chome chez les enfants au Sénégal: enquête chez les enfants de 2 à 6 ans du bassin rachidien. Thèse Docteur de Médicine, Reims, 1990;28:II.
3. Verin P, Gendre P, Comte P. Current classification of trachoma (clinical, histological and ultrastructural). Rev Int Trach Pathol Ocul Trop Subtrop Santé Publique 1987;64: 115–21.
4. Bailey RL, Osmond C, Mabey DCW, et al. Analysis of the household distribution of trachoma in a Gambian village using a Monte Carlo simulation procedure. Int J Epidemiol 1989;18:644–51.
5. Resnikoff S, Cornand G. Malnutrition et trachome. Rev Int Trach Pathol Ocul Trop Subtrop Santé Publique 1987;54:75–87.
6. Taylor HR. Review of trachoma: an introduction. Rev Infect Dis 1985;7:71.
7. Treharne JD. The community epidemiology of trachoma. Rev Infect Dis 1985;7:760–3.
8. Brilliant LB, Pokrel RP, Grasset NC, et al. Epidemiology of blindness in Nepal. Bull WHO 1985;63:375–86.
9. West SK, Munoz B, Turner V, et al. The epidemiology of trachoma in Central Tanzania. Int J Epidemiol 1991;20: 1088–92.
10. Wilson M, Keyvan L, Millan-Vellasco F, et al. L'épidémiologie du trachome dans les Chiapas (Mexique). Rev Int Trach Pathol Ocul Trop Subtrop Santé Publique 1987;64: 167–75.
11. Taylor HR. Trachoma research: laboratory and epidemiological aspects. Rev Int Trach Ocul Trop Subtrop Santé Publique 1987;54:25–44.
12. Mage Y, Guillaume JB, Ingrand P, et al. Trachome au Nord Cameroun. Rev Int Trach Ocul Trop Subtrop Santé Publique 1991;58:179–85.
13. Thacker SB, Music SI, Pollard RA. Acute water shortage and health problems in Haïti. Lancet 1980:1:471–3.
14. Tielsch JM, West KP, Katz J, et al. The epidemiology of trachoma in Southern Malawi. Am J Trop Med Hyg 1988;38: 393–9.
15. Prost A, Negrel AD. Water, trachoma and conjunctivitis. Bull WHO 1989;67:9–18.
16. Dahgous T, Romdhane K, Kamoun M, et al. Le trachome après 20 ans de contrôle. Rev Int Trach Pathol Ocul Trop Subtrop Santé Publique 1979;46:39–53.
17. Dahgfous T, Nabli B, Messadi M. Stratégie de la lutte anti-trachomateuse en Tunisie. Rev Int Trach Pathol Ocul Trop Subtrop Santé Publique 1987;54:123–9.
18. Dolin PJ, Faal H, Johnson GJ, et al. Reduction of trachoma in a sub-Saharan village in absence of disease control program. Lancet 1997;1:1511–12.

Pediatr Infect Dis J, 2000;19:983–90

Vol. 19, No. 10
Printed in U.S.A.

Household crowding a major risk factor for epidemic meningococcal disease in Auckland children

MICHAEL BAKER, FAFPHM, ANNE MCNICHOLAS, MPH, NICHOLAS GARRETT, MS, NICHOLAS JONES FAFPHM, JOANNA STEWART, MSC, VIVIEN KOBERSTEIN AND DIANA LENNON, FRACP

Background. **New Zealand is in its ninth year of a serogroup B meningococcal disease epidemic with annual rates of up to 16.9 cases per 100 000. The highest incidence is in Maori and Pacific Island children in the Auckland region. We conducted a case-control study to identify potentially modifiable risk factors for this disease.**

Methods. **A case-control study of 202 cases of confirmed and probable meningococcal disease in Auckland children younger than 8 years of age recruited from May, 1997, to March, 1999, was undertaken. Controls (313) were recruited door-to-door by a cluster sampling method based on starting points randomly distributed in the Auckland region. They were frequency matched with the expected distribution of age and ethnicity in the meningococcal disease cases.**

Results. **With the use of a multivariate model and controlling for age, ethnicity, season and socioeconomic factors, risk of disease was strongly associated with overcrowding as measured by the number of adolescent and adult (10 years or older) household members per room [odds ratio (OR), 10.7; 95% confidence interval (CI), 3.9 to 29.5]. This would result in a doubling of risk with the addition of 2 adolescents or adults to a 6-room house. Risk of disease was also associated with analgesic use by the child, which was thought to be a marker of recent illness (OR**

Accepted for publication July 13, 2000.
From the Institute of Environmental Science and Research (ESR), Wellington (MB, AM); and ESR (NG), Auckland Healthcare (NJ, VK) and University of Auckland (JS, DL), Auckland, New Zealand.
Key words: Meningococcal disease, risk factors, epidemiology, case-control study, crowding, Auckland, New Zealand.
Reprints not available.

