Diagnosis of intestinal protozoan infections in patients in Cuba by microscopy and molecular methods: advantages and disadvantages

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ABSTRACT

Microscopy is the gold standard for diagnosis of intestinal parasitic diseases in many countries, including Cuba, although molecular approaches often have higher sensitivity as well as other advantages.

Fecal samples from 133 patients were analyzed by light microscopy and also real-time multiplex qPCR targeting Giardia duodenalis, Cryptosporidium spp., and Entamoeba histolytica, and, separately, Dientamoeba fragilis. Microscopy revealed G. duodenalis occurred most commonly (17 patients), followed by Blastocystis spp. (12 patients). In a few patients, Entamoeba histolytica/E. dispar, Cryptosporidium spp., and Cyclospora cayetanensis were identified.

Molecular analysis identified 4 more G. duodenalis infections and 2 more Cryptosporidium spp. infections; concordance between microscopy and PCR showed almost perfect agreement for G. duodenalis (κ = 0.88) and substantial agreement for Cryptosporidium (κ = 0.74). PCR indicated that E. dispar, rather than E. histolytica, had been identified by microscopy. Additionally, 16 D. fragilis infections were detected using molecular methods.

Although both microscopy and molecular techniques have a place in parasitology diagnostics, for parasites such as D. fragilis, where microscopy can underestimate occurrence, molecular techniques may be preferable, and also essential for distinguishing between morphologically similar microorganisms such as E. histolytica and E. dispar. Although in resource-constrained countries such as Cuba, microscopy is extremely important as a diagnostic tool for intestinal parasites, inclusion of molecular techniques could be invaluable for selected protozoa.

1. Introduction

Intestinal parasitoses are one of the main causes of health-service consultations in developing countries and are an important cause of morbidity worldwide. Among these, infections with some protozoa are recognized as having significant consequences on health, particularly in children (Hamdy et al., 2020). Direct consequences are usually gastro-intestinal disorders, such as diarrhea, dysentery, abdominal pain, vomiting, and lack of appetite, and indirect impacts include synergistic negative effects on nutritional status, stunting, and reduced educational achievement. For instance, every year there are more than 200 million symptomatic patients with giardiosis (Mmbaga and Houpt, 2017), and cryptosporidiosis is a leading cause of diarrhea in children younger than 5 years globally, only second after rotaviral enteritis (Mmbaga and Houpt, 2017).

Infections with Giardia duodenalis (syn. Giardia lamblia or Giardia intestinalis) Cryptosporidium spp., and Entamoeba histolytica are considered to be among the most common and important causes of parasite-related diarrhea in human populations. In contrast, the pathogenicities and symptoms associated with infections with Blastocystis spp. and Dientamoeba fragilis have been more controversial (Stensvold and Clark, 2016; Wong et al., 2018). Nevertheless, some evidence indicates that some sub-types of Blastocystis may be associated with irritable bowel syndrome (El-Badry et al., 2018; Rostami et al., 2017), or, at the very
least, be an indicator of dysbiosis (Cifre et al., 2018). However, such associations have been more difficult to identify for D. fragilis. A large case-control study recently reported that both Blastocystis spp. and D. fragilis were less likely to be identified in cases with gastrointestinal symptoms \( n = 1374 \) (Blastocystis spp. analyses; \( n = 1515 \) (D. fragilis analyses)) than in controls without such symptoms \( n = 1026 \) (Blastocystis spp. analyses); \( n = 1195 \) (D. fragilis analyses)), where investigation for Blastocystis spp. infection was conducted on a sub-set (de Boer et al., 2020; Bruijnesteijn van Coppenraet et al., 2015). A study in Denmark yielded similar results (Krogsgaard et al., 2015).

Microscopy of fecal smears or concentrates, with or without staining, has been the mainstay for many years for the diagnosis of intestinal protozoan infections and remains the cornerstone of the diagnosis of parasitic infections in many routine diagnostic laboratories (WHO, 1991). However, other methods are available, including detection of parasite antigen in feces by ELISA or immunochromatography (e.g., snap tests) and molecular methods (Garcia et al., 2017).

