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CRYPTOSPORIDIUM PARVUM IN CHILDREN WITH DIARRHEA IN MULAGO HOSPITAL, KAMPALA, UGANDA

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Abstract. A cross-sectional case-control study (ratio = 3:1) was conducted over a 15-month period to determine the prevalence and consequences of cryptosporidiosis in hospitalized diarrheic children (0–5 years old) at Mulago Hospital in Kampala, Uganda. *Cryptosporidium parvum* was detected and genotyped among 2,446 children of whom 1,779 (72.7%) had diarrhea, and 667 (27.3%) were age- and sex-matched controls. Of the 1,779 children with diarrhea, 532 (29.9%) had persistent (> 14 days) diarrhea and 1,247 (70.1%) had acute diarrhea. Overall, 444 (25.0%) of the 1,779 children with diarrhea had *C. parvum*, compared with only 57 (8.5%) of the 667 children without diarrhea ($\chi^2 = 80.2$, $P \leq 0.0001$). Within this group of infected children, 72.8% were infected with genotype 1, 18.4% with genotype 2, and 4.1% with a mixture of both genotypes, and 4.1% isolates were either unclassified or *C. meleagridis*. The prevalence was highest during the rainy months of April to June. Of the 532 children with persistent diarrhea, 166 (31.2%) had *C. parvum* compared with 278 (22.3%) of the 1,247 children with acute diarrhea ($\chi^2 = 15.8$, $P \leq 0.0001$). There was a significant association between *C. parvum* and malnutrition including stunting, being underweight, and wasting. Unfavorable outcome (death or failure to resolve within 14 days) occurred in 139 (72.8%) of the 191 children with *C. parvum*, and in only 65.1% of the 545 without (odds ratio = 1.117, 95% confidence interval = 1.005–1.243, $P = 0.05$), Of the 191 children with *C. parvum*, 24 (12.6%) died, compared with 34 (6.2%) of the 545 without *C. parvum* ($P = 0.005$). Mortality rates were higher among children with severe dehydration and persistent diarrhea, and in stunted or underweight children infected with *C. parvum*. Among Ugandan children, cryptosporidiosis, which remains untreatable, is frequently associated with diarrhea and other serious and unfavorable consequences.

INTRODUCTION

Diarrhea is responsible for more than 3.1 million deaths each year among children less than 15 years of age, mostly in developing countries.[1] While only 10–15% of children with acute diarrhea develop persistent diarrhea, approximately half of the estimated deaths are attributed to persistent diarrhea (> 14 days duration).[2] While mortality due to acute diarrhea has decreased in developing countries in recent years after the introduction of oral rehydration solution, it unfortunately has had only marginal impact on mortalities associated with persistent diarrhea.[3]

The mortality rate associated with persistent diarrhea in malnourished children is disproportionately high, accounting for up to 45% of diarrheal deaths in Bangladesh[4], Brazil[5], and in several African countries.[3] A recent study in Uganda has shown that among children less than 30 months of age in rural and semi-urban areas, a high proportion were either stunted or underweight and one-fourth of them had diarrhea.[6] It is possible that the high prevalence of malnutrition and concurrent infections are due to poor immune function and inadequate nutrition (Oriokot FM, Tumwine JK, unpublished data).

While the role of *Cryptosporidium parvum* as a cause of acute diarrhea in developing countries is well documented,[7] its probable contribution to persistent diarrhea and malnutrition in children remains uncertain. While no therapy currently exists for infection with *C. parvum*, two recent, randomized, controlled clinical trials with nitazoxanide have shown promise.[8,9] However, comprehensive studies on the prevalence of *C. parvum* in Uganda, and its contribution to chronic diarrhea and stunted growth and development have not been conducted. Therefore, the current study was designed to document the prevalence of diarrhea in children admitted to Mulago Hospital in Kampala, Uganda, establish the prevalence of cryptosporidiosis with acute and persistent diarrhea, and determine the association of the infection with stunted growth and malnutrition. We have also assessed the prevalence of *C. parvum* genotypes in infected children.

MATERIALS AND METHODS

Patients/study population. The study population included children 0–60 months old with diarrhea (persistent or acute) admitted to Mulago Hospital. An episode of acute diarrhea was defined as three or more loose bowel movements per day over a 72-hour period. When diarrhea persisted for more than 14 days, it was defined as persistent diarrhea.

