

PREVALENCE OF *CRYPTOSPORIDIUM PARVUM* INFECTION IN CHILDREN ALONG THE TEXAS-MEXICO BORDER AND ASSOCIATED RISK FACTORS

CHARLES T. LEACH, FELIX C. KOO, THOMAS L. KUHL, SUSAN G. HILSENBECK, AND HAL B. JENSON
Departments of Pediatrics, Microbiology, and Medicine, University of Texas Health Science Center at San Antonio, San Antonio, Texas; Department of Pediatrics, The University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma

Abstract. We examined the epidemiology of *Cryptosporidium parvum* in children aged 6 months to 13 years living in 1) colonias along the border (n = 105), 2) a clinic in an urban border community (n = 65), and 3) clinics in a large urban nonborder area (n = 109). Serum IgG and IgA anticryptosporidial antibodies were measured by enzyme-linked immunosorbent assay (ELISA). Overall, 70.2% (196/279) of subjects had detectable *C. parvum* antibodies. Prevalence rates were higher (93/105 [89%]) in the colonias and urban border community (53/65 [82%]) compared to the urban nonborder community (50/109 [46%]). Within colonias, independent risk factors for *C. parvum* infection included consumption of municipal water instead of bottled water, older age, and lower household income. Children living along the Texas-Mexico border have a higher rate of infection with *C. parvum* compared to children living in a large nonborder urban area. Within colonias, *C. parvum* infection was associated with source of water supply, age, and socioeconomic status.

INTRODUCTION

Cryptosporidiosis is an enteric infection caused by fecal-oral spread of the intestinal parasite *Cryptosporidium parvum*. Disease is typically mild in healthy persons, but can be severe in patients who are immunocompromised, such as those with acquired immune deficiency syndrome (AIDS).¹

Cryptosporidiosis is endemic in developing countries, such as Mexico, as a result of poor sanitation and crowded living conditions.² Recent large outbreaks in several communities in the United States highlight the importance of cryptosporidiosis as a major public health problem.³ Forty-three counties in Texas are contiguous or are within 150 miles of the border with Mexico. More than 340,000 persons in these counties live in an estimated 1,500 communities known as colonias.⁴ Colonias are rural and unincorporated subdivisions along the U.S.-Mexico border characterized by substandard housing, inadequate plumbing and sewage disposal, inadequate access to drinking water, poor drainage, and substandard sanitation.⁵

Characterization of the epidemiology of cryptosporidiosis may identify geographic and sociodemographic risk factors that may globally contribute to waterborne disease. The prevalence of *C. parvum* in children living in colonias along the Texas-Mexico border was compared to children living in border and nonborder urban areas of south Texas.

MATERIALS AND METHODS

Study population. Three study sites were used for enrollment in 1996 and 1997: 1) seven colonias located 2–15 miles from the Texas-Mexico border in Hidalgo County, Texas, where on-site well-child clinics were conducted on a weekly basis by one of the investigators; 2) a general pediatric clinic in McAllen, Texas, 10 miles from the border, serving children from small and medium-sized border communities in Texas; and 3) two general pediatric clinics in San Antonio, Texas, located 225 miles from McAllen, Texas. Parents or guardians of children age 6 months to 13 years seeking well-child care were asked to allow their child to participate. Informed consent was obtained from the parent

or guardian of all patients. This study was approved by the Institutional Review Board at the University of Texas Health Science Center at San Antonio. After obtaining informed consent from a parent or legal guardian of the child, a questionnaire was completed by the parent/guardian and blood was collected from the child. The human experimentation guidelines of the U.S. Department of Health and Human Services and the University of Texas Health Science Center at San Antonio were followed.

