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Sociological factors in the spread of variola minor in a semi-rural school district

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Several studies have emphasized the role of the nursery or the primary school as a source of cases introducing communicable diseases into the household, as well as the subsequent occurrence of real intra-household outbreaks (Lidwell & Sommerville, 1951; Ipsen, Donovan & James, 1952; Knight *et al.* 1954; McCarroll, Melnick & Horstmann, 1955; Meyer, 1962). The present paper records an examination of the roles of the school class and the household in the spread of an epidemic of variola minor (alastrim) through Vila Guarani, a semi-rural school district of the City of São Paulo, Brazil. A detailed study on the spread of the disease in the district school has been published already (Angulo, Rodrigues-da-Silva & Rabello, 1964), as well as an examination of the spread in the district households (Angulo, Rodrigues-da-Silva & Rabello, 1967).

MATERIALS AND METHODS

Twenty-two households, in which fifty-two cases of variola minor occurred, were surveyed. In two of these households it was not possible to obtain data referring to all members of the household, and these households are excluded from the analysis of data in the paper. A description of the school and its population, as well as the procedures employed there during the field study, have been reported (Angulo *et al.* 1964). The characteristics of the households with cases, the methods used in surveying these households and the definitions used in that and in the present study have also been reported (Angulo *et al.* 1967). Twenty-two households without cases but including one or more members who had known contacts with patients were also surveyed and visited until three or more weeks after last contact. When referring here to a 'social unit' we mean a discrete group of persons regularly associated for a defined social function, like family life or school-class attendance.

An environmental survey of the district was conducted to determine its socio-economic characteristics and to establish space relations between infectives and contacts. Vila Guarani was connected with the remainder of the City of São Paulo through a single street. The district had no public sewerage or water-supply

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system and consisted of poorly built small houses without proper sanitation. A primary day-school was located in the district but there was no other similar place for customary gathering of persons. Although minor differences in the standard of living could be detected among the study households, these differences were not great. This group of households may be taken as representative of the district population because the socio-economic structure of the district was extremely simple and homogeneous. Heads of families were low-income, unskilled workers with little education.

RESULTS

Spread in the district

Chain of contagion

The chain of disease transmission depicted in Fig. 1 includes the fifty-four cases infected in the district, two travellers with variola who stayed for a short time in Vila Guarani and six related cases appearing in a home from the City of Rio de Janeiro (Rodrigues-da-Silva, Rabello & Angulo, 1963). The accuracy of the diagram in Fig. 1 is supported by the following facts. (*a*) Systematic tracing of sources of infection and of their contacts clearly disclosed how the disease was introduced in the district. (*b*) There was no report of any previous occurrence of variola in epidemic or endemic form in Vila Guarani. None of the school teachers knew of any previous occurrence in the district, nor did the school orderly who had lived in Vila Guarani for the previous twenty-two years. In the households surveyed, persons with a history of previous variola unanimously reported that they had had the disease in other places, most of them in north-eastern Brazil. A great many of the inhabitants of Vila Guarani had moved there in the past few years. (*c*) The chain of contagion was compiled from dates of onset obtained through personal interviews. In addition, the dates of onset and information about personal contacts were usually confirmed by members of the household and neighbours. Contacts with other patients were also investigated and, in these few instances, dates of onset and the type and frequency of contacts were utilized to determine the most probable infecting contact. (*d*) The social structure of the district was extremely simple and personal associations were similarly simple and easy to trace. (*e*) In the few instances where the date of onset could not be accurately established, it is believed that the date recorded did not differ from the actual date of onset by more than three days. (*f*) The evidence supporting person-to-person transmission as the mode of transmission was extremely strong and no indication or suggestion of other modes of spread was obtained (Angulo *et al.* 1964, 1967).

The role of social units

The chain of person to person transmission of the disease appears to be composed, not of individuals, but of discrete groups of cases related in time and space (Fig. 1). These relationships correspond to a well-defined social unit, either a household or a school class.