Given the excellent sensitivities and specificities achieved by molecular methods, detection of parasite-specific DNA by PCR is fast gaining popularity. Not only is PCR simple and potentially offers a more rapid turnaround time, but it also allows discrimination between morphologically indistinguishable parasites that are of different clinical relevance (such as Entamoeba dispar and E. histolytica). In addition, multiplex PCR enables samples to be investigated for several pathogens simultaneously, and can also be used to determine relative copy numbers, although the potential for quantification is often not used in the diagnostic setting. However, due to the requirement for comparatively costly equipment and reagents, including some for which refrigeration is essential, such diagnostic assays have not been implemented in many diagnostic labs, and are particularly underused in labs in less-developed regions. Nevertheless, where facilities and resources are available, multiplexed PCR-based methods that target the most relevant gastrointestinal parasites can provide fast, reliable results and could be implemented in routine clinical diagnostics (Laude et al., 2016). However, comparison of commercial multiplex real-time PCR assays has indicated that performance may be variable, and the required sensitivities and specificities, along with lab workflow, diagnostic algorithms, and population should be considered, as well as the cost, when considering incorporating such assays into the diagnostic lab (Paulos et al., 2019).

The objective of the present study was to compare the results from microscopy-based diagnostic tests for intestinal protozoa with those obtained by real-time molecular assays (commercial multiplex for Cryptosporidium spp. G. duodenalis, and E. histolytica and a published PCR protocol for D. fragilis) among a group of patients with different gastrointestinal disorders.

2. Materials and methods

2.1. Study population

A descriptive cross-sectional study was conducted between January and September 2019 among 133 patients either attending the Pediatric Hospital “William Soler” or for whom stool samples had been submitted to the “Pedro Kouri” Institute; both institutes are located in Havana, Cuba. Patients included in the study had gastrointestinal disturbances or there was clinical suspicion of intestinal parasitic infection. Some of the children included in the study were participating in a surveillance program for intestinal parasitic infections. Information on demographic and clinical variables (gender, age, symptoms, and some risk factors for parasitic infections) was recorded in standard epidemiological-questionnaire forms by nursing or medical staff at sample submission.

2.2. Sample analysis

2.2.1. Analysis by microscopy-based techniques

One stool sample from each patient was examined for intestinal parasites. For all samples \( N = 133 \), direct wet mounts were stained with Lugol’s iodine (particularly useful for identification of Giardia and Blastocystis cysts; WHO, 1991; Wolfe, 1992; Núñez and Cordoví, 2006) and also examined following formalin-ethyl acetate concentration. A modified Ziehl-Neelsen (mZN) acid-fast stain was used for coccidian parasites such as Cyclospora and Cryptosporidium spp. (Henriksen and Pohlien, 1981; Garcia, 2001; Walochnik and Aspock, 2012); however, this investigation was only conducted on diarrheic samples \( n = 31 \).

Fixatives were not used, and the samples were analyzed on arrival at the lab, less than an hour after collection. Each sample was analyzed independently by two experienced microscopists; for all samples there was concurrence between the results obtained by each microscopist.

2.2.2. Analysis by molecular assays for detecting intestinal parasites

DNA was extracted from all 133 stool samples using the QIAamp DNA Stool Kit (QIAGEN Inc., Valencia, California, USA) following the manufacturer’s protocol, and using approximately 200 μg from each well-mixed sample. DNA was stored frozen at \(-18 \) °C before investigation by PCR. A multiplex real-time PCR (qPCR) detection kit (VIASURE Cryptosporidium, Giardia & E. histolytica Real-Time PCR Detection Kit, CerTest Biotec S.L., Zaragoza, Spain) was used for molecular detection of Cryptosporidium spp., G. duodenalis, and E. histolytica following the manufacturer’s instructions, and including the internal control and appropriate controls provided in the kit.

For detection of D. fragilis, a previously published qPCR assay targeting a 77-bp fragment of the SSU rDNA gene was performed on all samples as previously described (Stark et al., 2006) using the following primers and probe: DF3 (5’TGTGAATACTGTCCCGGTTCT3'), DF4 (5’TGAACAGATTTCCACCGAGTCA3'), and Taqman probe (5’-FAM-CACACCGGCGGTTCTCCTA-3’). Briefly, amplification reactions were performed in a Rotor-Gene® 5plex equipment (Qiagen, Germany), in a volume of 25 μl with PCR buffer (HotStarTaq mastermix, Qiagen), 5 mM MgCl2, 2 pmol of each D. fragilis-specific primer, 1.25 pmol of D. fragilis-specific XS-probe, and 5 μl of the DNA sample. Amplification consists of 15 min at 95 °C followed by 50 cycles of 15 s at 95 °C, 30 s at 60 °C, and 30 s at 72 °C. DNA extracted from a D. fragilis-positive sample was used as a positive control for PCR; this sample had been identified by identification of an abundance of D. fragilis trophozoites, and had been independently confirmed by PCR. Ultrapure water was used as template in a negative control, and negative and positive controls were included in each amplification run.

