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PREFACE

The International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) is an autonomous, international, philanthropic and non-profit centre for research, education and training as well as clinical service. The Centre is derived from the Cholera Research Laboratory (CRL). The activities of the institution are to undertake and promote study, research and dissemination of knowledge in diarrhoeal diseases and directly related subjects of nutrition and fertility with a view to develop improved methods of health care and for the prevention and control of diarrhoeal diseases and improvement of public health programmes with special relevance to developing countries. ICDDR,B issues two types of papers: scientific reports and working papers which demonstrate the type of research activity currently in progress at ICDDR,B. The views expressed in these papers are those of authors and do not necessarily represent views of International Centre for Diarrhoeal Disease Research, Bangladesh. They should not be quoted without the permission of the authors.

ABSTRACT

To assess the mode of transmission of *Shigella* infection in rural Bangladesh, questionnaire and culture surveys were conducted in baris (neighbourhoods) where persons with diarrhoea associated with *Shigella* infection and index controls with non-*Shigella* diarrhoea lived. Nineteen percent of persons in *Shigella* baris and 7 percent of persons in control baris were infected during the survey periods ($p<.001$). The prevalence of *Shigella* infection was highest for children 1-9 years of age and for females older than 39 years and was not related to socioeconomic status, family size or household crowding. Use of surface water for drinking was not a risk factor for *Shigella* infection; in fact, use of river water was more frequent in control baris.

Both household and bari contacts of *Shigella* index cases frequently excreted different serotypes from that excreted by the person with the index case. In *shigella* baris, families with
infection were significantly more likely than uninfected families 1
to have a history of an overnight stay away from home by a family member during the previous week. These observations suggest there were multiple introductions of *Shigella* into some families and that the epidemiology of *Shigella* infection for families in rural Bangladesh differs from that observed for families living in more industralized countries.

INTRODUCTION

In most developing countries, diarrhoeal diseases cause considerable morbidity and mortality, especially in infants and children (1,2). In many countries, much of the diarrhoeal illness of known etiology results from *Shigella* infection in children living in crowded areas with limited water availability and poor sanitation (3-5).

Shigellosis emerged as a major diarrhoeal disease problem in Bangladesh following the 1971 war of independence (6). In 1972 and 1973, surveillance at the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B, formerly the Cholera Research Laboratory) in Dacca revealed that 15% to 30% of cases of diarrhoea in the Dacca urban area in the non-cholera season were associated with *Shigella* infection. Subsequent studies in rural Bangladesh identified *Shigella* as the third most frequent etiologic agent in stools of children 2-9 years of age seen at a treatment centre (7) and as the second most frequent etiologic agent in children with diarrhoea in the same age group studied longitudinally in their village for 1 year (8). Because little information is available on the epidemiology of *Shigella* infection in rural areas of Bangladesh, an investigation was conducted in villages in Matlab Thana, approximately 30 miles southeast of Dacca. The epidemiology of *Shigella* infection affecting families in rural Bangladesh differed in several respects from the pattern of *Shigella* infection in families living in more industrialized countries.

MATERIALS AND METHODS

The study was conducted in the ICDDR,B vaccine trial survey (VTS) area; the 234 villages in the area were served by a central diarrhoea hospital in Matlab Bazar (9).

Outpatients or hospitalized persons who had a stool culture positive for *Shigella* during a 6-week period in February or March 1974 served as *Shigella* index patients. If more than 1 patient met these criteria on 1 day, a random number table was used to select 1 index patient. Outpatients or hospitalized persons who had a rectal swab culture negative for shigellae, salmonellae, and vibrios were selected as index controls using a random number table. Surveys were initiated with 48 hours of arrival of the *Shigella* patients and index controls at the hospital.

A pretested questionnaire administered by Bengali-speaking field workers was used to record family census data, type of water sources, and their use for drinking and bathing by all families in *Shigella* and control baris (clusters of homes of patrilineally related families). Household crowding was expressed both as the number of persons per sleeping room and as the number of square feet of dwelling per person. A socioeconomic score was calculated for each family using housing construction, availability of adequate kitchen facilities and food supplies, farm equipment, boat ownership, number of livestock and percentage of eligible children enrolled in school. A separate socioeconomic score, based on criteria defined for the VTS area 1974 census (10), was also calculated. The number of overnight trips taken by family members in the week preceding the questionnaire survey was recorded.