2.4, CI 1.5 to 4.0); number of days at substantial social gatherings (10 or more people for > 4 h; OR 1.8, CI 1.2 to 2.6); number of smokers in the household (OR 1.4, CI 1.0 to 1.8); sharing an item of food, drink or a pacifier (OR 1.6, CI 1.0 to 2.7); and preceding symptoms of a respiratory infection (cough, "cold or flu," runny nose, sneezing) in a household member (OR 1.5, CI 1.0 to 2.5).

***Conclusion.* Some of these identified risk factors for meningococcal disease are modifiable. Measures to reduce overcrowding could have a marked effect on reducing the incidence of this disease in Auckland children.**

INTRODUCTION

Meningococcal disease is caused by infection with *Neisseria meningitidis.* Although nasopharyngeal carriage with *N. meningitidis* is relatively common, invasive disease is rare. The events that cause meningococcal disease and epidemics are poorly understood but are thought to include a combination of organism, host and environmental factors.[1]

New Zealand is in the ninth year of a serogroup B meningococcal disease epidemic.[2, 3] The incidence of disease has risen from 53 cases (1.5 per 100 000) in 1990 to a peak of 613 cases (16.9 per 100 000) in 1997. The epidemic has increasingly been dominated by a single serogroup B strain, B:4:P1.7^{h},4 of lineage III. Serogroup B epidemics typically begin slowly, usually reach annual rates of 5 to 20 cases per 100 000 population and may persist for 5 to 10 years or longer.[4] A similar epidemic in Norway lasted 10 to 15 years.[5] Given the potentially prolonged duration of the epidemic and the current lack of a vaccine against group B disease, it was decided to undertake an investigation to identify potentially modifiable risk factors for the disease.

A disproportionately large number of meningococcal disease cases have been seen in Maori and Pacific Island children in the Auckland region. The city has a population of 1.1 million, of which 8% are children younger than 5 years of age. In this age group Maori make up 21%, Pacific Island children 19% and "others" (predominantly of European ancestry) 60%. In 1997 the rates of meningococcal disease in Auckland children younger than 5 years of age were 300 per 100 000 for Maori, 684 per 100 000 for Pacific Island children and 50 per 100 000 for others. In South Auckland annual disease rates have reached as high as 1521 cases per 100 000 for Pacific Island children younger than 1 year of age. The investigation therefore focused on identifying potentially modifiable risk factors for meningococcal disease in Auckland children.

METHODS

The investigation method was a prospective case-control study of meningococcal disease, using community controls. The method, including the control selection procedure and the questionnaire, was pilot tested during April and May, 1996.

Cases. The study was restricted to children younger than 8 years of age because they accounted for two-thirds of cases, and disease rates fell markedly among those older than 7 years of age.

The study included both laboratory-confirmed and non-laboratory-confirmed cases that met the definition for a probable case. Probable cases were included because prehospital antibiotic use is being actively promoted to improve disease outcome and is known to reduce the probability of isolating organisms from cases at the time of admission to hospital.[3] Because the use of prehospital antibiotics could differ in different sections of the community, a bias could have been introduced by restricting the study to laboratory confirmed cases.

Laboratory confirmation criteria were culture of *N. meningitidis* from blood, cerebrospinal fluid (CSF) or other sterile site; identification by PCR of *N. meningitidis* DNA in blood or CSF; or demonstration of Gram-negative diplococci in CSF or blood. Criteria for probable cases were either septicemia or meningitis, as well as a petechial or purpuric rash on the trunk or at least two other regions. The criteria for septicemia included at least two of the following: fever; tachycardia; one sign of shock (e.g. hypotension, hypothermia or reduced peripheral circulation); coagulopathy; decreased level of consciousness; or failure to feed in children younger than 1 year. Tachycardia and hypotension were measured against age related normal ranges. The criteria for meningitis included fever and at least one of the following: neck stiffness; positive Kernig's sign; bulging fontanel; or CSF findings consistent with bacterial meningitis (raised white blood cell count, elevated protein and decreased glucose measured against normal ranges used at the admitting hospitals). The hospital records of all probable cases were subsequently reviewed by the study pediatrician, with further independent external review of a subset by two senior pediatricians. A decision tree was used to methodically score the probable cases against a range of criteria, and they were retained in the study only if the discharge diagnosis and treatment were also consistent with meningococcal disease.