2.3. Statistical analysis

All data were entered into a spreadsheet and analyzed using EPINFO 6.04 and EPIDAT 3.1 statistical programs. Cohen’s kappa index (κ) was used to test the concordance between the results from the molecular assays and coproscopy for G. duodenalis and Cryptosporidium spp. (Cohen, 1960). To investigate associations between infections and the continuous variable (age) Mann-Whitney U tests were used; contingency table analyses for assessing associations with categorical variables (gender, urban/rural residence, different symptoms); P values below 0.05 were considered statistically significant.

3. Results

3.1. Cohort description

Of the 133 patients, 68 (51%) were female and the median age was 25 years (ranging from 2 to 78 years). The majority of the patients (121 of 133; 91%) described their homes as urban, and the others lived in a rural location. The most common symptom reported among all patients,
regardless of the result of investigation, was abdominal pain (41 patients; 31%) followed by diarrhea (31 patients; 23%), nausea (18 patients; 14%), and flatulence (16 patients; 12%).

3.2. Parasites identified using by microscopy-based and molecular techniques

From 133 patients, an intestinal parasite of relevance was identified by light microscopy-based methods in 29 (22%), with *Giardia* identified most frequently (Table 1). Of these, 21 (72%) were single infections and 8 were dual infections; both *G. duodenalis* and Blastocystis spp. were identified in 5 patients, *E. histolytica/E. dispar* complex and Blastocystis spp. in 2 patients, and 1 patient was infected with both *C. cayetanensis* and Blastocystis spp.

Using the multiplex kit for *G. duodenalis*, *Cryptosporidium* spp., and *E. histolytica*, 21 patients were found to be positive for *Giardia* (the 17 cases that were positive by microscopy and 4 others) and 5 patients were found to be positive for *Cryptosporidium* spp. (the 3 cases that were positive by microscopy and 2 others) (Table 1). Cohen’s kappa index (κ) for agreement between methods for detection was 0.85 (almost perfect agreement) for *G. duodenalis* and 0.74 (substantial agreement) for *Cryptosporidium* spp., although with wide CI due to the few samples that were positive. However, as one of the two additional *Cryptosporidium* cases was not associated with diarrhea it had not been examined by mZN for coccidia. Of the 6 additional cases of *Cryptosporidium* or *Giardia* infection identified by PCR, none were identified to also be infected with other parasites, either by PCR or by microscopy.

No cases were found to be positive for *E. histolytica* by PCR, suggesting that those cases previously identified as potential *E. histolytica* cases by microscopy were actually *E. dispar*.

Although *Dientamoeba fragilis* was not detected using microscopy, qPCR identified 16 positive samples (as illustrated by the results from 10 randomly-selected positive samples in Fig. 1). Replicates produced the same results. In seven of these patients (44%), no other intestinal parasites were detected by microscopy or PCR. In four patients of the *D. fragilis*-positive patients, co-infection with *Blastocystis* spp. was identified and in four patients, coinfection with *G. duodenalis* was identified by both microscopy and PCR. In one *D. fragilis*-positive sample, co-infection with *E. histolytica/E. dispar* was identified by microscopy. Thus, in all those samples in which *Blastocystis* spp. cysts were detected by microscopy, another intestinal protozoan was also identified.

3.3. Demographic and clinical associations with the most frequently intestinal parasites

Although no associations between parasitic infections and gender or with urban/rural residence were identified, there were associations between age and some parasites. In those patients in which *Giardia* infection was detected (n = 21, including those identified only by molecular methods, and irrespective of co-infections) the median age was 14 years. This is significantly younger than the median age of the whole cohort. Similarly, the median age of those in which Blastocystis spp. was identified (n = 12, irrespective of co-infections) was significantly lower than that of the whole cohort, being only 9 years. However, if those patients who were infected with both *Giardia* and Blastocystis were removed from the analysis, then the median age of the Blastocystis cases (n = 7) was 22 years and no longer significantly different from that of the whole cohort. In contrast, the median age of the *Giardia* cases (n = 15) remained significantly lower at 8 years. The median age of patients in which *D. fragilis* was diagnosed (n = 16, regardless of co-infection) did not differ significantly from the median age of the entire cohort.