Each person in a study bari was questioned for 10 consecutive days about the occurrence of dysentery, diarrhoea or loose stools during the previous 24 hours. An adult family member responded for young children. Respondents were included in the questionnaire survey tabulations if they answered questions on 5 or more days.

Rectal swabs obtained from all available bari members on each of the 10 survey days were streaked directly on MacConkey and Salmonella-Shigella (SS) agars in the bari. Plates were transported to the laboratory and incubated overnight at 37°C. One or 2 non-lactose-fermenting colonies per plate were identified and serotyped using standard techniques (11). Persons were included in the culture survey tabulations if 5 or more cultures were obtained or at least one culture was positive for *Shigella*.

Results were analyzed using the chi-square, Fisher's exact, median, and unpaired Student's t tests.

RESULTS

Seven *Shigella* index patients and 8 index controls were selected. The median ages of *Shigella* patients and index controls (5 years and 1.5 years, respectively) were not significantly different. One hundred ninety-two (75%) of the 257 persons in the 39 families in *Shigella* baris and 213 (80%) of the 267 persons in the 43 families in control baris were included in the questionnaire survey; 170 (66%) persons in *Shigella* baris and 184 (69%) in control baris were included in the culture survey.

Thirty-three (19%) persons in *Shigella* baris and 13 (7%) persons in control baris had 1 or more positive cultures for *Shigella* ($p<.001$). For *Shigella* and control baris combined, the infection rate was 13%. Of the 46 persons with *Shigella* infection identified in the field studies, 15 (32%) had normal bowel habits. Age-specific prevalence rates were highest for persons 1-4 years old (22%), 5-9 years old (15%), and those older than 39 years (15%) (Table I). Only 1 (4%) of 27 children less than 1 year old was infected. Females 40 years of age and older were more likely than males to be infected; however, the age- and sex-specific prevalence rates for males and females were not significantly different.

The prevalence of *Shigella* infection for members of *Shigella* index families (6 of 36 or 17%) was similar to the rate for control index families (5 of 40 or 13%). Though the number of index cases was small, the age of the index patient had no effect on the infection rate for household contacts.

Four (57%) of the *Shigella* index families had 2 or more infected members. In 3 of these 4 *Shigella* index families, infected household contacts excreted a different *Shigella* serotype from that excreted by the index patient (Table 2).

The prevalence of *Shigella* infection among *Shigella* bari contacts (27/134 or 20%) was significantly higher than that among control bari contacts (8/144 or 5%) ($p<.001$). Sixteen (50%) of the 32 *Shigella* bari contact families and 9 (26%) of the 35 control bari contact families had one or more infected members ($p<.05$). In both *Shigella* and control baris, infected bari contacts often excreted different *Shigella* serotypes from those excreted by the index patient and index family members (Table II).

The age distribution was similar for families of different sizes and different socioeconomic status in both *Shigella* and control baris. There was no association between family size or socioeconomic status and prevalence of *Shigella* infection. When the average number of persons per sleeping room was used as an index of household crowding, there was an inverse correlation between infection and crowding ($r=-0.83$). However, when crowding was expressed as the number of square feet of dwelling space per person, there was no significant association between infection and crowding.

Analysis of water source utilization by *Shigella* and control bari families revealed that the availability of water sources (drilled wells with pumps (tube wells), manmade ponds (tanks), ditches, canals, and rivers] was similar for *Shigella* and control baris with one exception; rivers were more often present in or near control baris. The only significant difference in water-source-utilization patterns in *Shigella* and control baris was that rivers

TABLE I--*SHIGELLA* INFECTIONS* BY AGE AND SEX, *SHIGELLA* AND CONTROL BARIS COMBINED, BANGLADESH

Age (yrs)	Males			Females			Total		
	No. Cultured	No. Positive	% Positive	No. Cultured	No. Positive	% Positive	No. Cultured	No. Positive	% Positive
<1	12	1	8	15	0	0	27	1	4
1-4	36	6	17	23	7	30	59	13	22
5-9	41	8	20	32	3	9	73	11	15
10-19	24	4	17	53	3	6	77	7	9
20-39	13	4	31	53	2	4	66	6	9
≥40	8	0	0	44	8	18	52	8	15
Total	134	23	17	220	23	10	354	46	13

* Index cases excluded.

