsewhere in the province who were hospitalized in Halifax. The peaks of greatest incidence for diphtheria fell in November, and for scarlet fever in March, as is to be expected in these latitudes. Relatively little meningitis appeared until early in December. In contrast to diphtheria and scarlet fever there was very little indication of concentration of meningitis cases in any one area, and only one instance of multiple cases in a family was recorded.

Table 1 gives the three diseases by attack rates at different ages. The high incidence of diphtheria among civilians in older ages will be discussed more fully later. It is suggested that the decline in rate for diphtheria in the 10–14 year age group is a result of relatively complete immunization among these school children; at any rate a similar decline is not evident for scarlet fever, which is also abnormally predominant in the older ages. More differences in the behavior of meningitis as compared with scarlet fever and diphtheria are revealed in this table. The peak of incidence for meningitis is definitely in the preschool children, with a drop in adolescence followed by a rise in the adult years. This might be attributed to greater opportunities for exposure among adult male laborers who constituted the greater number of cases in these age groups. Females were definitely in the majority among adults in the other two diseases.

TABLE 1

Civilian Population Halifax 1940–1941
Diphtheria, Scarlet Fever, and Meningococcus Meningitis Cases
Attack Rate per 100,000 Population *

Age Groups	*Diphtheria*	*Scarlet Fever*	*Meningococcus Meningitis*
0– 4 years	1,300	1,225	575
5– 9	1,833	2,455	144
10–14	1,254	1,702	148
15–19	1,463	1,070	212
20–24	1,490	1,060	215
25–29	963	675	168
30–34	544	451	187
35–39	409	253	156
40–44	281	258	71
45–49	252	27	27
50–54	141	...	71
55–59	168	...	42
60+	138	35	35
Attack Rate at all ages	935	871	164

* Age specific attack rates based upon age distribution of population at census of 1931 and total population of 69,326 according to the Dominion Census of 1941.

NOTE: The Dominion Census figures are probably incomplete. Sugar ration cards issued place the population at over 100,000, which would give correspondingly lower rates at various ages for the three diseases.

The scarlet fever was extensive but mild both among civilians and the armed forces. The characteristics of the scarlet fever were so similar to the diphtheria in selection by age, sex, secondary cases, occupations, and geographical distribution as to suggest that the same factors which helped to spread the diphtheria bacillus were operative on the hemolytic streptococcus. Cases

TABLE 2

Halifax Diphtheria 1940–1941
Complications and Deaths Compared to Liverpool (Shone, et al., 1939)

	Liverpool			Halifax
	Mitis	*Intermedius*	*Gravis*	*Gravis*
Number of cases	783	571	749	649
Case Fatality Rate	2.43	10.70	6.58	3.69
% Laryngeal Diphtheria	8.7	0.9	0.9	3.6
% Tracheotomy	5.2	0.5	0.8	0.8
% Paralysis	2.8	15.8	12.3	2.8
% Myocarditis	3.7	14.5	10.9	8.5
% Hemorrhage	0.3	2.1	1.6	....
% Nasal (Severe Epistaxis)	...	...	...	11.0

of scarlet fever and other streptococcus infection combined with diphtheria were noted, but there was no constant association of streptococcus infection with the bull necks and other severe local pharyngeal lesions of diphtheria. Throat cultures on scarlet fever patients and contacts revealed a predominant strain classified as type 19 by the Lancefield precipitin method. This strain was easily recognizable but, because of weak agglutinins, was hard to classify as to serological type in the field by the Griffith method, although independent typings in Ottawa, Boston, and New York suggested that, had agglutinations alone been relied upon, this would have been called a type 17. This is not an indictment of the slide agglutination method of Griffith, but suggests one of those unusual strains with agglutinating and precipitating antigens belonging to different types as have been reported by Lancefield.[2] With a more easily typed epidemic strain and highly type-specific antiserum the method should prove helpful in separating out carriers of epidemic types from those carrying less dangerous Group A strains. This is particularly valuable in army and navy cantonments where one case of scarlet fever may otherwise tie up much of the complement of a ship or barracks.

