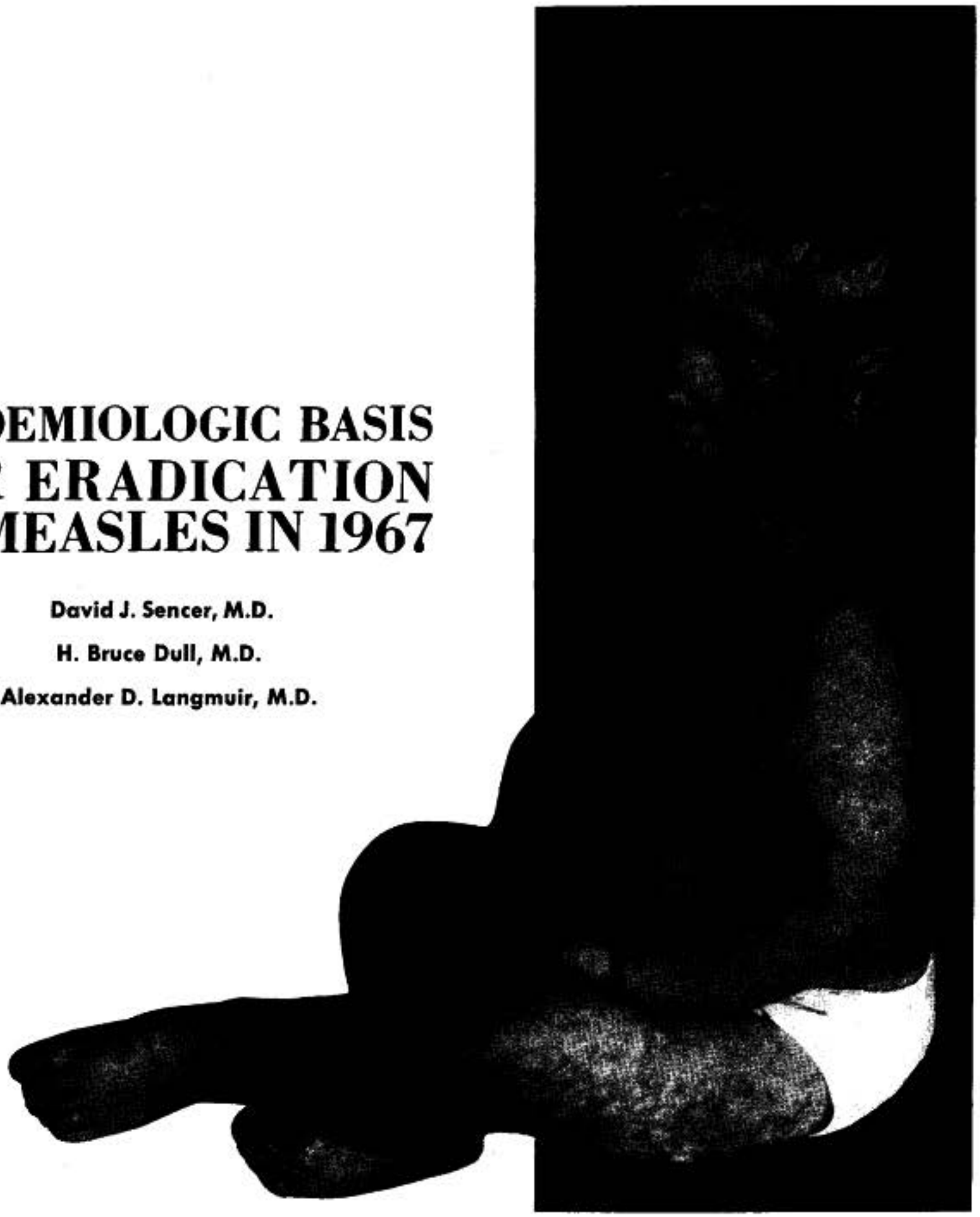
EPIDEMIOLOGIC BASIS FOR ERADICATION OF MEASLES IN 1967

David J. Sencer, M.D.

H. Bruce Dull, M.D.

Alexander D. Langmuir, M.D.



A STATEMENT BY THE PUBLIC HEALTH SERVICE

FOR CENTURIES the measles virus has maintained a remarkably stable ecological relationship with man. The clinical disease is a characteristic syndrome of notable constancy and only moderate severity. Complications are infrequent, and, with adequate medical care, fatality is rare. Susceptibility to the disease after the waning of

maternal immunity is universal; immunity following recovery is solid and lifelong in duration.

The infection spreads by direct contact from person to person and by the airborne route among susceptibles congregated in enclosed spaces. The disease occurs ubiquitously throughout the world in periodic cycles of considerable regularity. With the exception of a few extremely isolated population groups, essentially all children experience the infection sometime before adolescence. The reservoir of infection is man himself. No nonhuman sources of infection are known. Chronic carriers do not exist.