Regarding symptoms, Table 2 provides an overview of the most frequently reported symptoms and their occurrence in patients in whom *Giardia*, *D. fragilis*, *Cryptosporidium* spp. and/or *Blastocystis* spp. were detected, and also patients in whom no positive findings (protozoan parasites or commensals) were recorded. Investigations of associations between symptoms and specific infections were hampered by the relatively low numbers of positive samples and that several positive samples were with dual infections.

Those patients in which no protozoan infection was detected were less likely to report abdominal pain than those patients in which *Giardia* or *D. fragilis* were identified. Similarly, patients in which no protozoan infection was detected were also less likely to report diarrhea than those patients with *Giardia* infection, and were also less likely to suffer from flatulence. Although *Cryptosporidium* infection was associated with diarrheal symptoms, it was not possible to identify statistically significant associations within this dataset. As previously noted, *Cryptosporidium* was detected by PCR in one patient without diarrhea, which therefore was not analyzed by mZN.

### Table 1

Comparison of identification of intestinal parasites by microscopy-based and molecular-based methods among 133 patients with gastrointestinal symptoms.

<table>
<thead>
<tr>
<th>Intestinal parasites identified</th>
<th>Number of positive cases identified</th>
<th>Proportion infected (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Giardia duodenalis</em></td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Cryptosporidium spp.</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Entamoeba histolytica/ <em>E. dispar</em></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Blastocystis spp.</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td><em>Cyclospora cayetanensis</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><em>Dientamoeba fragilis</em></td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Total infected with at least one intestinal protozoan parasite</td>
<td>29</td>
<td>38</td>
</tr>
</tbody>
</table>

| Modified Ziehl-Neelsen (particularly relevant for identifying *Cryptosporidium* spp. and *Cyclospora cayetanensis*, was used only on diarrheic samples (n = 31), but all samples were examined by other light microscopy approaches and by PCR (N = 133). |
| Blastocystis spp. and *Cyclospora cayetanensis* not investigated by PCR. |
| *Cyclospora cayetanensis* only investigated by modified Ziehl-Neelsen in diarrheic samples (n = 31). |
| PCR only detects *Entamoeba histolytica*. |

4. Discussion

Protozoan intestinal infections are recognized as an important cause of morbidity in developing countries, with children the most vulnerable population (Harhay et al., 2010). Transmission of intestinal protozoa is mainly through the fecal-oral route, following ingestion of the infectious stages, often with contaminated water and food. Some intestinal protozoa are host-specific, but for others, such as some *Cryptosporidium* species, zoonotic transmission may also occur. Previous survey-type studies in Cuba, particularly among children, have identified *G. duodenalis* and Blastocystis spp. as occurring most commonly, but *Cryptosporidium* spp., *Cyclospora*, and *E. histolytica/dispar* have also been reported (Vital et al., 1999; Mendoza et al., 2001; Núñez et al., 2003; Canete et al., 2012). *D. fragilis* infection has not previously been reported in Cuba, although there are anecdotal reports from the 1940s, but this could be associated with lack of sensitive diagnostic tests. It is thus particularly relevant that use of molecular methods indicated that *D. fragilis* infection occurs relatively commonly in Cuba. This suggests a need for further investigation, particularly regarding whether *D. fragilis* infection is associated with clinical symptoms.
The occurrence of the four predominant symptoms recorded in association with specific identified protozoal infections or no infections identified.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abdominal pain (n = 41)</th>
<th>Diarrhea (n = 20)</th>
<th>Nausea (n = 18)</th>
<th>Flatulence (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Giardia infections (n = 21)</td>
<td>14/21 (67%)</td>
<td>9/21 (45%)</td>
<td>5/21 (24%)</td>
<td>11/21 (52%)</td>
</tr>
<tr>
<td>Giardia as mono-infection (n = 11)</td>
<td>8/11 (73%)</td>
<td>6/11 (55%)</td>
<td>1/11 (9%)</td>
<td>5/11 (45%)</td>
</tr>
<tr>
<td>All D. fragilis infections (n = 16)</td>
<td>10/16 (63%)</td>
<td>4/16 (25%)</td>
<td>2/16 (13%)</td>
<td>7/16 (44%)</td>
</tr>
<tr>
<td>D. fragilis as mono-infection (n = 7)</td>
<td>5/7 (71%)</td>
<td>2/7 (29%)</td>
<td>1/7 (14%)</td>
<td>4/7 (57%)</td>
</tr>
<tr>
<td>All Cryptosporidium infections (n = 5)</td>
<td>1/5 (20%)</td>
<td>4/5 (80%)</td>
<td>1/5 (20%)</td>
<td>0/5 (0%)</td>
</tr>
<tr>
<td>All Blastocystis infections (n = 12)</td>
<td>5/12 (42%)</td>
<td>3/12 (25%)</td>
<td>5/12 (42%)</td>
<td>3/12 (25%)</td>
</tr>
<tr>
<td>No protozoal infection identified (n = 72)</td>
<td>15/72 (21%)</td>
<td>13/72 (18%)</td>
<td>9/72 (13%)</td>
<td>0/72 (0%)</td>
</tr>
</tbody>
</table>