Gravis diphtheria seems to have been an imported infection in Halifax. The first case suspected of being caused by this strain appeared in September, 1940. The patient was one of the crew of a Norwegian tanker. He was followed by more cases from Norwegian sailors off a whaling ship anchored next to this tanker in the Basin. Some of these men developed symptoms ashore in a Salvation Army Hostel but within 24 hours of leaving their ship. More cases followed rapidly from the waterfront area and it was soon apparent that Halifax was not only dealing with an unusual number of cases but that the clinical severity of these infections was greater than usual. The infecting organism was identified by fermentations and characteristic colony appearance on blood tellurite medium as the *gravis* strain.* A small outbreak at a summer camp two months before had been identified as caused by the *mitis* variety, which suggests that the later epidemic infection was imported from sources outside of Halifax. The fact that this was exclusively a *gravis* epidemic does not necessarily imply severe infection. Observations vary from the high mortality found in Leeds [4] and by German observers to a position somewhat more virulent than *mitis* and less severe than

* Mueller [3] has shown that the Halifax *gravis* strains are resistant to the inhibiting effect of small amounts of iron on toxin production. This ability to produce toxin in the presence of iron compounds in a concentration similar to that found in the local tissues of the pharynx may be associated with the rapid spread and relative severity of the diphtheria in Halifax.

diphtheria caused by the *intermediate* strains as revealed by Shone [5] in Liverpool. Table 2 shows a comparison of the Halifax cases with the series reported from Liverpool. The Halifax cases resemble *mitis* infection in the high incidence of laryngeal diphtheria and deaths were certainly fewer here than in most recorded outbreaks of *gravis* diphtheria. However, doctors in Halifax who were familiar with the clinical picture of diphtheria in that locality were in agreement that the disease in the present epidemic showed more extensive membranes and a higher proportion of septic and toxic complications.[6] The low case fatality rate may be explained in part by the abnormal age distribution, with a high percentage of cases in the older age groups. If the Halifax case fatality rates by ages are weighted by a normal percentage age distribution of cases, as for instance Massachusetts cases from 1918 to 1929, the expected deaths are half again as many as were observed. In other words, as the peak of greatest incidence of cases shifts to older age groups it travels away from the high case fatality rates of infancy and gives an apparent mildness to the disease, as shown by a decrease in the number of deaths.

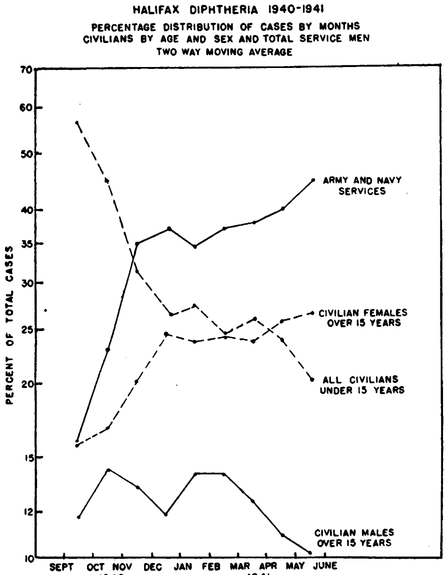

FIGURE 1

In the first stages of the epidemic the age distribution was normal. In December there was a decline in cases after the peak of November, followed by a rise in January, when there was a marked shift to the older age groups and the female sex. This dropping off of younger cases coincided with relatively thorough immunization of the school age population. The epidemic was maintained through June, when 50 civilian cases were reported, and the indications are that the epidemic is not yet burned out and that there is still a large reservoir of susceptibles in the unimmunized population.*

The curve of incidence among the armed forces followed or led the civilians very closely. Study of the records suggests that the epidemic started in the Norwegian merchant marine and quickly spread among the civilians in the waterfront area. Cases in the services appeared first chiefly in the Royal Canadian Navy personnel, whose contacts would be greatest along the waterfront. As with the civilians, there was a decline over the period of the Christmas holidays, followed by an increased incidence in January. Figure 1 shows how the forces climbed steadily in percentage of total cases in the given month, followed by the adult females, whereas the older civilian males and children of both sexes dropped off. Figure 2, cases of diphtheria by age and sex, shows even more markedly the preponderance of female cases between the ages of 15 and 30 years. History of contact with the forces was more than plentiful among diphtheria cases in women between the

* This is borne out by more recent figures on diphtheria in Halifax. From July 1, 1941, to April 30, 1942, 609 cases of diphtheria have been reported.