***Cryptosporidium parvum* antibodies.** IgG and IgA cryptosporidial antibodies were measured using an enzyme-linked immunosorbent assay (ELISA) method adapted from that described by Brannan and others.⁶ The sensitivity and specificity of this test for *C. parvum* has been previously established.⁷ Purified sonicated oocysts were diluted to 5x10⁶/mL in carbonate buffer (pH 9.6) and 100 µL was added to each well of a 96-well ELISA plate (Nunc, Waperville, IL). The plate was incubated at 4°C for 18–36 hours and then washed 3 times with 0.05% Tween 20 in phosphate-buffered saline (PBS). To block, the plate was incubated at 37°C for 1 hour with 100 µL of 1% bovine serum albumin in each well. After washing as before, 200 µL of a 1:20 dilution (in a 1% solution of bovine serum albumin [BSA] in PBS) of the serum was added to each well and incubated at 37°C for 1 hour. The plate was washed as before, then incubated with 100 µL of a 1:150 dilution (in 1% BSA/PBS) alkaline phosphatase-conjugated goat antibodies to human IgA or IgG (Sigma, St. Louis, MO) at 37°C for 1 hour. After washing, color was developed by adding 100 µL of 0.4 mg/mL p-nitrophenyl phosphate (Sigma) in 10% diethanolamine in PBS. The amount of substrate hydrolysis was measured as the absorbance at 410 nm using an automated microplate reader (Dynatech Laboratories Inc., Chantilly, VA).

Negative controls included sera from two young children (ages 6 months and 1 year) who were repeatedly negative for anticryptosporidial antibodies. Sera from two adults with recent cryptosporidial disease were used as positive controls. All patient samples were tested in duplicate. An ELISA assay was considered valid if both positive controls displayed an absorbance that was at least 2 standard deviations above the mean absorbance of the negative controls. No assays

TABLE 1

Demographic and environmental characteristics of participants from colonias, an urban border community, and an urban nonborder community (San Antonio)*

Characteristic	All sites (n = 279)	Colonias (n = 105)	Urban border communities (n = 65)	San Antonio (n = 109)	P-value between groups†
	Mean (SE)				
Age (yr)	7.1 (0.2)	7.1 (0.4)	8.8 (0.3)	96.2 (0.4)	<0.001
Maternal age (yr)	32.0 (0.4)	30.9 (0.5)	35.6 (0.9)	30.7 (0.7)	<0.001
Maternal education					
Primary (yr)	7.0 (0.1)	6.5 (0.2)	7.1 (0.2)	7.4 (0.2)	0.002
Secondary (yr)	2.2 (0.1)	1.2 (0.2)	2.5 (0.2)	3.0 (0.2)	<0.001
Total (yr)	9.2 (0.2)	7.6 (0.3)	9.6 (0.4)	10.4 (0.3)	<0.001
Persons in household	5.3 (0.1)	6.1 (0.2)	5.2 (0.2)	4.7 (0.1)	<0.001
No. of cities of residence	1.8 (0.1)	2.2 (0.1)	2.2 (0.1)	1.3 (0.1)	<0.001
	No. (%)				
Ethnicity					<0.001
Hispanic	249 (89.2)	104 (99.0)	62 (95.4)	83 (76.1)	
Anglo	8 (2.9)	1 (1.0)		7 (6.4)	
Black	7 (2.5)			7 (6.4)	
Asian	1 (0.4)			1 (0.9)	
Multiracial	14 (5.0)		3 (4.6)	11 (10.1)	
Born in Mexico	48 (17.3)	25 (23.8)	20 (30.8)	3 (2.8)‡	<0.001
Resided in developing country	58 (2.1)	26 (24.8)	28 (43.1)	4 (3.7)‡	<0.001
Day care attendance	15 (5.4)	6 (5.7)	1 (1.5)§	8 (7.3)	0.26
School attendance	193 (69.4)	72 (68.6)	60 (92.3)	61 (56.5)	<0.001
Monthly household income					0.003
<\$250	32 (11.5)	16 (15.2)	7 (10.8)	9 (8.3)	
\$250–499	49 (17.6)	23 (21.9)	13 (20.0)	13 (11.9)	
\$500–749	57 (20.4)	26 (24.8)	14 (21.5)	17 (15.6)	
\$750–999	50 (17.9)	23 (21.9)	11 (16.9)	16 (14.7)	
\$1,000–1,499	59 (21.1)	17 (16.2)	16 (24.6)	26 (23.9)	
\$1,500–2,000	13 (4.7)		3 (4.6)	10 (9.2)	
>\$2,000	6 (2.2)			6 (5.5)	
No response	13 (4.7)		1 (1.5)	12 (11.0)	
Source of water					<0.001
Bottled	121 (43.4)	66 (62.9)	38 (58.5)	17 (15.6)	
Municipal	128 (45.9)	39 (37.1)	13 (20.0)	76 (69.7)	
Spring or well	15 (5.4)		9 (13.8)	6 (5.5)	
No response	15 (5.4)		5 (7.7)	10 (9.2)	
Sanitary facility					0.001
Flush toilet	270 (96.8)	98 (93.3)	65 (100)	107 (98.2)	
Pit toilet/outhouse	8 (2.9)	7 (6.7)		1 (0.9)	
No response	1 (0.4)			1 (0.9)	
Breastfed	148 (53.0)	67 (63.8)	41 (63.1)§	40 (36.7)	<0.001
Contact with any farm animal	86 (30.8)	62 (59.1)	14 (21.5)	10 (9.2)	<0.001