Medical practitioners are legally required to notify meningococcal disease to the local Medical Officer of Health. Laboratory data on confirmed cases are routinely matched with notification data so that reporting of confirmed cases is complete. Reporting for probable cases is believed to be near complete because of the high levels of professional awareness during the current epidemic and the requirement for the Medical Officer of Health to provide chemoprophylaxis for close

contacts. The study aimed to recruit all laboratory-confirmed and probable cases of meningococcal disease in children younger than 8 years of age residing in the Auckland urban area during the study period of May, 1997, to March, 1999.

Controls. Controls were recruited door-to-door by cluster sampling. The primary sampling unit was a meshblock which in urban areas usually occupies a city block and contains ~120 people. Meshblocks were selected in such a way that the probability that a particular meshblock was included was proportional to the number of households in that meshblock. A starting point was randomly selected within each meshblock

Control recruiters visited 20 successive households, beginning from the designated starting point, and recruited as potential controls all children <8 years of age identified in the visited households. Households in which no one was at home were visited again. At least 2 subsequent visits were carried out before the attempt was abandoned. All of the return visits had to be on a different day and time, and at least one of the three visits had to be during a weekend.

From these potential controls the study controls were selected based on age and ethnicity, given that these are well-established risk factors for meningococcal disease[2, 3] This selection was achieved by assigning each recruited potential control a probability for inclusion in the study that would result in a group of study controls of an age and ethnic distribution similar to those expected in the cases. These probabilities were calculated from the age and ethnic distribution of meningococcal disease cases that had occurred in the Auckland region during the 1992 to 1996 period and the distribution of the Auckland population in the 1996 census. Four age groups (<1, 1 to 2, 3 to 4, 5 to 7) and three ethnic groups (Maori, Pacific Island, other) were used. Probabilities ranged from 0.7 for a Pacific Island child younger than 1 year of age to 0.04 for a child age 5 to 7 years of other than Maori or Pacific Island ethnicity. Control recruitment was conducted on a continuous basis so as to provide controls for interview at about the same rate as cases were occurring in the study population

Questionnaire. The questionnaire was developed after a review of the literature on known and suspected risk factors for meningococcal disease and wide consultation. It was pilot tested during April and May, 1996.

The questionnaire recorded demographic details and, for cases, details of the child's illness symptoms and time of onset. It also recorded, for both cases and controls, a range of exposures focused on those that occurred during the 2 weeks before hospitalization for cases or date of recruitment for controls. The exposures covered were symptoms of respiratory infection in the child or family member; medicine use; "bumps or knocks" to face or nose; sharing an item of food, drink, or pacifier; measures of crowding [based on household membership, split into children (younger than 10 years of age) and adolescents and adults (10 years of age or older) and number of rooms in the house]; attendance at preschool, school and social gatherings; travel by public transport; bed sharing; passive tobacco smoke exposure; respondent's assessment of dampness of house and condensation, mold or mildew in child's bedroom (supported by showing interview subjects photos of window condensation and mildew on walls); ventilation of bedroom; home heating; exposure to fumes from indoor combustion; dust exposure; and exposure to animals. For the questions on recent illness and medicine use by cases, the interview subject was specifically asked to exclude the period after onset of the first symptom of meningococcal disease. Some exposures were also recorded on a daily basis, allowing them to be subsequently analyzed according to whether they occurred during the incubation period for meningococcal disease (taken to be 3 to 9 days for this study).

The questionnaire also asked about longer term host and environmental factors, including operation to remove tonsils or adenoids; general health of child; antibiotic use and utilization of health care services in the preceding 12 months; duration of breast-feeding (exclusively and partially); number of different households in which child currently lives and number of changes of address over the preceding 12 months; and socioeconomic status (home, telephone and motor vehicle ownership, parental education, parental employment status, household income, possession of a Community Services Card which is issued to adults on a low income).

The questionnaire was administered to the parents or primary caregivers of the cases and controls after written informed consent. The interview had to take place within 14 days of the patient's being hospitalized with meningococcal disease or recruitment of the control. To assist recall a calendar was used to clearly identify the exposure period of interest.

Statistical analysis. The statistical package SUDAAN[6] was used to allow for the cluster effect caused by the method of control selection. Risk factors were assessed by logistic regression with the outcome of case or control and a base model of variables used in the design of the study and socioeconomic measures as explanatory variables. Factors of interest were added to this base model. The base model included variables for the age and ethnic group used as strata, year and month of interview, age nested within age group, possession of a Community Services Card and tertiary education of a parent. Variables from each section of the questionnaire were then added to the base model

individually. This allowed us to see which of the several closely related measures in a section appeared to best explain the risk of developing meningococcal disease. Any likely confounders were also included. The best variable from each group of questions that showed some indication of a relationship with disease was then selected and incorporated into a multivariate model. Odds ratios and 95% confidence intervals were calculated for each of these variables.