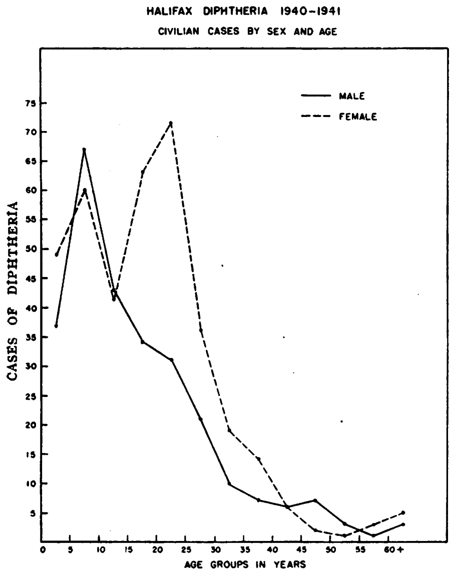

FIGURE 2

ages of 15 and 30. One cannot escape the conclusion from the study of available data that in its later stages this epidemic was maintained by the exchange of infection between the soldiers, sailors, and aviators and their wives or sweethearts in the town of Halifax. This does not preclude the possibility of reservoirs of infection among carriers and missed cases of nasal diphtheria in the preschool age group but, in the opinion of the authors, this was not the principal source of infection in the Halifax epidemic.

As might be expected of any community with areas of overcrowding and poor housing, Halifax had a concentration of cases where housing conditions were at their worst. A map showing the distribution of tuberculosis deaths in Halifax in recent years reveals a concentration of cases in the same areas as the diphtheria spot map. Here one also finds the largest number of multiple cases in houses and families. A carrier survey of over one thousand Halifax school children in February showed rates as high as 30 per cent for carriage of the diphtheria bacillus in one of the schools of this district, and 20 per cent in another. Not a single carrier of virulent organisms was found in certain of the schools in the better residential district. The average percentage of carriers among school children and clinic populations in the February survey was 11 per cent. In June, 840 school children were cultured and only 2 per cent were found to be carriers. Although there were 50 cases reported in this month, they were chiefly among adults.

Control measures included Schick surveys, isolation of carriers, and the establishment of clinics for active immunization against diphtheria. This was carried out with fluid toxoid, 3 doses at 3 week intervals, followed by a repeat Schick test in 3 months. As the attendance at toxoid clinics grew to hundreds and, for a brief period, even to thousands, practical considerations made it necessary to establish the following routine: All children under 12 years received toxoid at their first visit without regard to primary Schick test or sensitivity test. Older clinic patients received a Schick test in one arm and in the other arm 1/10 ml. of toxoid diluted 1/10 intradermally. This " Moloney Test " of sensitivity to bacterial proteins should be read in 48 hours, but for administrative reasons these patients were instructed to return in 5 days. At that time their Schick tests were read and, if positive, the first dose of toxoid was given. If there was a history of erythema or induration at the site of the Moloney test, toxoid was given in higher dilution and more frequently.

Toxoid reactions occurred only rarely among the older patients but were at times severe, with headache, swelling of the arm, and fever of short duration. Comparative studies on toxoid reactions from materials prepared at the Connaught Laboratories in Toronto and from other sources showed no signifi-

TABLE 3

Halifax Diphtheria 1940–1941
Estimated Percentage Distribution of Immunes in the Population by Age Groups from Schick Test Surveys and Records of Toxoid Clinics *

Age Group	(1) % Natural Immunes† by Schick Survey	(2) % Immunized with Toxoid July 1, 1940–May 31, 1941	(1) and (2) Total % of Immunes	(3) % Immunized with Toxoid Before July 1, 1940	(1), (2), and (3) Total % of Immunes
0– 4	11	14	25	...	...
5– 9	30	26	56	...	...
10–14	45	24	69	...	...
15+	51	1.7	52.7	...	...
All Ages (adjusted)	44.8	7.4	52.2	4.6	58‡