* OR = Odds ratio; CI = Confidence Interval; SE = standard error; ND = not done.

† Chi-square test was used for categorical variables; one-way analysis of variance used for continuous variables.

‡ No response from 2 subjects.

§ No response from 1 subject.

were invalid. A sample was considered positive if the mean absorbance was at least 2 standard deviations above the mean absorbance of the negative controls.

Questionnaires. Information elicited by the questionnaires included demographics, maternal education, household income, number of persons in household, number of cities of residence, primary source of drinking water (bot-

tled, municipal, or springs/wells), sanitation facilities (flush toilet or pit toilet/outhouse), breastfeeding history, past and current day care and school attendance, and recent exposure to pets or farm animals. Questionnaires were completed by the research nurse or by the parent or guardian under the supervision of the research nurse.

Statistical analysis. Demographic and environmental characteristics were compared across study sites using chi-square tests for independence for categorical variables, and one-way analysis of variance for continuous variables to identify imbalances in possible risk factors that might contribute to the site-specific differences in prevalence. Associations between seroprevalence and explanatory variables were examined by univariate logistic regression analysis. Odds Ratios (OR) and 95% confidence intervals (CI) were estimated from the regression coefficients and their associated standard errors. Categorical explanatory variables were

TABLE 2

Prevalence of anti-*Cryptosporidium* antibodies in children age 6 months to 13 years in south Texas

Site	No. positive/no. tested (%)*
Colonias	93/105 (88.6)
Urban border community	53/65 (81.5)
San Antonio	50/109 (45.9)
All sites	196/279 (70.2)

* P < 0.05 (Chi-square) for colonias and urban border community versus San Antonio.

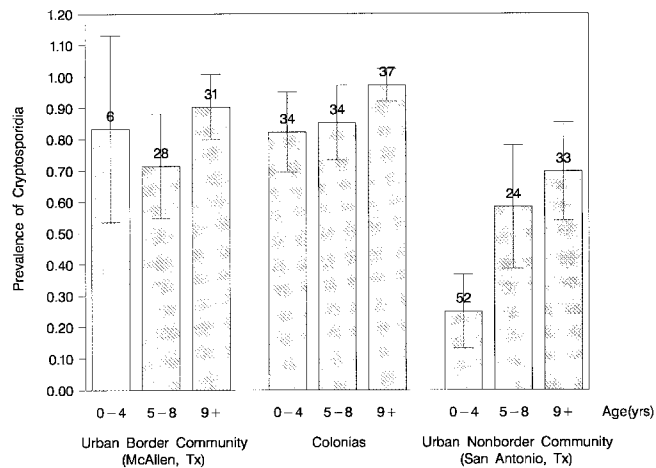


FIGURE 1. Prevalence in children living in Texas according to site and age. Error bars represent the mean \pm 1.96 \times standard error.

either dichotomous and treated as dummy variables, or ordinal and treated as integer-valued variables. Goodness-of-fit was verified using the Hosmer-Lemeshow test for goodness-of-fit.⁸ Stepwise multiple logistic regression was used to identify independent predictors of infection, and summarized as above. Goodness-of-fit was again verified by the Hosmer-Lemeshow test. All statistical tests were two-sided using the 0.05 level of significance. Analyses were performed using SAS (Version 6.11, Cary, NC).