Study design. This was a cross-sectional case-control study in which every three children with diarrhea were matched for age and sex with a child without diarrhea. The control children were included for the purpose of establishing whether there was a difference between the prevalence of *C. parvum* in children with diarrhea compared with those without diarrhea.

Inclusion criteria. Children 0–60 months old admitted to Mulago Hospital from November 1999 to January 2001 with acute or persistent diarrhea and whose caretakers consented to participate were entered into the study. Children without diarrhea in the previous 72-hour period were matched for age and sex and recruited as the controls.

Exclusion criteria. Children with dysentery, measles, or any form of cancer, or children whose parents or caretaker could not ascertain their age were excluded from the study.

Sample size determination. A formula by Kish was used to calculate the sample size.[10] Assuming the prevalence of *C. parvum* to be 18%, and a margin of error of 1% and 95% confidence, a sample size of 2,202 was calculated for determining the prevalence of *C. parvum.*[11] The sample for the case-control study was calculated using the formula of Fleiss.[12] With 80% power and 95% confidence intervals and relative risk worth detecting at 1.52, the sample size of the

affected population (children with diarrhea) was 1,399 and that of the controls (children without diarrhea) was 588. The prevalence of diarrhea due to *C. parvum* was estimated to occur in 12.2% of the children with diarrhea and in only 8% of the control children based on several other case-control studies.[13]

Recruitment and management. Eligible children were recruited up to a total of 15 children/day. The children were selected using systematic sampling by taking every sixth child with diarrhea. Due to resource constraints, it was not possible to follow-up all the children. Seven-hundred thirty-six randomly selected children were followed-up for two weeks. Five of the 15 children were selected every day for follow-up using simple random sampling.

All children had their clinical and nutritional status assessed. All patients were managed with appropriate fluid therapy. Some received antibiotics if they had concurrent infections such as respiratory infections.

Measurements. Measurements were carried out using international guidelines.[14] Children were weighed to the nearest 100 grams using a hanging spring scale (Salter Weight-Tronx, Ltd., West Bromwich, United Kingdom) that was checked and adjusted daily. Children were weighed almost nude with only underpants retained for privacy. Height for children 24–59 months old and length for those less than two years old were measured using adjustable wooden boards constructed locally according to specifications of the United Nations.[12] Height was measured to the nearest 0.1 cm. Mid upper arm circumference was measured to the nearest 0.1 cm. The age of the child was ascertained from the child health card or baptismal or birth certificates. If none of these were available, age was assessed using a calendar of local events such as the 1996 general election. Background sociodemographic data was collected using a questionnaire.

Laboratory procedures. Stools were collected from enrolled children for diagnostic microbiology. *Cryptosporidium* oocysts were detected by modified acid fast staining of fecal smears and analysis by polymerase chain reaction–restriction fragment length polymorphism (PCR-RFLP). Fecal DNA was extracted from stool specimens and a PCR fragment from the *Cryptosporidium* oocyst cell wall protein gene was amplified.[15] The PCR-RFLP assay provided a sensitive method for the detection of cryptosporidiosis in patients and allowed the genotyping of the *C. parvum* isolates. Over the first six months, some 650 stool samples were also examined by microscopy and PCR for *Cyclospora*, and by microscopy for *Giardia* and *Entameba histolytica*. However, due to the miniscule number of positive samples (one, two, and one, respectively), further testing for these pathogens was abandoned. No enteric viruses or bacteria were sought in these samples. The prevalence and contribution to diarrhea of the microsporidium *Enterocytozoon bieneusi* was also analyzed by PCR as previously reported.[16]

Data management. Data was processed using EPINUT in the Epi-Info version 6.0 computer statistical package[17] and SPSS software (SPSS, Inc., Chicago, IL). Data were summarized using frequency tables, bar charts, histograms, means, and standard deviations. Possible risk factors for persistent diarrhea were analyzed as follows. For categorical risk factors, contingency tables were used and the strength of association was measured using the chi-square test statistic and its associated P value. For continuous risk factors, the Student t-test was used to compare the mean value of the risk factors in the study and control children.

Ethical considerations. The study was reviewed and approved by the Mulago Hospital Research and Ethics Committee. Relevant treatment was offered to the children and the attending pediatrician was advised of the results of the stool examinations. Children were followed-up until discharged from the hospital. No follow-up in the community was done because of budgetary constraints. Children meeting the inclusion criteria had their stools collected into sterile containers. Since there is no effective therapy for *C. parvum,* children with this infection were offered symptomatic treatment as well as relevant treatment for any concurrent infection.