* The figures are based on 8,783 primary Schick tests and 8,417 completed immunizations.
† The rate of natural immunization during the epidemic is not considered in this table. Evidence from Schick testing at different times between September, 1940, and June, 1941, is not conclusive as to the extent of natural immunization at the subclinical level.
‡ Includes approximately 1.2 per cent of the population who have developed clinical diphtheria within the past 6 years.

cant difference in percentage of reactions. With proper precautions by sensitivity tests it was felt that immunization of older individuals with toxoid was a safe and advantageous method. Credit is due to the efficient follow-up work of the public health nurses that 92 per cent of the patients immunized completed their full course of 3 doses of fluid toxoid, and 70 per cent of those who started immunization completed their course and returned for a repeat Schick test. Shift to Schick-negativity among those immunized was

TABLE 4

Halifax Diphtheria 1940–1941
Incidence of Diphtheria in Previously Immunized Population According to the Time Interval Between Immunization and Onset Compared with Incidence in the Estimated Susceptibles of the Total Population

Interval Between Immunization and Onset	Immunized Population Observed at this Interval	Cases in Immunized Population	Attack Rate per 100,000 Population
0– 1 month	5,156*	7	135.7
1– 2	5,134	3	58.4
2– 3	5,096	3	58.8
3– 4	5,018	1	19.9
4– 5	4,817	..	....
5– 6	4,742	..	....
6– 7	4,616	1	23.8
7– 8	2,761	..	....
8– 9	176	..	....
9–10	131	..	....
10–11	101	..	....
11–12	31	..	....
Total Cases in Immunized Population		15	296.6
	Estimated Susceptible Population†	*Cases in Unimmunized Population*	*Attack Rate per 100,000 Population*
	29,117	590	2,027.0

* Period of observation between July 1, 1940, and June 30, 1941. Eighty-six per cent of the attendance at the toxoid clinics was in the 6 week period between October 20 and December 1, 1940.
† Based on 42 per cent estimated Schick positives in population. See Table 3.

over 95 per cent, according to tests given 3 months after completion of immunization.

An attempt was made to determine the immune status of the community and the results of immunization. It has already been shown that the case incidence among school age children decreased as the epidemic progressed. Table 3 shows the levels of immunity estimated for different age groups in the epidemic year. Note the rise in immunes in the 10–14 year age group. Another method of evaluating the effect of toxoid is to study the diphtheria occurring in immunized children compared with the rates for the estimated unimmunized susceptible population. Table 4 shows a comparison of cases among those receiving 3 doses of toxoid in the epidemic year with those having no history of previous immunization. From this evidence it would seem that the effect of active immunization with fluid toxoid is to protect against diphtheria after a relatively short interval. The transient protection afforded by passive immunization was seen in four contacts who developed diphtheria within a month of receiving 10,000 units of antitoxin prophylactically. A small clinic was established to Schick test, culture, and immunize contacts of cases. Even among the Schick-positive contacts, toxoid was employed in preference to prophylactic antitoxin to avoid unnecessary sensitization to horse serum.

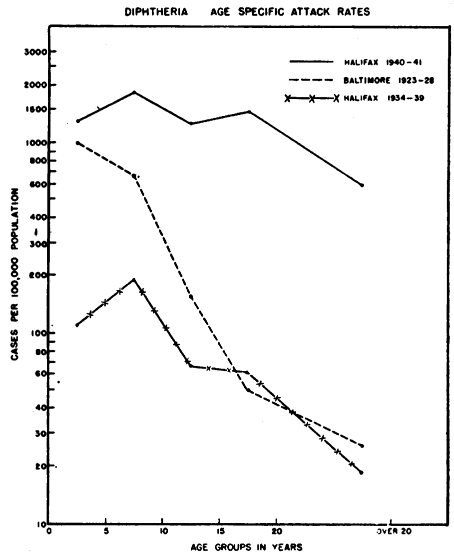

FIGURE 3

The level of natural immunity to diphtheria in the population can be seen in Table 5 of Schick test results in previously unimmunized individuals by age and sex. The relatively higher percentage of negative Schick reactions among males than females at all ages is consistent with findings reported elsewhere as reviewed by Doull.[7] The explanation for this phenomenon is obscure. The generally low level of immunity as indicated by the Schick