TABLE II—*SHIGELLA* SEROTYPES RECOVERED FROM INDEX PATIENTS, HOUSEHOLD CONTACTS, AND BARI CONTACTS IN *SHIGELLA* AND CONTROL BARIS

Bari	Serotype from Index Patient	Serotype(s) from Household Members (No. of Persons)		Serotype(s) from other Bari Members (No. of Persons)	
Shigella 1	*S.boydii* 11			*S.flexneri* 1	(3)
				S.flexneri 6	(1)
Shigella 2	*S.flexneri* 2	*S.flexneri* 1	(1)	*S.sonnei*	(1)
Shigella 3	*S.dysenteriae* 9	*S.flexneri* 1	(1)	*S.flexneri* 1	(4)
		S.flexneri 3	(1)	*S.flexneri* 2	(2)
		S.boydii 12 and *S.flexneri* 1	(1)	*S.boydii* 4	(1)
				S.boydii 15	(1)
Shigella 4	*S.boydii* 5	*S.boydii* 5	(1)	*S.flexneri* 1	(1)
				S.boydii 5	(2)
				S.sonnei	(1)
Shigella 5	*S.sonnei* and *S.flexneri* 3			*S.flexneri* 1	(1)
				S.sonnei	(2)
				S.dysenteriae 2	(1)
Shigella 6	*S.flexneri* 3	*S.flexneri* 2	(1)	N.A.*	
Shigella 7	*S.flexneri* 2			*S.flexneri* 2	(1)
				S.flexneri 4 and *S.dysenteriae* 2	(2)
				S.boydii 1	(1)
				S.boydii 11	(1)
				S.boydii 15	(1)

contd. .../7/

* N.A. = Not applicable. Only single family cultured.

TABLE II (contd.)

Bari	Serotype from Index Patient	Serotype(s) from Household Members (No. of Persons)		Serotype(s) from other Bari Members (No. of Persons)	
Control 1		*S. sonnei*	(2)	*S. sonnei* *S. flexneri* 5	(2) (1)
Control 2		*S. flexneri* 3	(1)	*S. flexneri* 1 *S. flexneri* 3 *S. sonnei* *S. dysenteriae* 2	(1) (1) (1) (1)
Control 3		*S. boydii* 12	(1)		
Control 4		*S. flexneri* 2	(1)		
Control 5	*S. flexneri* 4†				
Control 6				*S. flexneri* 2	(1)
Control 7					
Control 8				N.A.*	

† Recovered from a stool culture obtained 10 days after return to bari; 9 preceding daily rectal swab cultures were negative.

*N.A. = Not applicable. Only single family cultured.

were used as a source of drinking water more frequently by families in control baris. The frequency of use of tube-well water for drinking was similar for infected and noninfected families in both *Shigella* and control baris. There was no significant difference in the infection rate for individuals using only tube-well water for drinking and individuals using surface water sources for drinking (16% and 12%, respectively).

For persons with or without a recent overnight trip, the prevalence of *Shigella* infection was the same (22%) in *Shigella* baris and similar (4% and 5%, respectively) in control baris after exclusion of index families. However, in *Shigella* baris, 94% of infected families but only 62% of uninfected families (p=.04) had a history of overnight travel by 1 or more family members during the previous week.

DISCUSSION

This study was conducted during a 6-week period in the dry winter season in Matlab. Two-thirds of *Shigella* and control bari residents participated in the 10-day culture surveys. When interpreting the data from control baris, it must be acknowledged that some of the control index cases may have had *Shigella* infection at the time of initiation of the study since only 1 rectal swab was collected at the hospital. In spite of these limitations, the data suggest that the epidemiology of shigellosis in this environment is more complex than in the United States.

The prevalence of *Shigella* infection for persons residing in villages in rural Bangladesh (13%) was appreciably higher than rates found in field studies of shigellosis in Central America (12) and the United States (13). The age distribution of persons with *Shigella* infection in our study is similar to that observed in field studies of *S. dysenteriae* type 1 infection in Dacca (14) and in Central America (15) with children 1-9 years old at highest risk and similar to observations of *Shigella* species infection in Dacca, where the infection was the most prevalent for children less than 5 years old (16). Only 1 child less than 1 year of age was infected, a finding that may be related to a protective effect of breast feeding or limited exposure to contaminated foods and water sources (17). In contrast, studies of *Shigella* infection in an urban area of Bangladesh (16) and in the United States (18) have shown higher infection rates for children less than 1 year old. Further epidemiologic studies are required to determine the factors responsible for the rarity of infection in infants in rural Bangladesh.