Despite the extent of the epidemiologic knowledge of measles, health officials have been frustrated in their efforts to bring this disease under control. During the past 50 years the doctrine has become widely accepted in health circles that since control measures have failed, man should learn to adapt himself to the measles virus. Thus, by judicious use of immune globulin for modification of the disease among exposed young children at great risk, and by providing adequate medical care to all patients, the damaging effects of the disease could be mitigated. Until very recently, this deep respect for the biological balance of the human race with the measles virus had become accepted doctrine. Eradication was not considered to be scientifically tenable.

All of this has now changed. With the isolation of the measles virus and the development and extensive field testing of several potent and effective vaccines, the tools are at hand to eradicate the infection. With the general application of these tools during the coming months, eradication can be achieved in this country in the year 1967.

This paper states the epidemiologic basis in support of this statement, specifies the essential conditions, and outlines the priorities for attaining this goal.

Theory of Measles Epidemics

Long experience has shown that measles recurs in a characteristic epidemiologic pattern that can be explained fully on the basis of the balance of immunes and susceptibles in the population. In small, closed population groups, such as nurseries or classrooms containing young susceptible children, explosive outbreaks follow promptly on the introduction of a single case. Attack rates are high; the duration of the outbreak is short. The supply of susceptibles becomes exhausted in the course of only a few generations of cases. Despite the subsequent introduction of a new case, another outbreak will not occur until a new crop of susceptibles has been garnered. This may require the passage of 2 or more years.

In more diverse and dispersed population groups, the introduction of a new case of measles is usually followed by an outbreak with a smaller attack rate, spottier distribution, and longer total duration. The proportion of susceptibles is reduced, but the epidemic frequently dies out before the supply of susceptibles is completely exhausted.

In large population centers, as in cities or whole metropolitan areas, measles epidemics recur in 2- to 3-year cycles, with many minor and some major variations in severity and extent. A notable feature of such urban epidemics is their long duration. They usually begin in the fall or early winter, build to a peak in the spring, and continue until the closing of schools. Occasionally, an epidemic will be split over a summer vacation period, with incidence increasing sharply in the early fall following the opening of schools.

The epidemic curve of measles in an urban area represents a composite of many discrete epidemics of shorter duration, beginning at varying times during the epidemic and centering in various local communities, ethnic groups, and school districts that comprise any large population. It is frequently possible to trace the progressive spread of measles from one area to another over the course of a single winter and spring epidemic period.

Most urban epidemics result in large numbers of cases among kindergarten and first- and sec-

---

The authors are from the Public Health Service's National Communicable Disease Center, Atlanta, Ga. Dr. Sencer is chief and Dr. Dull is assistant chief of the Center. Dr. Langmuir is chief of the Epidemiology Program. *This paper was presented at the American Public Health Association's meeting in San Francisco, November 1, 1966.*

ond-grade school children. In fact, the supply of susceptibles in such groups may be largely exhausted in a relatively short time. Infection is regularly carried back to the home where preschool siblings may become infected. In many homes where infants and preschool children have no school-age siblings, the children have an excellent opportunity to escape infection throughout the epidemic. These are the susceptibles that support the next epidemic a few years later when they congregate in school.

This general experience with measles epidemics has provided the basis for formulating an epidemic theory of measles that can be expressed in simple mathematical terms. The theory accounts reasonably well for the major epidemiologic characteristics of measles epidemics on the basic assumption that incidence is a function of the proportion of the population that is susceptible and the contact rate.

Of particular relevance to the prospects of eradicating measles are the meticulous studies of Hedrich (*1*). He used data from Baltimore, Md., from 1897 to 1927 to quantitate the ebb and flow of susceptibles. He kept a progressive monthly balance sheet, using new births to measure the flow of susceptibles, and corrected estimates of measles cases to measure the flow of immunes. He was thus able to calculate the proportion of the child population of Baltimore that was susceptible at any given time.

While the incidence of measles in Baltimore fluctuated widely from year to year in a roughly 2- to 3-year periodicity, there was a remarkably narrow range of fluctuation in the balance of susceptibles and immunes. Just prior to major epidemics, the proportion of the population under 15 years of age estimated to be susceptible ranged from 45 to 50 percent. At the end of the epidemics, this proportion had fallen only to the level of 30 to 35 percent. Thus a large number of susceptibles escaped infection even during the most severe epidemics.

Examining the evidence from the point of view of immunity, it is evident that when the level of immunity was higher than 55 percent, epidemics did not develop. This is an estimate of the threshold of herd immunity providing protection to the city against a measles epidemic.