The flow of the epidemic through the district obviously included two distinct types of transmission, inter-social unit and intra-social unit. Since the district

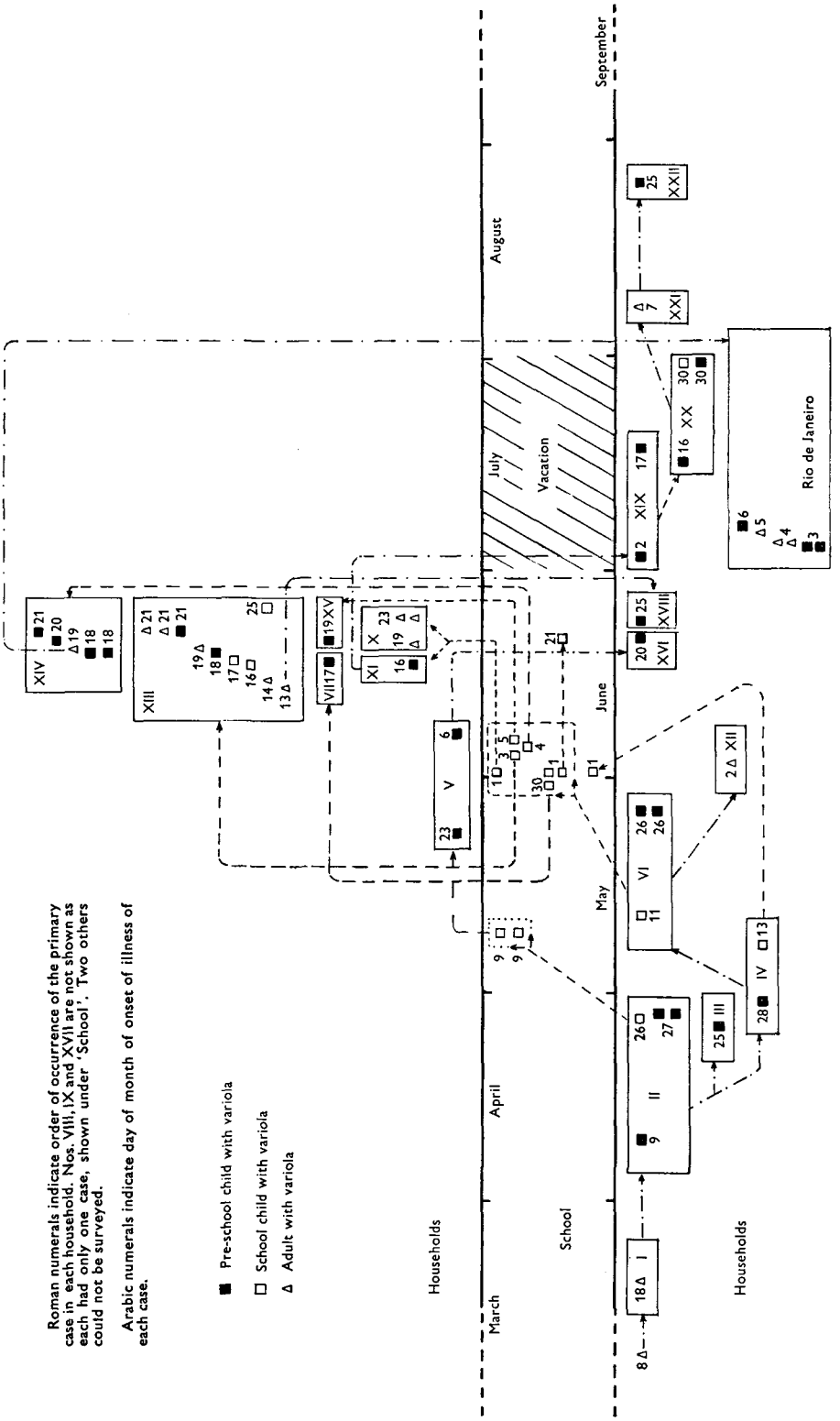

Fig. 1. Epidemic spread by date of onset, house and school, Vila Guarani.

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consisted of only two types of social units, the household and the school class, the following possibilites of inter-social unit transmission existed: household to household, household to school class, school class to school class, and school class to household. The chain of disease transmission in the district shows that all four types of inter-social unit transmission actually occurred during the epidemic (Fig. 1). Moreover, each type predominated during a certain interval of the epidemic period, and thus four stages of the epidemic might be recognized. These stages compose a cycle whose completion coincided with the ending of the epidemic.