RESULTS

Prevalence of diarrhea. During the 15-month study period, 63,200 children were seen in the Acute Care Unit, Ward 15, and the Nutrition Ward of Mulago Hospital, of whom 13,556 (21.4%) had diarrhea.

Type of diarrhea. A total of 2,446 children were enrolled, of whom 1,779 (72.7%) had diarrhea and 667 (27.3%) were without diarrhea. Among the 1,779 children with diarrhea, 532 (29.9%) were classified as having persistent diarrhea (lasting 14 days or more) and 1,247 (70.1%) were classified as having acute diarrhea.

Sociodemographic characteristics. The sociodemographic characteristics and age distribution of children with diarrhea attending Mulago Hospital are shown in Table 1. The age distribution ranged between 3 and 36 months. It peaked at 10 months, then subsided after 36 months.

Prevalence and age distribution of cryptosporidiosis in children. A summary of characteristics of cryptosporidiosis in children with and without diarrhea is shown in Table 2. Overall, 444 (25.0%) of the 1,779 children with diarrhea had *C. parvum* compared with only 57 (8.5%) of the 667 children without diarrhea ($\chi^2 = 80.2$, $P \leq 0.0001$). The age distribution of children with cryptosporidiosis followed the same age distribution of children with diarrhea in this population (3–36 months). The PCR-RFLP analysis showed that of the 444 children with *C. parvum*, 326 (73.7%) were infected with genotype 1 (human), 85 (19.2%) with genotype 2 (zoonotic), and 19 (4.2%) with a mixture of genotypes 1 and 2. Fourteen (3%) isolates could not be classified as either genotype. Five isolates were classified as *C. meleagridis*.

Persistent (≥ 14 days) versus acute diarrhea. The mean duration of persistent diarrhea was 23.2 (SD = 13.66) days, while that of acute diarrhea was 4.79 (SD = 2.26) days. Of the 532 children with persistent diarrhea, 166 (31.2%) had cryptosporidiosis compared with 278 (22.3%) of the 1,247 children with acute diarrhea. This difference was statistically significant ($\chi^2 = 15.8$, $P < 0.0001$).

Breastfeeding. Among the children with diarrhea, 1,055 were still breastfeeding, and of these, 278 (26.4%) had *C. parvum*. Of the 724 children who were no longer breastfeeding, 210 (29.0%) had cryptosporidiosis. This difference was not statistically significant ($\chi^2 = 1.52$, $P = 0.217$). However, among the five babies who were exclusively breastfeeding and had diarrhea, none had cryptosporidiosis. The mean age of the exclusively breast-fed children with diarrhea was 10.06 (SD = 6.62) months, while that of those with diarrhea but not

TABLE 1
Sociodemographic and other characteristics of the children with and without diarrhea*

Characteristic	Children with diarrhea	Children without diarrhea	Odds ratio (95% CI)	*P*
Sex				
Female (%)	786 (44.2)	322 (48.3)	1.18 (0.98–1.42)	0.077
Male (%)	993 (55.8)	345 (51.7)		
Roof materials				
Temporary (%)	18 (1.0)	6 (0.9)	1.3 (0.42–3.18)	0.802
Permanent (%)	1,761 (99.0)	661 (99.1)		
Wall materials				
Temporary (%)	162 (9.1)	71 (10.6)	1.19 (0.88–1.16)	0.248
Permanent (%)	1,617 (90.9)	596 (89.4)		
Education of caretaker				
Up to grade 7 (%)	1,181 (66.4)	477 (71.5)	1.27 (1.04–1.55)	0.016†
≥Secondary school (%)	598 (33.6)	190 (28.5)		
Still breastfeeding				
Yes (%)	1,055 (59.3)	232 (34.8)	2.73 (2.26–3.30)	<0.0001†
No (%)	724 (40.7)	435 (65.2)		
Dehydrated				
Yes (%)	468 (25.0)	6 (0.9)	39.3 (16.9–97.9)	<0.0001†
No (%)	1,311 (75.0)	661 (99.1)		
Patient's age in months (SD)	13.50 (8.17)	13.89 (5.35)	–	0.384

* CI = confidence interval.
† Statistically significant.

exclusively breastfed was 10.49 (SD = 3.94) months. This difference was not statistically significant ($P = 0.951$).