RESULTS

A total of 285 subjects (Table 1) were enrolled at the three study sites: 1) the colonias (n = 105), 2) an urban border community (McAllen, Texas) (n = 65), and 3) an urban nonborder community (San Antonio, Texas) (n = 115). Hispanics predominated in all 3 groups (89.2% overall). These groups differed with respect to mean age of child and mother, socioeconomic status, average size of the households,

school attendance, water supply, sanitary facilities, history of breastfeeding, and contact with farm animals.

Prevalence of *C. parvum*. IgG or IgA anti-cryptosporidial antibodies were detected in 196 (70.2%) of children overall (Table 2). Antibody prevalence was higher in children living in colonias (93 of 105; 88.6%) and the urban border community (53 of 65; 81.5%) compared to children living in San Antonio (50 of 109; 45.9%) ($P < 0.05$). An age-related increase in antibody prevalence was observed for patients from the colonias and San Antonio, but not for those residing in the urban border community (Figure 1). The lower sample size and higher prevalence observed for children aged 0–4 years from the urban border community likely precluded a similar statistically significant trend in this cohort.

Risk factors for *C. parvum* infection. Multiple plausible risk factors for *C. parvum* infection were examined first by univariate logistic regression analysis, and then by stepwise multiple logistic regression, to reduce the effects of socio-demographic differences in the populations (Table 3). Initially, subjects from all 3 sites were included. Variables found to be significant in the univariate analysis included residence in a colonia or urban border community, older age, lower household income, less secondary maternal education, school attendance, increased size of household, increased number of cities of residence, and exposure to farm animals. Stepwise logistic regression of the entire cohort identified three independent risk factors for *C. parvum* infection: residence in a colonia, residence in the urban border community, and older age in the child. There were too few instances of use of pit toilets/outhouses (8/285) or day care attendance of the child (15/285) to determine the independent risk of these factors.

Because of the strong independent risk for children living in colonias, as well as their unique living environment, children from colonias were examined separately for risk factors for *C. parvum* infection. By univariate analysis, only increased age and lower household income were associated with infection in these children. However, multivariate analysis identified three factors independently associated with

TABLE 3
Risk factors for *Cryptosporidium parvum* seropositivity in children age 6 months–13 years residing in South Texas*

Risk factor	All sites				Colonias			
	Univariate analysis (N = 285)		Multivariate analysis† (N = 241)		Univariate analysis (N = 104)		Multivariate analysis† (N = 104)	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Living in colonia‡	5.34	2.73–10.47	9.67	4.54–20.6	NA		NA	
Living in urban border community‡	2.19	1.10–4.3	4.02	1.77–9.15	NA		NA	
Age of child§	1.21	1.12–1.30	1.16	1.07–1.27	1.21	1.0–1.47	1.29	1.05–1.58
Municipal water source‡	0.71	0.43–1.19	NS		7.6	0.94–61.3	10.1	1.10–92.8
Household income¶	0.79	0.66–0.94	NS		0.55	0.32–0.94	0.47	0.27–0.82
Secondary education (mother)§	0.78	0.67–0.90	NS		1.07	0.73–1.56	NS	
Breastfed‡	1.43	0.85–2.39	NS		1.91	0.57–6.39	NS	
Maternal age§	1.03	0.99–1.07	NS		0.95	0.84–1.07	NS	
Primary education (mother)§	0.90	0.77–1.05	NS		1.25	0.96–1.64	NS	
School attendance by child‡	3.46	2.0–5.97	NS		1.66	0.49–5.67	NS	
Persons in household§	1.24	1.05–1.47	NS		1.05	0.76–1.44	NS	
Number of cities of residence§	1.96	1.39–2.75	NS		1.47	0.78–2.78	NS	
Exposure to any farm animals‡	2.58	1.37–4.84	NS		0.44	0.11–1.74	NS	

* NA = not applicable; NS = not significant.

† By stepwise logistic regression. All variables with univariate $p < 0.05$ with significant diversity were considered for the model.

‡ Risk associated with factor relative to not having factor.

§ Risk associated with an additional unit (e.g., year of age, person in household, etc.).

¶ Risk for an income level relative to the preceding income level (see Table 1).