Most inter-social unit transmission of disease occurred, not between members of well-separated houses, but between persons from houses sharing a latrine, a clothes-washing basin and a yard. According to the information consistently obtained from household members, it was in this yard that personal contacts between members of different households most frequently occurred. Small crowded houses impelled people to gather in this yard and there was general reluctance to quarantine patients, since the eruption was benign. Nine classes briefly met daily in the central yard of the school, before and after leaving classrooms. It was at this time that class to class transmission probably occurred (Angulo *et al.* 1964).

Factors influencing the spread in the district

Social-unit composition

As shown in Table 1, a greater proportion of the households with cases had at least one school child. Forty per cent of these households included two or more school children, while less than 15% of the households without cases had two or

Table 1. *Study households by specified number of school children and pre-school children and vaccination level*

Type of household	Total number of households	Number of households with specified number of: School children 0	School children 1	School children 2+	Pre-school children 0	Pre-school children 1	Pre-school children 2+	Number of households with vaccination level of: < 50%	⩾ 50%
With cases	20	6	6	8	4	4	12	13	7
Without cases	22	11	8	3	10	6	6	5	17

more school children. In addition, a greater proportion of the households with cases had at least one pre-school child, compared with the households without cases. Households with a vaccination level of 50% or higher are significantly more frequent among households without cases (Yates corrected $\chi^2 = 6{\cdot}02$, $P = 0{\cdot}014$). The proportion of persons with a previous (successful) vaccination was also higher in the total population of the households without cases (62·7% compared with 50·5%). Although the characteristics of school classes without cases were not determined, the evidence obtained in classes where cases occurred indicate that the vaccination level was influential (Angulo *et al.* 1964).

Type of inter-social unit transmission

Table 2 shows the number of resulting cases by type of inter-social unit transmission. Because the actual length of the infectivity period for all cases was unknown, the total period of transmission is calculated as the interval between the first and last onset of illness for any given type of inter-social unit transmission. This criterion cannot be applied to occurrences in the school, because here the students responsible for the introductions did not attend the school during the whole eruptive stage nor during the pre-eruptive stage but on certain known days of their eruption (Angulo *et al.* 1964). Thus the total period for household to school class transmission is calculated from the date (29 April 1956) of the first class attendance by a student in the eruptive stage to the date (19 May) of the last

Table 2. *Number of cases of variola minor by type of inter-social unit transmission*

Type of inter-social unit transmission	Total period of transmission (days)*	Social units affected†		Number of resulting cases
		Number	Rate of transmission (per day)	
School class to household	43	12	0·28	23
Household to household	160	11	0·07	20
Household to school class	20	3	0·15	9‡
School class to school class	18	2	0·11	2

* See text for definition of this period.

† The households include twenty-one households actually surveyed plus two households which were not surveyed but whose primary cases were identified in the school. Household I is not included, since the source of infection for the traveller introducing variola minor in this household (the first household infected in the district) is unknown.

‡ Includes only those cases infected in the same class as the student introducing the disease.

class attendance by a student in the eruptive stage. The total period of class to class transmission is calculated from the date (29 April) of the earliest introduction resulting in transmission to another class to the date (17 May) of the last introduction which resulted in transmission to another class.

Household to household transmission was responsible for spread of variola minor from household I, through which it was introduced into the district, only to households II, III and IV, all living in the same group of houses sharing living facilities (Figs. 1 and 2). A restricted household to household transmission also occurred in the neighbourhood comprising the households XIX, XX, XXI and XXII where the disease was spreading after closure of the school for vacation in July. In contrast, the topographical distribution of homes affected by school class to household transmission was widespread. This is observed in spite of school class to household transmission being in operation for only one fourth of the period of household to household (Table 2). School class to school class transmission seems to have been the least efficient in the spread of variola minor. Class to class spread

occurred in only two instances, although twenty-seven classes used nine classrooms and shared two latrines (Angulo *et al.* 1964).

Family status of persons involved in inter-social unit transmission

All inter-social unit transmissions involved only one person from each school class or household, whatever the social units involved. When the person infected in an inter-social unit transmission was a school child, the secondary attack rate (SAR) in his household was twice the rate found in the households where the disease was introduced by pre-school children (Table 3). In the households where adults introduced the disease very small numbers were involved.