Nutritional status and outcome. The relationship between the nutritional status and cryptosporidiosis is summarized in Table 2. Information on outcome was available on 736 (who were a subset of the 1,779) children with diarrhea. Unfavorable outcome was defined as either death or failure of the diarrhea to cease within two weeks. Of the 191 children with cryptosporidiosis, 139 (72.8%) had an unfavorable outcome, while among the 545 children without cryptosporidiosis, 355 (65.1%) had an unfavorable outcome (odds ratio = 1.117, 95% confidence interval = 1.005–1.243, $\chi^2 = 3.738$, $P = 0.05$).

Mortality. Of the 444 children with cryptosporidiosis investigated, 191 were followed-up, of whom 24 (12.6%) died compared with 34 (6.2%) of the 545 without the infection, indicating that those with cryptosporidiosis had a significantly higher ($\chi^2 = 7.799$, $P = 0.005$) mortality rate than those without the infection. However, it was difficult to determine with certainty whether the cause of death was due to

TABLE 2
Characteristics of the children with and without *Cryptosporidium parvum* in Mulago Hospital*

	Children with diarrhea					Children without diarrhea				
	C. parvum					*C. parvum*				
Variable	Yes	No	Odds ratio	95% CI	*p*	Yes	No	Odds ratio	95% CI	*p*
Diarrhea type										
Persistent (%)	31.2	68.8				–	–	–	–	–
Acute (%)	22.3	77.7	1.53	1.22–1.91	0.001†	–	–	–	–	–
Sex										
Male (%)	21.2	78.8	0.99	0.79–1.22	0.900	22 (38.6)	308 (50.5)	0.62	0.34–1.11	0.858
Female (%)	20.9	79.1				35 (61.4)	302 (49.5)			
Wasted	177	483	1.59	1.27–1.99	0.0003†	24 (42.1)	265 (43.4)	0.95	0.53–1.09	0.846
Not wasted	267	1,159				33 (57.9)	345 (56.6)			
Underweight	259	659	1.42	1.14–1.78	0.0014†	36 (63.2)	361 (59.2)	1.18	0.65–2.15	0.559
Normal weight	186	676				21 (36.8)	249 (40.8)			
Stunted	181	460	1.31	1.04–1.64	0.0160†	31 (54.4)	274 (44.9)	1.46	0.82–2.61	0.170
Not stunted	263	875				26 (45.6)	336 (55.1)			
Age, months (SD)	13.26 (8.01)	13.82 (8.55)			0.208	17.7 (11.0)	19.7 (11.72)	–	–	0.220
Duration (SD)‡	12.21 (12.21)	10.00 (11.40)			<0.0001†	–	–	–	–	–
WHZ (SD)	–1.26 (2.34)	–0.96 (2.47)			0.022*	–1.52 (1.93)	–1.48 (1.90)	–	–	0.875
WAZ (SD)	–2.21 (2.05)	–1.67 (2.46)			<0.0001†	–2.31 (2.29)	–2.05 (2.67)	–	–	0.478
HAZ (SD)	–1.43 (2.52)	–1.08 (2.77)			0.015*	–1.90 (2.56)	–1.46 (2.97)	–	–	0.274
C. parvum type										
1 (%)	74.0					72.0	–	–		
2 (%)	19.0					10.5	–	–		
Mixed (%)	4.0					3.5	–	–		
Other (%)	3.0					14.0	–	–		

* CI = confidence interval; WHZ = weight-for-height z-score; WAZ = weight-for-age z-score; HAZ = height-for-age z-score.
† *p* value significant at the <0.05 level. The genotype of *C. parvum* (whether type 1 or 2) did not impact the findings.
‡ Duration of diarrhea on admission to the hospital was determined from the history given by the caretakers of the patients.

cryptosporidiosis. The mortality rates were worse among stunted or underweight children with cryptosporidiosis than among those without *C. parvum*.