TABLE 4
Seroprevalence of *Cryptosporidium parvum* in persons from various countries*

Country	Description of population	% Prevalence (no. positive/ no. tested)
Australia ¹⁷	Healthy children and adolescents (age 0–16 yr)	10.3 (38/369)
	Healthy adults	7.6 (6/79)
Brazil ¹³	Random children (age 0–4 yr) in rural village	75 (30/40)
China ¹³	Random children in 3 rural villages	49.5 (302/610)
	Age 0–4 yr	32.0 (184/225)
	Age 5–7 yr	54.4 (74/136)
	Age 8–16 yr	62.6 (156/249)
France ¹⁸	Random adults in 3 rural villages	50.0 (18/36)
	Healthy adults	64 (ND)
Germany ¹⁹	Healthy children, adolescents, and adults	15.5 (71/458)
	Age 0–5 yr	17.8 (15/84)
	Age 6–15 yr	11.5 (14/122)
	Age ≥ 16 yr	16.7 (42/252)
Papua New Guinea ¹⁷	Healthy children, age 0–7 yr	16.1 (38/205)
Peru ¹⁶	Random population	64.0 (249/389)
	Age 0–9 yr	62.1 (159/256)
	Age 10–19 yr	64.0 (32/50)
	Age ≥ 20 yr	69.9 (58/83)
Romania ⁶	Hospitalized or institutionalized children, age 12–52 months†	72.8 (67/92)
Scotland ²⁰	Blood donors	85.7 (18/21)
Thailand ²¹	Healthy infants and children, age 1–61 months	89.5 (17/19)
United States ²²	Healthy hospital workers	16.6 (3/18)
United States ¹⁵	Adult volunteers	35.0 (7/20)
United States ²³	Peace Corps volunteers‡	32.0 (24/75)
United States ²⁴	Dairy farmers	44.3 (31/70)
United States ²⁴	Nondairy farmers	24.0 (12/50)
United States ¹³	Hospitalized children	12.8 (ND)
United States ⁷	Healthy children, adolescents, and adults	31.1 (250/803)
	Age 0–4 yr	13.0 (49/378)
	Age 5–13 yr	37.8 (86/228)
	Age 14–21 yr	58.4 (115/197)
United States ²⁵	Blood donors	15.5 (59/380)
Venezuela ¹⁶	Random children	64.3 (54/84)
	Age 0–3 yr	61.5 (32/52)
	Age 4–6 yr	68.8 (22/32)

* ND = no data; yr = Age in years.

† 79% were HIV-1 infected.

‡ Before international travel.

cryptosporidial infection: consumption of municipal water (OR 10.1, 95% CI 1.10–92.8), increased age of the child (OR 1.29, 95% CI 1.05–1.58), and lower annual household income (OR 2.13, 95% CI 1.22–3.70).

DISCUSSION

Cryptosporidiosis is recognized as a major emerging infection in the United States.⁹ Human and several mammalian species can be infected with *C. parvum* transmitted by the fecal-oral route. Outbreaks have been described as a result of transmission in day care centers, swimming pools, public water supplies, and other water sources.¹⁰

Previous epidemiologic studies of *C. parvum* have typically utilized pathogen detection in feces as a marker of acute infection. In numerous studies, *C. parvum* was more commonly found in feces of diarrheal patients from poorly developed countries compared to the U.S. and Europe.¹⁰ Although detection of anticryptosporidial antibodies in serum indicates past (not active) infection, this method is useful for epidemiologic studies. A higher prevalence of cryptosporidial infection in developing countries has been established using serologic methods similar to those used in the current study.¹⁰

The present study was stimulated by an interest in health concerns of the large population living along the Texas-Mexico border. Numerous other diseases attributable to environmental contamination occur more commonly in this region.^{11,12} However, no information exists regarding infection with *C. parvum*. *Cryptosporidium parvum* infection in children residing in colonias is of particular interest because these communities are populated by families of lower socioeconomic status, and typically have a substandard water supply and limited sanitation facilities.

An age-related increase in *C. parvum* seroprevalence was observed for children living in colonias and San Antonio (Figure 1). In San Antonio children, *C. parvum* seroprevalence increased from 25% at ages 0–4, to 58% (ages 5–8) and 70% (age 9–13). Children ages 0–4 in colonias had a seroprevalence of 82%, which increased to 85% by ages 5–8, and 97% by ages 9–13. Age-related increases of cryptosporidiosis have been previously reported for children living in other areas (Table 4).