Table 3. *Inter-social unit transmission of variola minor. Secondary attack rate by family status of primary cases*

Family status (school attendance)*	Total number of households	Total number of susceptible household members	Secondary cases	Secondary attack rate (%)
Pre-school children	6	26	5	19·2
School children	11	66	25	37·9
Adults	3	2	0	0·0
Total	20	94	30	31·9

* Of patient introducing variola minor into the household.

Table 4. *Intra-social unit transmission of variola minor. Secondary attack rate by family status of primary case*

	Transmission to persons with same family status			Transmission to persons with other family status		
Family status* (school attendance)	No. of persons	No. of cases	SAR (%)	No. of persons	No. of cases	SAR (%)
Pre-school children	8	3	37·5	18	2	11·1
School children	17	3	17·6	49	22	44·9
Adults	1	0	0·0	1	0	0·0
Total	26	6	23·1	68	24	35·3

* Of patient introducing variola minor into the household.

Family status of persons involved in intra-social unit transmission

Pre-school children introducing variola minor into their households showed the greatest ability to transmit the disease to housemates with the same family status compared with school children transmitting the disease to housemate school children (Table 4). When transmission to persons with different family status is examined, school children had the greatest ability to transmit variola minor. It is difficult to determine the efficiency of adults to transmit variola minor to housemates with the same or different family status, since very small numbers are involved.

Place of occurrence of disease-transmitting contacts

Disease-transmitting contacts between members of different households could occur at the school or at places (houses, playgrounds, streets, bars, etc.) other than the school. The information about the possible source of infection for the twenty-one persons introducing variola minor in the twenty-two households with cases which were surveyed, and for the three students introducing the disease into school classes, strongly suggested that transmission almost constantly occurred at home or at the school. Only one disease-transmitting contact seemingly occurred in a playground and no contact with an infective from another household was recorded as occurring in the streets, bars or groceries for the remaining patients who had a primary infection. Moreover, all persons reporting frequent personal contacts with patients referred to neighbours exclusively.

Eleven school children seemingly infected in the school introduced variola minor into twelve households (Fig. 1). Of the eighteen school children developing the disease, eleven were infected in the school and seven were infected at home (Fig. 1). Furthermore, although there were eight school children in the population of the eleven households affected through household to household spread, only one school child was infected in these eleven inter-household transmissions (the first household affected in the district is not included, as the corresponding inter-household spread did not occur in Vila Guarani). The evidence on class to class spread suggested that this spread occurred outside the classroom and, probably, in the school central yard, where children met before and after attending classes (Angulo *et al.* 1964).

Degree of exposure

For unvaccinated susceptible persons in school classes the SAR was 19·6% (Angulo *et al.* 1964). This is significantly lower (Yates corrected $\chi^2 = 11{\cdot}26$, $P < 0{\cdot}001$) than the SAR of 55·3% for unvaccinated susceptible persons in households (Angulo *et al.* 1967). There were at least 55 exposed susceptible persons previously vaccinated in the three school classes where the students introducing disease attended classes during the eruptive stage of illness (Angulo *et al.* 1964). None of these fifty-five persons developed variola. In contrast, nine of the fifty-six susceptible persons, previously vaccinated, exposed in their household showed variolous manifestations. This difference is significant (Yates corrected $\chi^2 = 9{\cdot}62$, $P = 0{\cdot}002$).

In two of the three school classes in which secondary cases did not occur it was firmly established that the children with variola did not attend classes during illness (Angulo *et al.* 1964). In the two classes with secondary cases, the patients introducing the disease attended classes during the eruption. The child attending classes for the longest period of time during the eruptive stage gave rise to the largest number of cases.