Studies in other urban areas comparable to those of Hedrich in Baltimore have not been reported. It must be recognized that the immune threshold of the 55 percent estimated for Baltimore for the period 1897 to 1927 may not have direct applicability to other communities in the United States in 1966. In fact, it is difficult to estimate whether the threshold of herd immunity for an average American city now would be higher or lower than Hedrich's estimate for Baltimore 30 to 70 years ago. Obviously, a considerable variability must be assumed for this threshold from urban area to urban area and within varying ethnic and socioeconomic groups in a single urban area.

There is no reason, however, to question the validity of the basic assumption that the occurrence of measles epidemics depends upon the balance of immunes and susceptibles, and that for all areas and special groups in this country the immune threshold is considerably less than 100 percent.

Therefore, in a country where smallpox, diphtheria, and poliomyelitis have been brought under effective control through immunization of a moderately high proportion, but by no means all infants and children, so also can measles be controlled with the attainment of immunity levels that are reasonable and wholly practical to achieve. Since chronic carriers as in diphtheria, and inapparent infection as in poliomyelitis, do not exist in measles, the course of measles that will follow a nationwide control program will be comparable to that of smallpox; namely, the total disappearance of the infection promptly when the immunity thresholds have been attained.

Essential Conditions for Eradication

With these theoretical considerations, it is now possible to specify the four essential conditions for eradication: (*a*) routine immunization of infants, (*b*) immunization of all susceptible children on entry to school or other place of congregation, (*c*) surveillance, and (*d*) epidemic control.

Routine immunization of infants. All infants should receive measles vaccine at approximately 1 year of age. This practice should be incorporated in the regular schedule of good pediatric practice and well child care. It should become as routine as DTP, polio, and smallpox

immunizations. To the degree that this becomes a universal practice for all infants, the following conditions become of diminishing importance.

Immunization on school entry. All children not immunized in infancy and who escape the natural disease should be immunized against measles at the time of or just before admission to school.

The term "school" must be interpreted broadly to include not only first grade of primary school, but also kindergarten, nursery school, day care homes, and even Sunday schools. While parents should assume primary responsibility for immunization of their children, school authorities may find it distinctly to their advantage also to assume a share of the responsibility to insure that all pupils have been protected. A measles epidemic can be disruptive and frequently costly if funds are made available on the basis of pupil days of attendance.

Surveillance. Effective control depends on knowledge of incidence and epidemiologic characteristics of current cases. Intensive efforts should be initiated by all health authorities—Federal, State, and local—to encourage complete and prompt reporting of all children with measles by name, address, and date of onset. Reports should come not only from practicing physicians, but from school nurses or other designated school officials knowing of absenteeism due to measles. Since measles has been poorly reported up to the present time, some increase in reported incidence above comparable periods in recent years may be expected at the beginning of the eradication program.

The conduct of sample surveys for status of measles immunity is an important aspect of a sound surveillance program. Such surveys are simple to perform, and serve to guide the health authority to areas where intensive immunization efforts are needed.

Epidemic control. Whenever a cluster of cases of measles, or even a single case is reported in a previously uninfected area, the threat of an epidemic is imminent. Immediate steps should be taken to verify the diagnosis, trace the source of infection, detect other unreported cases, and determine exposed susceptible contacts. From this information, a plan for containment of the outbreak can be developed and should be promptly executed. Local resources should be relied on for the main control effort.

The containment plan should include the administration of immune globulin to exposed susceptible contacts and administration of measles vaccine to all available susceptibles in the surrounding community or local area. Particular emphasis should be directed to susceptible children in kindergarten, nursery schools, and the lower primary grades of public schools. Such groups are readily accessible and in face of an imminent epidemic, full cooperation and prompt response can be relied on.

Whether the immunizations are carried out in private physicians' offices, in health department clinics, or in specially arranged clinics in the affected and neighboring schools, should be a matter for local option. The only essential condition is the prompt achievement of a high level of immunization.

When measles has become so widespread that epidemics are already present in several schools and in different communities within a city or county, more extensive communitywide measures must be undertaken. Then the full resources of the health and medical services of the total community, backed by well-coordinated voluntary agencies, will need to be mobilized. Again, priority should be directed first to the immunization of susceptible children in schools or who congregate in other enclosed spaces. If such immunization programs are carried out promptly and effectively, an epidemic of measles can be contained within 2 to 3 weeks. The continuation of an epidemic longer than 3 weeks is a clear indication of the inadequacy of the planned control program.

Conclusion

The availability of potent and effective measles vaccines, which have been tested extensively over the past 4 years, provides the basis for the eradication of measles in any community that will raise its immune thresholds to readily attainable levels. Effective use of these vaccines during the coming winter and spring should insure the eradication of measles from the United States in 1967.

REFERENCE

(1) Hedrich, A. W.: The corrected average attack rate from measles among city children. Amer J Hyg 11: 576–600, May 1930.