Three independent factors were found to be associated with *C. parvum* infection in children residing in colonias: 1) consumption of municipal water; 2) older age; and 3) lower household income. Older age and lower household income (a measurement of socioeconomic status) are es-

established risk factors for *C. parvum* infection,¹³ as well as other infections spread through fecal-oral contact.¹² The independent risk of consumption of municipal water indicates that the municipal water sources within these colonias were intermittently or regularly contaminated with *C. parvum*. The age-associated increase indicates that this was not the result of a recent outbreak, but due to increased cumulative risk with advanced age. However, we cannot identify specific contaminated municipal water sources since detection of antibodies to *C. parvum* only documents past infection with this organism. Therefore, all sources of drinking water since birth could be potential sources for acquisition of *C. parvum*. Large outbreaks of cryptosporidiosis attributable to contaminated municipal water supplies have been documented in other regions of the United States.^{14,15}

These data indicate that the prevalence of infection with the intestinal parasite *C. parvum* is very high among children living in colonias (89%) and urban communities (82%) along the Texas-Mexico border and is comparable to the prevalence observed in developing countries such as Brazil¹³ and Venezuela¹⁶ (Table 4). Infection within colonias was associated with previously described factors (older age and lower household income) as well as consumption of municipal water. The high prevalence of *C. parvum* infection is likely a sentinel for higher prevalence of other waterborne infections as well. Characterization of *C. parvum* infection in the colonias might be useful to investigate the potential for other waterborne infections in these areas, and to identify the specific risk factors of waterborne disease transmission. Ongoing public health measures should continue to emphasize the importance of personal hygiene as well as to provide and monitor the quality of drinking water in these areas.

Acknowledgments: The authors thank Patty Heard for technical assistance and Pearl Mast, Viola Herrera, and Margaret Fragoso for enrollment of participants. Abbott Laboratories provided instrumentation. We thank Dr. Derek A. Mosier (Kansas State University) for providing *C. parvum* oocysts. We are grateful to the clinic staff at the University Health Center-Downtown (San Antonio, Texas), the Kenwood Clinic (San Antonio, Texas), and the El Milagro Clinic (McAllen, Texas) who made this study possible. We thank Fernando Guerra, M.D., Director of the San Antonio Metropolitan Health District, and D. Michael Foulds, M.D., for their encouragement and assistance.

Financial Support: This study was funded by a grant from the South Texas Health Research Center.

Authors' Addresses: Charles T. Leach and Hal B. Jenson, Department of Pediatrics, Mail Stop 7811, University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, Texas 78229-3900, phone 210-567-5250, FAX 210-567-6305; Felix C. Koo, University of Texas-Pan American, 1201 West University Drive, Edinburg, Texas 78539, phone 956-381-2298, FAX 956-381-2438; Thomas L. Kuhls, Norman Regional Pediatrics, 1125 N. Porter, Suite 200, Norman, OK 73071, phone 405-321-5114, FAX 405-321-6482; Susan G. Hilsenbeck, Baylor College of Medicine, One Baylor Plaza, Houston, TX, phone 713-798-1627, FAX 713-798-1642.

Reprint requests: Charles T. Leach and Hal B. Jenson, Department of Pediatrics, Mail Stop 7811, University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, Texas 78229-3900, phone 210-567-5250, FAX 210-567-6305.