As expected, the prevalence of shigellosis was significantly greater in *Shigella* baris than in control baris. Since *Shigella* infection was not more common for *Shigella* index families than for control index families, the increased prevalence of infection in *Shigella* baris can be attributed to the higher prevalence in bari contact families. The factors responsible for these higher rates were not identified. However, since bari contacts often excreted different serotypes from those excreted by the index patient or index family, it is unlikely that direct spread from index families to other bari residents accounted for most of the infections.

In 3 of 4 *Shigella* index families with multiple infected members, infected contacts excreted a different *Shigella* serotype than that excreted by the index patient. This characteristic of endemic *Shigella* infection in rural Bangladesh is in contrast with the situation in the United States, where *Shigella* infection is often characterized by the person-to-person spread of a single serotype among family members that leads to high attack rates for household contacts of *Shigella* index patients (19-21), and suggests that person-to-person spread was not the most important mode of transmission in Matlab.

In the United States, secondary attack rates are often higher for family members exposed to index patients less than 5 years old (19). In Dacca, secondary infection rates were highest in *S.dysenteriae* and *S.flexneri* index families when the index case was a female $\geq$10 years of age (22). In our study the number of index cases was small, but the age of *Shigella* index patients had no effect on the frequency with which household contacts had *Shigella* infection.

In this study, the prevalence of shigellosis seemed unrelated to family size or household crowding expressed as number of square feet of dwelling per person. Similarly, in family studies of *S.dysenteriae* and *S.flexneri* infection in Dacca, the attack rate was not higher in more crowded households (22). Mosley *et al.* reported that *Shigella* infection in the United States correlated with household crowding (21), but two more recent studies of shigellosis in urban areas in the United States did not demonstrate this correlation (19,20).

Infection rates were highest for bari contact families with high socioeconomic status; in contrast, attack rates were highest in families with the lowest income in the study of *S.dysenteriae* and *S.flexneri* infection in Dacca (22). In studies of endemic and epidemic shigellosis in the United States, attack rates were highest for families with low socioeconomic status (13,18,20,21), possibly because of poor personal hygiene or sanitation, poor quality or limited availability of water, or household crowding.

The higher frequency of overnight travel outside the bari among members of infected families in *Shigella* baris suggests that individuals may frequently acquire infection away from home. Multiple introductions into the bari apparently occur. The manner in which some of these organisms then spread to other bari members was not defined, but waterborne and foodborne transmission may both be important.

Rural Bangladeshis frequently defecate on the banks of tanks, canals, and rivers (10). Since no water-treatment facilities are available, surface water is frequently contaminated with feces. Waterborne transmission of *Shigella* may have occurred in this study; however, in contrast with results of the study of *S.dysenteriae* type 1 infections in Dacca, which showed that attack rates were highest for contacts of index patients who used water from unprotected sources for drinking (14), there was no association between infection and use of surface water for drinking. In fact, river water was used for drinking more frequently by families in control than in *Shigella* baris; in contrast, observations in rural Bangladesh indicate that use of river and canal water is a risk factor for *V.cholerae* infection (23,24). Rivers may be less likely than other surface water to be contaminated by *Shigella*. Use of tube-well water for drinking did not protect individuals from infection.

Shigellosis has been classified as a water-washed infection, that is, one that is common in areas where water availability for use for personal hygiene is limited (25). We did not assess water utilization quantitatively, but the multiplicity of serotypes suggests that *Shigella* infection may not be transmitted primarily from person-to-person by the fecal-oral route in the bari.

In industralized countries, foodborne shigellosis is characterized by common source outbreaks with high attack rates for individuals who have ingested contaminated foods that have not been properly handled (26). In rural Bangladesh, where personal hygiene is frequently not optimal and there are no facilities for refrigerating food, foodborne transmission of *Shigella* may also occur. Further studies of the relative importance of contaminated food, water, and person-to-person transmission of *Shigella* infection in Bangladesh are warranted in order that measures to interrupt transmission can be taken.

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