RESULTS

Study participants. Characteristics of cases and controls are shown in Table 1.

Of 386 meningococcal disease cases notified in Auckland children < 8 years of age during May, 1997, to March, 1999, 159 were laboratory-confirmed and 227 were non-laboratory-confirmed. Of the non-laboratory-confirmed cases, 125 meet the definition for a probable case based on clinical information available around the time of hospitalization. This meant that 284 notified cases in total were recruited to the study. Of these, 243 (86%) were successfully interviewed within 14 days of hospitalization, of whom 134 were laboratory-confirmed and 109 were probable cases. However, 41 of the probable cases were subsequently discarded from the study because they failed to meet the more rigorous case definition applied at chart review. This process left 202 cases in the study, of whom 134 (66%) were laboratory-confirmed and 68 (34%) were probable cases.

A total of 9309 houses were visited as part of the control recruitment process. In 8460 (91%) of these adult household member was at home who agreed to discuss the study. Of these, 2010 (24%) households had eligible children and 1759 (86%) agreed to participate. These 1759 households yielded 2759 children as potential controls. From this group 374 were randomly selected for interview, using the process described in Methods, and 313 (84%) were successfully interviewed within 14 days of being recruited.

Analysis of risk factors. Independent risk factors for meningococcal disease are shown in Table 2 and described in more detail below.

Household density. The strongest independent risk factor for development of meningococcal disease in this population was the number of adolescents and adults usually living in the house per room. The number of rooms included the kitchen, dining room, living room/s, bedrooms and sleeping areas in "caravans" (camper vans), "sleep-outs" (sheds) and garages. The median number of rooms per household in both cases and controls was 6 with a range of 2 to 11. The number of adolescents and adults ranged from 1 to 10 for the controls with a median of 3, whereas in cases it ranged from 1 to 12 with a median of 4. Adolescent and adult density was treated as a continuous variable with a median of 0.43 adolescents and adults per room for controls (range, 0.13 to 1.43) and a median of 0.6 (range, 0.17 to 1.75) for cases. When categorized this variable did not show any threshold effect. Several other measures of household density were also associated with an increased risk of disease in the individual analyses but were less important. These measures included the number of adolescents and adults per bedroom, total number of people per room, total number of people per bedroom, proportion of household who were adolescents and adults, number of household members, number of adolescents and adults and use of a "sleep-out" or "caravan." Acute measures of household density referred to the incubation period and included the total number of person nights, total number of adolescent and adult person nights, maximum number on any one night and maximum adolescents and adults on any one night.

Recent illness and general health status. Evidence of a respiratory infection in the child or their household

TABLE 1. Characteristics of study participants

Characteristic	Variable	Cases		Controls	
		No.	%	No.	%
Age	0–1 yr	55	27	65	21
	1–2 yr	63	31	85	27
	3–4 yr	46	23	83	26
	5–7 yr	38	19	80	26
Sex	Male	114	56	167	53
	Female	88	44	146	47
Ethnicity	Maori	71	35	61	19
	Pacific Island	106	52	178	57
	Other	25	12	74	24
Season	Summer (January–March)	28	14	59	19
	Autumn (April–June)	40	20	57	18
	Winter (July–September)	88	44	135	43
	Spring (October–December)	46	23	62	20
Community Services Card	Yes	150	74	182	58
	No	52	26	131	42
Tertiary education of either parent	Yes	44	22	127	41
	No	158	78	186	59

TABLE 2. Independent risk factors for meningococcal disease in Auckland children: frequencies and odds ratios

Risk Factor	Case	Control	Individual Analyses*		Combined Analysis†	
			Odds ratio	P‡	Odds ratio	P‡
No. of adult and adolescent household members/room	Median, 0.60	Median, 0.43	14.3 (5.5,37.1)§	<0.0001	10.7 (3.9,29.5)	<0.0001
Analgesic use by child	46%	23%	2.9 (1.8,4.5)	<0.0001	2.4 (1.5,4.0)	0.0006
No. of days of attendance at substantial social gatherings	1 or more, 20%	1 or more, 13%	1.7 (1.2,2.6)	0.005	1.8 (1.2,2.6)	0.002
No. of smokers in usual household	1 or more, 67%	1 or more, 52%	1.6 (1.3,2.0)	0.0001	1.4 (1.0,1.8)	0.03
Sharing an item of food, drink or pacifier	71%	59%	2.1 (1.3,3.4)	0.004	1.6 (1.0,2.7)	0.07
Symptoms of respiratory infection in a household member	73%	59%	2.0 (1.3,3.1)	0.001	1.5 (1.0,2.5)	0.08
Bed sharing	72%	49%	2.4 (1.6,3.7)	0.0001	1.5 (0.9,2.5)	0.11
Symptoms of respiratory infection in child	29%	18%	2.0 (1.2,3.2)	0.008	1.3 (0.8,2.4)	0.33

* Base model (includes variables for age group, ethnic group, year and month of interview, possession of a Community Services Card and tertiary education of a parent) plus individual variable.