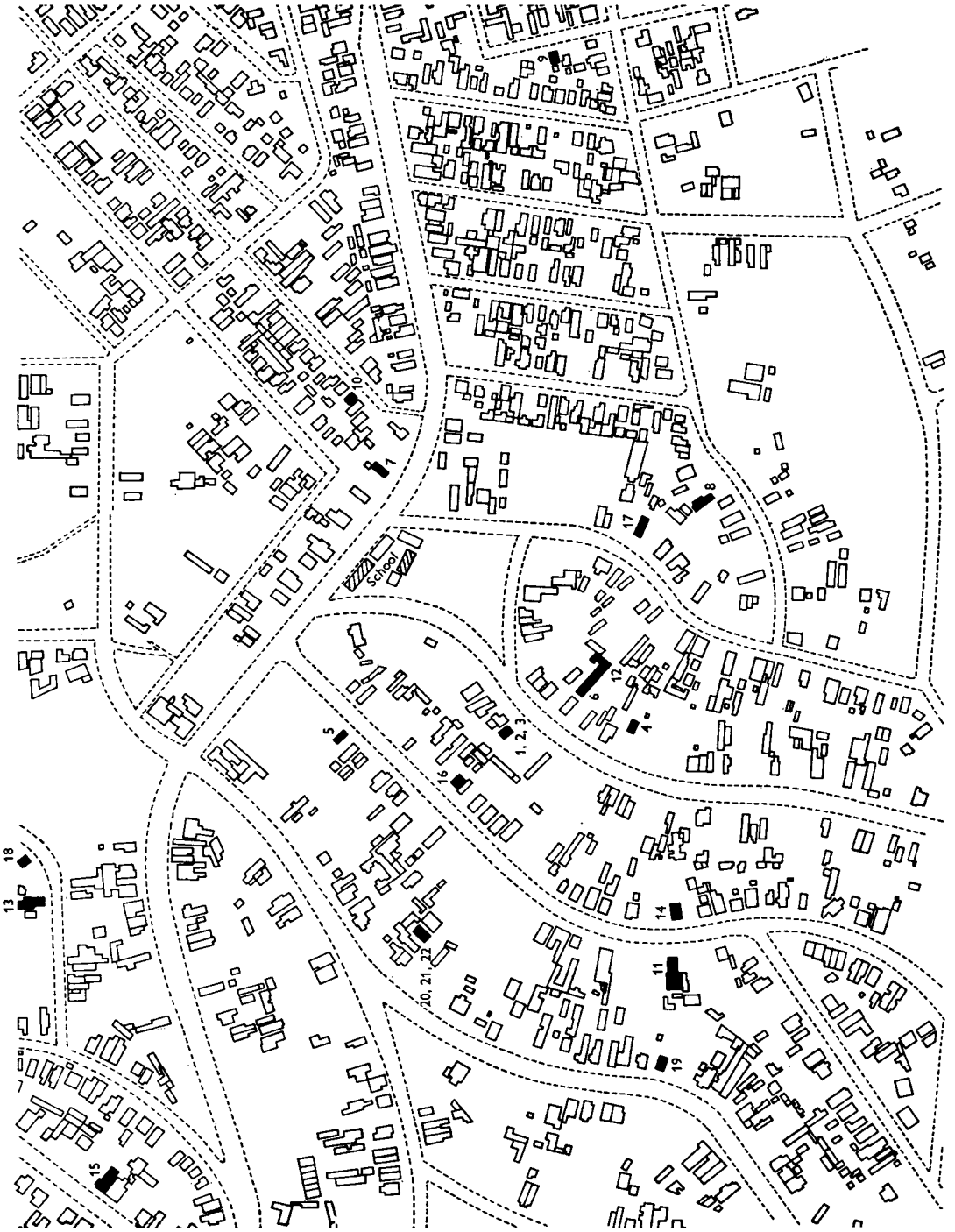

Fig. 2. Geographic distribution of households with cases of variola minor, Vila Guarani.

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Preventive measures

With the exception of two patients admitted on the first day of eruption, eight other patients were isolated on the fourth to the tenth day of eruption in a hospital located 10km from the district. Two additional patients were isolated at unknown intervals after onset of eruption. The SAR is higher, though not significantly, in the eleven households where the patients remained at home than in the six where the patients were isolated in hospital, even though the former households had a higher vaccination rate (Table 5).

Table 5. *Effect of hospitalization on secondary attack rate*

Transmission of disease in households*	Number of households	Vaccination level† (%)	Exposed susceptible persons	Secondary cases	SAR (%)
With hospitalization of one or more patients	6	33·3	25	6	24·0
Without hospitalization of patients	11	56·3	69	24	34·8

* Includes the seventeen households with exposed susceptible household members.
† Includes the primary case in each household.