There was no significant difference among those with wasting (Tables 2 and 3). Of the 203 with dehydration on admission, 33 (16.3%) died, while only 25 (4.8%) of the 521 without dehydration died, clearly indicating the risk faced by dehydrated children. Of the 267 children with persistent diarrhea, 31 (11.8%) died compared with only 27 (5.8%) of the 469 children with acute diarrhea ($P = 0.005$). Of the 144 children infected with *C. parvum* type 1, 17 (11.8%) died compared with 5 (13.9%) of the 36 children infected with type 2. Two of the 20 children with mixed infections with types 1 and 2 died. The numbers in this mixed group are too small to allow meaningful interpretation.

Multiple regression analysis was used to disentangle the separate influence of various factors on mortality of children with diarrhea, as shown in Table 4. Whereas several factors were associate with *C. parvum* in the bivariate analysis, only persistent diarrhea and mortality were significantly associated with it in the multivariate analysis. A summary of the statistical analysis of factors associated with cryptosporidiosis among children with diarrhea is shown in Table 5. While cryptosporidiosis was present in this population all year round, the highest prevalence was during the rainy months of April, May, and June.

DISCUSSION

This is the first comprehensive report on diarrhea, malnutrition and cryptosporidiosis in children in Uganda. It also includes a comprehensive genotypic analysis involving a large number of *C. parvum* isolates. The high prevalence of *C. parvum* is remarkable, given the fact that similar studies have shown consistently lower rates: 3.5% in Turkey,[18] 7.5% in Burkina Faso,[19] and 18% in Zambia.[11] The reasons for this are not clear but it is possible that the application of new molecular techniques in the current study could have contributed to the considerably higher detection rate. The PCR-RFLP analysis was 32% more sensitive in detecting *C. parvum* in the stools analyzed than was modified acid fast staining, which was performed on the first 650 samples collected. The ability to genotype each of the 444 *C. parvum* isolates in this study reflects the specificity and sensitivity of the PCR-RFLP method, as described previously.[20]

In the current study, we found a tight overlap between the age distribution of those with diarrhea and cryptosporidiosis. This was expected since a high proportion of the children 3–36 months of age acquire the infection for the first time.[13] These results are consistent with studies from South Africa.[21] The occurrence of *C. parvum* in a large proportion of diarrheic children less than three years of age has been reported in many of the developing countries, including those in sub-Saharan Africa.[22] Children in developing countries, such as Uganda, become exposed to cryptosporidiosis within a few weeks after birth, and with maternal protection through breastfeeding, symptomatic infections sometimes are delayed until 6–24 months of age. While the protection afforded by continuous breastfeeding was not so apparent in the current study, none of the five babies who had diarrhea but were exclusively breast-fed had cryptosporidiosis.

There was a clear seasonal variation in the rate of detection of *C. parvum*, with the highest prevalence recorded in the rainy season between April and June. This seasonal variation has also been observed in the United States,[13] Burkina Faso,[19] and South Africa.[21] It seems that after the primary infection, which is mostly symptomatic after three months of age, subsequent regular exposure to the parasite tends to be transient and asymptomatic, as shown in another study from Nigeria.[22]

TABLE 3
Factors associated with mortality (in the bivariate analysis) among children with diarrhea in Mulago Hospital between November 1999 and January 2001*

Factor	Pearson's χ^2	*p*	Odds ratio	95% confidence interval
Cryptosporidium parvum	7.799	0.005	2.01	1.23–3.31†
Enterocytozoon bieneusi	0.199	0.665	0.86	0.43–1.69
Persistent diarrhea	9.031	0.005	2.02	1.23–3.32†
Wasting (WHZ < –2.0)	1.082	0.298	1.30	0.792–2.14
Underweight (WAZ < –2.0)	7.575	0.006	2.13	1.222–3.73†
Stunting (HAZ < –2.0)	9.881	0.002	2.75	1.325–3.58†
Meeting WHO criteria for AIDS	5.785	0.016	3.60	1.325–9.75†
Dehydration	26.023	<0.0001	3.39	2.068–5.55†
Unsafe water source	0.002	0.968	0.98	0.437–2.21
Residence in Kampala	2.436	0.119	0.66	0.391–1.11

* WHZ = weight-for-height z-score; WAZ = weight-for-age z-score; HAZ = height-for-age z-score; WHO = World Health Organization; AIDS = acquired immunodeficiency syndrome.
† Statistically significant.