† Base model plus all variables given in table.

‡ Probabilities calculated for Satterthwaite chi square.

§ Numbers in parentheses, 95% confidence intervals.

and the use of analgesics were associated with disease. Household respiratory infection was defined as a member of the household, other than the case or control, having at least one of the following symptoms in the past 2 weeks: cough; "cold or flu"; runny nose; or sneezing. Individual respiratory infection was defined as four or more of the following symptoms in the past 2 weeks: "cold or flu"; runny nose; sneezing; sore throat; or ear ache. Analgesic use was defined as analgesics taken in the past 2 weeks, excluding, for cases, those taken for identified early symptoms of meningococcal disease. These analgesics were predominantly acetaminophen products. Individual respiratory infection and analgesics were correlated, so it is possible that they were both measuring the same illness in the child. Because analgesics showed a stronger relationship with meningococcal disease, the use of analgesics may be a better measure of more severe illness than reported individual symptoms. Individual respiratory infection also interacted with bed sharing (Table 3). Several other measures of recent illness were also associated with meningococcal disease in the individual analyses but were less important. These measures included sore throat, antibiotic use in the previous 14 days and number of visits to doctor/s within the last 12 months.

Social gatherings. The number of days of attendance at substantial social gatherings (10 or more people for >4 h per day) during the incubation period was associated with disease. Such gatherings excluded preschool and school attendance. Several other measures of social gathering during the incubation period were also associated with an increased risk of disease in the individual analyses but were less important. These measures included attendance at any social gathering of 10 or more people, total number of hours at social gatherings and number of attendances at substantial social gatherings

TABLE 3. Relationship of bed-sharing and respiratory infection in meningococcal cases and controls

	With Respiratory Infection				Without Respiratory Infection			
	Bed sharing		No bed sharing		Bed sharing		No bed sharing	
	No.	%	No.	%	No.	%	No.	%
Case	46	67%	12	27%	100	43%	44	26%
Control	23	33%	32	73%	130	57%	128	74%

Passive smoking. The number of smokers in the household was associated with disease. Having one or more smokers who were reported to smoke in the same room as the case was associated with an increased risk of disease in the individual analyses but was less important than the number of smokers in the household.

Sharing food, drink, pacifier. Sharing an item of food, drink or pacifier within the previous 2 weeks was associated with disease. Sharing an item of food and drink was defined as sharing a drink from a glass, cup, bottle or can that was being used by someone else or sharing an item of food that was partially eaten by someone else.

Bed sharing. Sharing a bed in the past 2 weeks was associated with disease. This question was recorded as "yes" if it occurred at least half the night. Sharing any time in the last 2 weeks was more important than regular bed sharing, although both were associated with disease.

The following exposures did not emerge as important in the model: medical history of asthma or otitis media; removal of tonsils and adenoids; amount of antibiotic use in the past year; duration of exclusive or any breast-feeding; travel by public transport; number of different households currently lived in; number of changes of address in previous year; and exposure to pets or dust.

Results from combined model. Table 2 shows the results of the logistic regression which combined the base model and the variables adolescent and adult density; analgesic use by the child; number of days of attendance at substantial social gatherings; number of smokers in the household; sharing an item of food,

drink or pacifier; symptoms of respiratory infection in a household member; bed sharing; and symptoms of respiratory infection in the subject. The individual results for these variables when they were included with the base model are also shown.

In the combined analysis adolescent and adult density remained as the variable showing the strongest association with the chance of becoming a case with an odds ratio of 10.7. This would mean that if a family living in an average size house of six rooms increased the number of adolescents or adults by one there would be a 50% increase in risk of meningococcal disease for a child living in the same household. If they increased the number by two adolescents or adults there would be a doubling of risk, by four adolescents or adults a 5-fold increase in risk and by six a 10.7-fold increase. If the house had only four rooms then there would be almost a doubling of risk with the addition of just one extra adolescent or adult.

Analgesic use and attending substantial social gatherings were also still strongly associated with the risk of contracting the disease. Living in a household with higher numbers of smokers was also associated with a higher risk. Although the odds ratios for sharing an item of food, drink or pacifier and household respiratory infection was reduced in the combined analysis, there was still an indication that these factors were associated with an elevated risk of disease.