The City of São Paulo Department of Health conducted a compulsory mass vaccination of the school population and offered vaccination to the district inhabitants. Vaccinations were initiated on 6 June, when all but one of the cases infected in the school had already occurred, and continued until 30 June (Angulo *et al.* 1964). No remarkable difference was found when the SAR was compared between households with at least one primary vaccination after onset of the first case and households with no primary vaccination after onset of the first case.

DISCUSSION

The study households without cases differed from the households with cases in having a smaller proportion of school children and pre-school children and having a higher vaccination level. Variables such as sex, ethnic group or number of adults showed no remarkable difference when compared between the two groups of households. Although the characteristics of school classes without cases were not determined, it seems that the vaccination level influenced the number of cases appearing (Angulo *et al.* 1964).

Once the disease was introduced into a social unit (a household or a school class), intra-social unit spread progressed independently, since it was not associated with spread in neighbouring social units (Angulo *et al.* 1964, 1967). The chance for transmission of the disease outside homes or the school was very small, as suggested by the constant occurrence of a single introduction into households and school classes. The degree of exposure to infective persons was clearly higher in households than in school classes. The contrast between the relatively high transmissibility of variola minor in households and the very narrow flow of the disease through the

district, a very large part of which was strikingly spared, has its counterpart in an epidemic of poliomyelitis (Nolan, Wilmer & Melnick, 1955).

Household to household transmission occurred almost exclusively in groups of dwellings sharing a yard, a latrine and a basin for washing clothes. In this respect certain places of social activities, like backyards and stairways common to several houses, have been found to influence the spread of several diseases, as they increase the rate of personal contacts (Peters, 1910; Halliday, 1928). Introduction of the disease into the school was difficult because it implied class attendance by school children during the period of illness (eruption) where clinical manifestations could easily be recognized or suspected by teachers and classmates. Also, some school children were kept at home, in spite of the mildness of the eruptive stage. The subsequent intra-class spread was seemingly influenced by the length of school attendance during illness (Angulo *et al.* 1964). These factors, together with a relatively high vaccination level (compared with that of households), class discipline and the short stay in the school (approximately four hours daily) were seemingly responsible for the very limited dissemination of disease in the school.

It is believed that closure of the school for the month of July (the customary winter vacation in the Southern Hemisphere) noticeably influenced the extent of spread during the epidemic because (*a*) after the school was closed, the only mechanism of spread in the district was household to household transmission, this mechanism being self-limiting and affecting restricted areas; (*b*) the school played a predominant role in the spread of disease through the district; (*c*) there was a pronounced decrease in the number of cases in July; (*d*) the mass vaccination campaign and isolation of patients were both incomplete and started too late for their results to be effective.

Transmission of variola minor between social units included all four types possible according to the simple social structure of the district. The rate of spread from school classes to households was at least twice the rate of any other type of inter-social unit spread. This type of transmission was directly and indirectly reponsible for the majority of cases during the epidemic, for the peak of the epidemic curve and for the extent of spread. It may thus be inferred that, if introduction into the school with subsequent spread among school children had occurred for a longer time, the epidemic would have lasted longer and would have included a greater number of cases. Also, if the disease had not been introduced into the school the epidemic would have been limited to the cluster of houses where introduction into the district occurred.

The outstanding influence of the school on the spread of variola minor in the district may be due to any of the following factors. (*a*) The school was the only place in the district where persons living in various neighbourhoods had regular repeated contacts. The school thus increased the rate of contact between persons from different families and acted as a nodal centre. The daily coming and going of school children represented lines of communication converging on the school, when variola minor was introduced into the school, and diverging from the school, when children infected in the school conveyed the disease to neighbourhoods other than those where variola minor was spreading before introduction into the school;

(*b*) The concentration of school children in a single school clearly contributed to spread of the epidemic through the district. (*c*) The great majority of school children were susceptible (had no previous variola). (*d*) The social activities of school children gave them the highest potential as transmitters of variola minor, not only in extra-household contacts but in intra-household spread as well.