TABLE 5

Results of Schick Testing by Age and Sex on Individuals with No History of Previous Immunization

Dalhousie Clinic, Halifax

Age Group	*Number Tested Males*	*% Negative*	*Number Tested Females*	*% Negative*	*Ratio of % Negative Males to Females*
0– 4 years	371	12	391	11	1.09
5– 9	1,167	35	1,239	25	1.40
10–14	1,645	49	1,672	41	1.19
15–19	407	59	582	43	1.37
20+	167	55	982	52	1.06
Unknown	67	63	93	38	1.66
Total	3,824	43	4,959	37	1.16

TABLE 6

Halifax Diphtheria 1940–1941

Results of Schick Tests in Children, 5 to 14 Years, Compared with Same Age Groups from Other Surveys as to Per Cent Schick-Negative and Recent Prevalence of Diphtheria

Includes Only Those with No History of Previous Immunization

Place of Survey	Rural or Urban	Year	Number Tested	Per cent Negative	Diphtheria, All Ages, Average Rate per 100,000 5 Years Preceding: Morbidity	Mortality
Alabama	Rural	1937–38	2,464	89	41.0	4.8
Virginia	Rural & Urban	1937–39	969	60	66.7	5.6
Baltimore, Md.	Urban	1933–34	1,863	51	63.0	3.8
Halifax, N. S.	Urban	1940–41	5,723	38	97.9	6.8
Kingston, N.Y.	Urban	1938	464	33	0.7*	0
Glace Bay, N. S.	Urban	1938	417	22	88.0†	10.3†
Cleveland, Ohio	Urban	1938	960	21	26.9	2.1

* Only 2 cases of diphtheria and no deaths reported from Kingston in the 6 year period, 1933 through 1938.

† These rates are from reported cases and deaths from diphtheria in Cape Breton County, Nova Scotia, in 1938 and 1939. For Glace Bay the average rates for the 10 year period, 1928 to 1939, are: morbidity, 27.0, and mortality, 5.8. The case fatality rate from these figures is 21 per cent which indicates incompleteness of reporting at that time. The more recent figures from the county in which Glace Bay is situated are considered a better index of the prevalence of diphtheria at the time of the survey.

test survey cannot be attributed in this instance to lack of experience with diphtheria in the past. Table 6 is a comparison of the Schick test levels in previously unimmunized school children in Halifax with surveys on a similar basis from other parts of North America.[8-14] Previous experience of the community with the disease, the attendant carrier rates, and the degree of urbanization are undoubtedly factors in determining the levels of natural immunity, but from the results shown in Table 6 this immunization seems to be more easily accomplished in the south than in northern climates.

The high age distribution of cases is also usually a characteristic of northern diphtheria.[15] In Figure 3 the age specific attack rates of Halifax diphtheria in the present epidemic and for the 5 years, 1934 to 1939, are compared with figures for Baltimore from 1923 to 1928. The two Halifax curves are similar, suggesting a permanent factor influencing the age distribution of cases. However, no such preponderance of adult females was seen in cases before the epidemic and the percentage in older age groups was not so great.

In conclusion, certain implications from this city's experience with epidemic disease should be emphasized in order to avoid, if possible, a similar experience in other communities.

1. The necessity for decent housing in defense areas.

2. To apply to civilian populations and to troops all the effective methods in our knowledge for the specific prevention of disease.

This is especially pertinent with reference to diphtheria. In this disease immunity decreases as one goes north as well as out in the rural areas. Likewise, it becomes less and less of a childhood disease. With this in mind, and particularly with reference to the United States Navy whose contacts are many in the north Atlantic, it is our opinion that every soldier and sailor should be Schick tested, and immunized if found to be susceptible.

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