There was a reduction in the odds ratio for bed sharing and individual respiratory infection when included in the combined analysis. This was partly a result of the correlation of respiratory infection with analgesic use and bed sharing with the density of adolescent and adult household members and number of days at substantial social gatherings. However, there was an interaction of bed sharing with respiratory infection ($P = 0.01$) when this interaction was included in the combined model (Table 3). There was an elevated risk of disease in those who shared a bed and also had a respiratory infection ($P = 0.05$, OR 6.7, CI 1.0 to 46.8) whereas the risk from bed sharing was not significant in those without a respiratory infection ($P = 0.82$, OR 1.1, CI 0.6 to 1.9). For those not sharing a bed there was no evidence of elevated risk from respiratory infection. There was no indication that the children were bed sharing because they were sick, because the percentage who shared a bed with and without respiratory infection was similar. The interaction still remained when usual bed sharing replaced bed sharing in the past 2 weeks.

None of the factors included in the combined analysis interacted with ethnicity; i.e. the risk of the factors did not differ in the Maori, Pacific Island or other ethnic groups.

DISCUSSION

This investigation has found that household crowding is the most important risk factor for meningococcal disease in Auckland children during the current prolonged serogroup B epidemic. This is the largest study of risk factors for meningococcal disease reported to date and the first carried out in New Zealand.

Crowded living conditions have long been associated with increased infectious disease transmission, especially those spread by the respiratory route, such as tuberculosis[7] and rheumatic fever.[8] The association between overcrowding and meningococcal disease has been shown in institutional settings as far back as World War I[9] and in home environments in several countries.[10–15] Recent case-control studies have confirmed the association in developed countries, particularly for children.[16, 17]

This study has found a much greater role for crowding as a risk factor for meningococcal disease than previous case-control studies[15–18] and has identified household members older than 10 years of age as the most important component of household density. Because *N. meningitidis* carriage occurs predominantly in adults[19, 20] and its droplet spread is facilitated by close and frequent contact,[21] it is biologically plausible that high adult density plays an important role in transmission of infection to children.

Where studies have not found a link between overcrowding and meningococcal disease, it has been suggested that a threshold for crowding may exist so that overcrowding must be severe to affect disease.[18, 22] The present study did not find a threshold effect. Rather there is continuously increasing risk with increased density. Census data show that South Auckland, which has the highest rates of meningococcal disease in New Zealand, has the highest proportion (4.5%) of crowded homes of any urban area in New Zealand.[23] The crowding measure used was based on the proportion of houses requiring two or more additional bedrooms to meet adequately the sleeping needs of the household, taking into account household composition.[23] In New Zealand 75% of occupants living in crowded conditions are Maori and Pacific Island people, yet together these two groups form only 20% of New Zealand's population. Young children are particularly affected; almost 60% of crowded homes include children younger than 5 years of age, more than 3 times the average for New Zealand households.[23] Although household crowding is unlikely to have caused the meningococcal disease epidemic in New Zealand, crowding has almost certainly intensified its effect among the most vulnerable, notably Maori and Pacific Island populations living in Auckland.

Our finding of an increased risk of disease when adult household members have had a recent respiratory infection is new. Glover[9] has previously postulated that

meningococcal carriers with a respiratory infection are more likely to cough and sneeze over household members and expose them to a higher infective dose of *N. meningitidis*, a factor believed to be important in the transmission of a number of infectious diseases.[24, 25] Further, the number of respiratory infections a person develops is increased by overcrowded living conditions.[26]

Our findings support previous evidence that infectious cofactors may be important in the development of invasive meningococcal disease.[13, 27, 28] Some measures we used (respiratory infection in a household member and analgesia use as an indicator of a more severe recent illness) were associated with an increased risk of disease. Respiratory infection in the subject, however, was associated with an increase risk of disease only in those who were also sharing a bed. Studies designed to assess the presence of a respiratory infection in a case or control based on symptom history have limitations. Such measures are prone to recall bias and potential confusion with the early onset of meningococcal disease itself. Although we have interpreted analgesia use to be an indicator of recent illness, we cannot exclude the possibility that acetaminophen use itself is a risk factor for meningococcal disease.

Attendance at large social gatherings for significant periods of time was also a risk factor, possibly through exposure to adults who carry the organism. Our study also identified passive smoking as a risk factor for children, although the size of the effect was somewhat smaller than that seen in some previous case-control[15–18, 27] and cohort studies.[29] An increased risk was identified from sharing an item of food, drink or a pacifier with another person. This association has not been previously reported in children, although it is consistent with the elevated risk of meningococcal disease found for students who shared drinks and cigarettes.[30] Some risk factors identified in previous studies were not found in the present study. These factors included dust exposure[16] and reduced duration of breast feeding.[15]

The findings of this study support the hypothesis that household crowding has a central role among causal factors for meningococcal disease. Crowding increases contact between young children and adolescents or adults who carry the organism.[31] Crowding may also increase exposure to infectious cofactors[32] or exposure to tobacco smoke,[17] further increasing the risk of invasive disease.