REFERENCES

- Ramratnam B, Flanigan TP, 1997. Cryptosporidiosis in persons with HIV infection. *Postgrad Med J* 73: 713-716.
- Soave R, Ruiz J, Garcia-Saucedo V, Garrocho C, Kean BH, 1989. Cryptosporidiosis in a rural community in central Mexico [letter]. *J Infect Dis* 159: 1160-1162.
- Steiner TS, Thielman NM, Guerrant RL, 1997. Protozoal agents: what are the dangers for the public water supply? *Annu Rev Med* 48: 329-340.
- Sharp, J. *Bordering the Future*. Austin (TX): Texas Comptroller of Public Accounts; 1998.
- Jones DB. 1989. Trouble on the border: international health problems merge at the Rio Grande. *Tex Med* 85: 28-33.
- Brannan DK, Greenfield RA, Owen WL, Welch DF, Kuhls TL, 1996. Protozoal colonization of the intestinal tract in institutionalized Romanian children. *Clin Infect Dis* 22: 456-461.
- Kuhls TL, Mosier DA, Crawford DL, Griffis J, 1994. Seroprevalence of cryptosporidial antibodies during infancy, childhood, and adolescence. *Clin Infect Dis* 18: 731-735.
- Hosmer DW, Lemeshow S, 1989. *Applied Logistic Regression*. New York: John Wiley & Sons.
- Guerrant RL, 1997. Cryptosporidiosis: an emerging, highly infectious threat. *Emerg Infect Dis* 3: 51-57.
- Current WL, Garcia LS, 1991. Cryptosporidiosis. *Clin Microbiol Rev* 4: 325-358.
- United States General Accounting Office. *Health Care Availability in the Texas-Mexico Border Area: Report to the Honorable Lloyd Bentsen, U.S. Senate, Washington, DC: General Accounting Office*.
- Leach CT, Koo FC, Hilsenbeck SG, Jenson HB, 1999. The epidemiology of viral hepatitis in children in South Texas: increased prevalence of hepatitis A along the Texas-Mexico border. *J Infect Dis* 180: 509-513.
- Zu SX, Li JF, Barrett LJ, Fayer R, Shu SY, McAuliffe JF, Roche JK, Guerrant RL, 1994. Seroepidemiologic study of *Cryptosporidium* infection in children from rural communities of Anhui, China, and Fortaleza, Brazil. *Am J Trop Med Hyg* 51: 1-10.
- Mac Kenzie WR, Hoxie NJ, Proctor ME, Gradus MS, Blair KA, Peterson DE, Kazmierczak JJ, Addiss DG, Fox KR, Rose JB, Davis JP, 1994. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *N Engl J Med* 331: 161-167.
- Hayes EB, Matte TD, O'Brien TR, McKinley TW, Logsdon GS, Rose JB, Ungar BL, Word DM, Pinsky PF, Cummings ML, 1989. Large community outbreak of cryptosporidiosis due to contamination of a filtered public water supply. *N Engl J Med* 320: 1372-1376.
- Ungar BL, Gilman RH, Lanata CF, Perez-Schael I, 1988. Seroepidemiology of *Cryptosporidium* infection in two Latin American populations. *J Infect Dis* 157: 551-556.
- Groves VJ, Lehmann D, Gilbert GL, 1994. Seroepidemiology of cryptosporidiosis in children in Papua New Guinea and Australia. *Epidemiol Infect* 113: 491-499.
- Kassa M, Comby E, Lemeteil D, Brasseur P, Ballet JJ, 1991. Characterization of anti-Cryptosporidium IgA antibodies in sera from immunocompetent individuals and HIV-infected patients. *J Protozool* 38: 179S-180S.
- Petry F, 1998. Epidemiological study of *Cryptosporidium parvum* antibodies in sera of persons from Germany. *Infection* 26: 7-10.
- Tzipori S, Campbell I, 1981. Prevalence of *Cryptosporidium* antibodies in 10 animal species. *J Clin Microbiol* 14: 455-456.
- Janoff EN, Mead PS, Mead JR, Echeverria P, Bodhidatta L, Bhaibulaya M, Sterling CR, Taylor DN, 1990. Endemic *Cryptosporidium* and *Giardia lamblia* infections in a Thai orphanage. *Am J Trop Med Hyg* 43: 248-256.
- Koch KL, Phillips DJ, Aber RC, Current WL, 1985. Cryptosporidiosis in hospital personnel. Evidence for person-to-person transmission. *Ann Intern Med* 102: 593-596.
- Ungar BL, Mulligan M, Nutman TB, 1989. Serologic evidence

- of *Cryptosporidium* infection in US volunteers before and during Peace Corps service in Africa. *Arch Intern Med* 149: 894–897.
24. Lengerich EJ, Addiss DG, Marx JJ, Ungar BL, Juranek DD, 1993. Increased exposure to cryptosporidia among dairy farmers in Wisconsin. *J Infect Dis* 167: 1252–1255.
25. Frost FJ, de la Cruz AA, Moss DM, Curry M, Calderon RL, 1998. Comparisons of ELISA and Western blot assays for detection of *Cryptosporidium* antibody. *Epidemiol Infect* 121: 205–211.