TABLE 4
Factors associated with mortality in the regression analysis*

	Coefficient (B)	Standard error	Odds ratio	95% CI	*P*
Cryptosporidium parvum	0.673	0.298	1.959	1.093–3.512	0.024†
Persistent diarrhea	0.648	0.297	1.911	1.068–3.420	0.029†
Wasted	–0.405	0.351	0.667	0.336–1.327	0.249
Underweight	0.522	0.393	1.685	0.779–3.642	0.185
Stunted	0.671	0.323	1.956	1.039–3.681	0.038†
Dehydration	1.440	0.294	0.237	0.133–0.421	<0.0001†
WHO criteria for HIV/AIDS	1.802	0.763	6.064	1.359–27.05	0.018†

* CI = confidence interval; WHO = World Health Organization; HIV = human immunodeficiency virus; AIDS = acquired immunodeficiency syndrome.
† Statistically significant.

TABLE 5
Summary of factors (in the bivariate analysis) associated with cryptosporidiosis among children with diarrhea in Mulago Hospital, November 1999 to January 2001

Factor	Pearson's χ^2	*P*	Odds ratio	95% confidence interval
Dehydration	7.70	0.006	1.28	1.08–1.53
Mortality	7.80	0.005	2.01	1.23–3.31
Wasting	6.55	0.010	1.24	1.05–1.46
Underweight	10.20	0.001	1.30	1.11–1.54
Stunted	5.77	0.016	1.22	1.04–1.44
Persistent diarrhea	15.81	<0.0001	1.40	1.19–1.65
Still breastfeeding	2.38	0.123*	1.13	0.97–1.33
Unfavorable outcome	3.74	0.053*	1.05	0.93–1.19

* Not significant.

The current study has shown cryptosporidiosis to be an important risk factor for malnutrition, including stunting, being underweight, and wasting. Similar results have been observed in Guinea-Bissau, where it was shown that cryptosporidiosis in children less than three years old can lead to a permanent growth retardation.[23] In fact, *C. parvum* was more common among children with malnutrition and in non-breast-fed children in Mexico,[24] and in non-breast-fed children with stunting in Bangladesh.[4] Effective treatment against cryptosporidiosis is largely still unavailable, although nitazoxanide was recently shown in clinical trials to have some promise.[8,9] Some of the 25% of the children with diarrhea due to cryptosporidiosis admitted to Mulago Hospital would have benefited from such a treatment, and it might have reduced the prospect of prolonged dehydration and the risk of wasting and death.

The contribution of prolonged cryptosporidiosis to malnutrition without apparent diarrhea is not clear and has received little attention. Given the extent and nature of the mucosal damage caused by *C. parvum*, it is more than likely to be significant. Unfortunately, children without diarrhea, even when malnourished, are seldom tested for the presence of enteric pathogens. Such an association can only be confirmed conclusively in cohort studies. The only evidence that asymptomatic cryptosporidiosis can cause retardation of weight gain comes from a single study in Peru.[25] There have been several studies from Brazil linking persistent diarrhea associated with cryptosporidiosis and other agents with malnutrition.[26] In particular, persistent diarrhea was shown in one study to result in long-term cognitive deficits in later years in children affected early in life.[27] One limitation of the current study is the fact that we were, unfortunately, unable to carry out tests for infection with human immunodeficiency virus (HIV) on these children due to financial constraints. This means that it is not possible to stratify our findings with respect to HIV infection. However, based on recent preliminary observations, approximately 46% of the 65 children with persistent diarrhea seen in the wards in our study were HIV-positive, of whom 23% were excreting *C. parvum* oocysts (an ongoing study).

This study showed for the first time that there were no apparent clinical differences between children infected with types 1 and 2 of *C. parvum*. There were a few children who were infected with a mixture of the two types. Several isolates were identified that were neither type 1 nor type 2, but were most closely related to *C. parvum* based on molecular genetic analyses (Akiyoshi DE, Tzipori S, unpublished data). In addition, five non-*C. parvum* isolates were identified as *C. meleagridis* by molecular analyses.[28] The presence of non-*C. parvum* isolates, including *C. meleagridis*, *C. muris*, *C. felis*, and a *Cryptosporidium* dog genotype from human infections, has been reported.[29–31] Genotype analysis of a subsample of type 1 and type 2 isolates using microsatellite polymorphisms identified several type 1 and type 2 alleles not seen among *C. parvum* from other geographic areas.[20] In contrast to the wide distribution of microsatellite alleles observed to date, the Ugandan *C. parvum* haplotypes suggest that geographically restricted haplotypes are found in this study population.

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