These findings have implications for efforts to reduce the burden on meningococcal disease among children in New Zealand. The most important preventive measure is to reduce household crowding, which is a major factor in the spread of other infectious diseases as well as meningococcal disease. Because overcrowding is often associated with poverty, policies are required that directly address the affordability of appropriate housing. Findings also support the need to continue efforts to reduce tobacco smoke exposure. Attendance at substantial social gatherings appears important but requires further investigation into its value as a modifiable risk factor.

ACKNOWLEDGMENTS

This study was funded by the NZ Health Research Council and Ministry of Health. We thank the families of cases and controls who took part in the study and the field workers, notifying doctors, hospital laboratories and the Auckland Public Health Protection service staff involved. We are also grateful to the following for critical input to components of the study: Carlene Lawes, Ross Nicholson and Richard Aickin for assisting with chart reviews; Alastair Scott and Chris Wild for statistical advise; Michael Bates, David Tipene-Leach and Colin Tukuitonga for reviewing the paper; Keith Cartwright, James Stuart and Rosalind Stanwell Smith, Public Health Laboratory Service (UK), and Marc Fisher, CDC (US), for reviewing the study protocol and questionnaire and/or providing copies of questionnaires they had used in previous meningococcal disease case control studies.

REFERENCES

1. Stephens DS. Uncloaking the meningococcus: dynamics of carriage and disease. Lancet 1999;353:941–2.
2. Martin D, Walker S, Baker M, Lennon D. New Zealand epidemic of meningococcal disease identified by a strain with phenotype B:4:P1.4. J Infect Dis 1998;177:497–500.
3. Baker M, Martin D, Kieft C, Jones N, Lennon D. The evolving meningococcal disease epidemic in New Zealand. NZ Public Health Rep 1999;7:57–60.
4. Wenger JD. Serogroup B meningococcal disease: new outbreaks, new strategies. JAMA 1999;281:1541–3.
5. Lystad A, Aasen S. The epidemiology of meningococcal disease in Norway 1975–1991. NIPH Ann 1991;14:57–66.
6. Software for the statistical analysis of correlated data, release 7.11. Research Triangle, NC: Research Triangle Institute, 1996.
7. Greenwood M. Epidemics and crowd-diseases. London: Unwin Brothers, 1935.
8. Perry CB, Roberts JAF. Study of the variability and incidence of rheumatic heart disease within the city of Bristol. Br Med J 1937;Suppl 2:154–8.
9. Glover JA. Observations on the meningococcal carrier rate and their application to the prevention of cerebrospinal fever. Med Res Counc Spec Rep (Lond) 1920;50:133–65.
10. Blum B, Elkin WF. The relationship of housing to the incidence of meningococcus disease in an outbreak in Oak Ridge, Tennessee. Am J Public Health 1949;39:1571–7.
11. Reingold AL, Hightower AW, Bolan GA, et al. Age-specific differences in duration of clinical protection after vaccination with meningococcal polysaccharide A vaccine. Lancet 1985;2:114–8.
12. Schwartz B, Al-Ruwais A, Ashi JA. Comparative efficacy of ceftriaxone and rifampicin in eradicating pharyngeal carriage of group A *Neisseria meningitidis*. Lancet 1988;2:1239–42.
13. Moore PS, Hierholzer J, DeWitt W, et al. Respiratory viruses and *Mycoplasma* as cofactors for epidemic Group A meningococcal meningitis. JAMA 1990;264:1271–5.
14. Jones IR, Urwin G, Feldman RA, Banatvala N. Social deprivation and bacterial meningitis in North East Thames region: three year study using small area statistics. BMJ 1997;314:794–5.
15. Moodley JR, Coetzee N, Hussey G. Risk factors for meningococcal disease in Cape Town. S Afr Med J 1999;89:56–9.
16. Stanwell-Smith RE, Stuart JM, Hughes AO, et al. Smoking, the environment and meningococcal disease: a case control study. Epidemiol Infect 1994;112:315–28.
17. Fischer M, Hedberg K, Cardosi P, et al. Tobacco smoke as a risk factor for meningococcal disease. Pediatr Infect Dis J 1997;16:979–83.