Closure of primary schools may be an important measure to take in an epidemic of variola minor, at least when cases are occurring among school children. In contrast, some epidemics of variola (usually variola major) in Europe have involved mostly adults (de Jongh, 1956; Dixon, 1962), resulting in a different epidemic pattern. It seems that, in those countries where endemicity of variola has disappeared, small, sporadic epidemics develop following importation of the disease by adults, with subsequent spread in the hospitals to which these patients are admitted. On the other hand, variola minor is endemic in Brazil and patterns essentially identical with that found in the present study have been observed in larger epidemics occurring in two small cities, in spite of the more elaborate urban environment (Angulo, unpublished observations).

SUMMARY

The mechanism of spread of an epidemic of variola minor (alastrim) occurring in 1956, in Vila Guarani, a semi-rural school district of the City of São Paulo, Brazil, is examined. Cases were grouped according to time and space relationships corresponding to either a household or a school class, as once variola minor was introduced into a household or a school class spread was independent of occurrences in neighbouring social units. The constant occurrence of a single introduction in school classes and households implied that the chance for transmission of the disease outside the homes or the school was very small. The secondary attack rate was higher in households than in school classes. Twenty households with cases had more pre-school children and school children and a lower vaccination level than twenty-two neighbouring households without cases but also including one or more persons who were known to have had personal contacts with patients.

Examination of the chain of contagion clearly shows that spread in the school was directly and indirectly responsible for the majority of cases in the epidemic, for the peak of the epidemic curve and for the extent of topographical spread of the epidemic. This predominant role of the school was accentuated by incomplete preventive measures (vaccination campaign and isolation of patients) applied late in the epidemic and it is attributed to the following facts. (*a*) There was a single school in the district, and school children were thus concentrated. (*b*) The school was the only place of the district where persons living in different neighbourhoods had regular, repeated contacts. (*c*) The great majority of school children had had no previous variola and many had no vaccination scar. (*d*) The social activities of school children gave them the highest potential as transmitters of variola minor.

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REFERENCES

ANGULO, J. J., RODRIGUES-DA-SILVA, G. & RABELLO, S. I. (1964). Variola minor in a primary school. *Publ. Hlth Rep., Wash.* **79**, 355.

ANGULO, J. J., RODRIGUES-DA-SILVA, G. & RABELLO, S. I. (1967). Spread of variola minor in households. *Am. J. Epidem.* **86**, 479.

DE JONGH, M. (1956). The alastrim epidemic in The Hague, 1953–1954. *Documenta Med. geogr. trop.* **8**, 207

DIXON, C. W. (1962). *Smallpox, p.* 425–45. London: J. A. Churchill Ltd.

HALLIDAY, J. L. (1928). An inquiry into the relationship between housing conditions and the incidence and fatality of measles. *Spec. Rep. Ser. med. Res. Coun.* no. 120.

IPSEN, J., DONOVAN, W. R. & JAMES, G. (1952). Sociologic factors in the spread of epidemic hepatitis in a rural school district. *J. Hyg., Camb.* **50**, 457.

KNIGHT, V., DRAKE, M. E., BELDEN, E. A., FRANKLIN, B. J., ROMER, M. & COPPLE, L. O. (1954). Characteristics of spread of infectious hepatitis in schools and households in an epidemic in a rural area. *Am. J. Hyg.* **59**, 1.

LIDWELL, O. M. & SOMMERVILLE, T. (1951). Observations on the incidence and distribution of the common cold in a rural community during 1948 and 1949. *J. Hyg., Camb.* **49**, 365.

MCCARROLL, J. R., MELNICK, J. L. & HORSTMANN, D. M. (1955). Spread of poliomyelitis infection in nursery schools. *Am. J. publ. Hlth.* **45**, 1541.

MEYER, M. B. (1962). An epidemiologic study of mumps; its spread in schools and families. *Am. J. Hyg.* **75**, 259.

NOLAN, J. P., WILMER, B. H. & MELNICK, J. L. (1955). Poliomyelitis; its highly invasive nature and narrow stream of infection in a community of high socio-economic level. *New Engl. J. Med.* **253**, 945.

PETERS, O. H. (1910). Observations on the natural history of epidemic diarrhoea. *J. Hyg., Camb.* **10**, 602.

RODRIGUES-DA-SILVA, G., RABELLO, S. I. & ANGULO, J. J. (1963). Epidemic of variola minor in a suburb of São Paulo. *Publ. Hlth Rep. Wash.* **78**, 165.