18. Stuart J, Cartwright K, Dawson A, et al. Risk factors for meningococcal disease: a case control study in south west England. Community Med 1988;10:139–46.
19. Caugant DA, Hoiby EA, Magnus P, et al. Asymptomatic carriage *of Neisseria meningitidis* in a randomly sampled population. J Clin Microbiol 1994;32:323–30.
20. Cartwright KAV, Stuart JM, Jones DM, Noah ND. The Stonehouse survey: nasopharyngeal carriage of meningococci and *Neisseria lactamica*. Epidemiol Infect 1987;99:591–601.
21. Broome CV. The carrier state: *Neisseria meningitidis*. J Antimicrob Chemother 1986;18(Suppl A):25–34.
22. Kaiser AB, Hennekens CH, Saslaw MS, Hayes PS, Bennett JV. Seroepidemiology and chemoprophylaxis of disease due to sulfonamide resistant *Neisseria meningitidis* in a civilian population. J Infect Dis 1974;130:217–24.
23. Statistics New Zealand. New Zealand now, housing. Wellington: Statistics New Zealand, 1998.
24. Denny FW. The clinical impact of human respiratory virus infections. Am J Respir Crit Care Med 1995;152:S4–12.
25. Aaby P, Bukh J, Lisse IM, Smits AJ. Overcrowding and intensive exposure as determinants of measles mortality. Am J Epidemiol 1984;120:49–63.
26. Brimblecombe FS, Cruickshank PL, Masters PL, Stewart GT, Sanderson D. Family studies of respiratory infections. Br Med J 1958;1:119–28.
27. Haneberg B, Tonjum T, Rodahl K, Gedde-Dahl TW. Factors preceding the onset of meningococcal disease with special emphasis on passive smoking, stressful events, physical fitness and general symptoms of ill health. NIPH Ann 1983;6: 169–74.
28. Cartwright KAV, Jones DM, Smith AJ, et al. Influenza A and meningococcal disease. Lancet 1991;338:334–57.
29. Yusuf HR, Rochat RW, Baughman WS, et al. Maternal cigarette smoking and invasive meningococcal disease: a cohort study among young children in metropolitan Atlanta, 1989–96. Am J Public Health 1999;89:712–17.
30. Imrey PB, Jackson LA, Ludwinski PH, et al. Outbreak of serogroup C meningococcal disease associated with campus bar patronage. Am J Epidemiol 1996;143:624–30.
31. Munford RS, Taunay ADE, Morais JSD, Fraser DW, Feldman RA. Spread of meningococcal infections in households. Lancet 1974;1:1275.
32. Openshaw PJM. When we sneeze does the immune system catch a cold? BMJ 1991;303:935–6.

Pediatr Infect Dis J, 2000;19:990–5

Vol. 19, No. 10
Printed in U.S.A.

Predictors of infectious complications after burn injuries in children

GAIL L. RODGERS, MD, JOEL MORTENSEN, PHD, MARGARET C. FISHER, MD, ADRIAN LO, MD, ADRIENNE CRESSWELL, MD AND SARAH S. LONG, MD

Background. **Infections are the major life-threatening complication of burn injury and occur with the greatest frequency in children. Knowledge of their occurrence and management, however, is extrapolated from studies in adults. We performed a prospective study of infectious complications in burned children.**

Objective. **To delineate epidemiology, risk factors and microbiology of infections in burned children where burn care and surgical interventions are optimal.**

Methods. **Children hospitalized for burns were entered into prospective study. Characteristics of the burn injury were assessed, and active surveillance for infections was performed.**

Results. **Seventy patients were entered [mean age, 42 months; mean total body surface area (TBSA), burn 15%]. Twenty-seven percent of patients developed 39 infections: 13 involved the burn wound (burn wound sepsis, 6; graft loss, 5; and cellulitis, 2); 13 were catheter-associated septicemia; 13 involved other sites (i.e. pneumonia, 4; urinary tract infection, 3; bacteremia, 2; endocarditis, 1; myocardial abscess, 1; toxin-mediated syndrome, 1; and otitis media, 1). Twenty-three infections were caused by a single organism, 9 infections by more than 1 organism and in 7 infections defined by CDC criteria no organism was recovered. Organisms causing infection were: *Staphylococcus aureus*, 19; *Candida albicans*, 4; *Pseudomonas aeruginosa*, 4; coagulase-negative *Staphylococcus*, 4; *Enterococcus* sp., 3; *Escherichia coli*, 1; *Klebsiella oxytoca*, 1; *Serratia marcescens*, 1; *Streptococcus pneumoniae*, 1;**

Accepted for publication June 27, 2000.
From the Section of Infectious Disease, St. Christopher's Hospital for Children (GLR, MCF, SSL); the Departments of Pediatrics (GLR, MCF, SSL), Pathology (JM) and Plastic Surgery (AC), MCP Hahnemann School of Medicine; and the Pennsylvania Center for Plastic Surgery (AL), Philadelphia, PA.
This work was presented in part at the Pediatric Academic Societies' 1998 Annual Meeting, held May 1 to 5 in New Orleans, LA.
Key words: Burn injury, infections.
Reprints not available.