* No other parasites were identified in any of the samples where Cryptosporidium spp. was detected.

1 All the samples in which Blastocystis spp. was detected were also found to contain other parasites (see section 3.2).

2 Samples in which commensals were found (e.g., Entamoeba coli and Endolimax nana) are not included in the “no protozoal infection” group.

Diagnosis of intestinal parasitic infections in Cuba is generally by microscopic examination of stool samples, primarily using direct wet mounts or formalin ethyl concentration, with staining with Lugol’s iodine and also mZN. More sensitive methods, such as immunofluorescence for Cryptosporidium and Giardia, are not used, reflecting the lack of equipment and reagent resources.

The sensitivity and specificity of coproscopy for detection of protozoan parasites is sometimes poor, and requires prolonged hands-on work by an experienced microscopist, particularly when excretion levels are low. Therefore, molecular assays are increasingly being used in diagnostic labs, with multiplex panels considered to be of particular value (Pacína et al., 2015). Various molecular diagnostic panels are now commercially available from different suppliers, with others under development or in the process of validation. In addition, molecular approaches can be used to provide more information regarding particular species or subtypes, which may simply not be possible to determine by microscopy-based methods.

However, molecular methods also have some disadvantages, often requiring refrigeration capacity for reagents along with expensive equipment and consumables. This is particularly so for multiplex panels, which provide simplicity and rapid turnaround times, but at a high cost. In addition, molecular assays only detect those pathogens for which the appropriate primers are used – other organisms of potential relevance will not be detected and additional analyses will be required should other parasites or other pathogens be suspected.

In the work described here, for both Giardia and Cryptosporidium a few positive additional samples were found by molecular methods (four more for Giardia and two for Cryptosporidium). However, the concordance between results from microscopy and PCR was good, being considered almost perfect agreement for G. duodenalis (κ = 0.85) and substantial agreement for Cryptosporidium spp. (κ = 0.74). A study in Côte d’Ivoire found only moderate diagnostic agreement (κ = 0.47) between microscopy (formalin-ether concentration) and a commercially available multiplex PCR gastrointestinal pathogen panel for detection of G. duodenalis (Becker et al., 2015). Moderate diagnostic agreement (κ = 0.424) was also found for G. duodenalis detection in a study from Timor-Leste and Cambodia using microscopy (zinc sulphate centrifugal flotation) and an in-house multiplex PCR (Llewellyn et al., 2016). In addition, a study from Venezuela (Incani et al., 2017) found only moderate concordance between microscopy and a multiplex PCR (κ = 0.4). These less-substantial agreements found in these three studies (Becker et al., 2015; Llewellyn et al., 2016; Incani et al., 2017) compared with ours may reflect that in these other studies the microscopy for Giardia cysts did not involve any staining; Lugol’s iodine (as used in our study) improves identification (Wolle, 1992).

As also pointed out by the authors of the study in Côte d’Ivoire (Becker et al., 2015), it is important to be aware that, from a clinical perspective, hypersensitivity of a molecular method may not always be highly useful. Positive results may require independent confirmatory methods to discriminate active infection from asymptomatic shedding of nucleic acids. For example, in our study, one of the additional Cryptosporidium results was associated with a patient who was not experiencing diarrhea. This may reflect asymptomatic infection, but could also perhaps indicate that this positive finding was not associated with infection, but rather with detection of DNA from low-level passage of non-infectious oocysts. This could be due to the Cryptosporidium being of a species that does not infect humans (the multiplex used does not...
specify which species it detects) or because the oocysts were inactivated prior to ingestion. The only symptom recorded in this patient was nausea, which could be associated with Cryptosporidium, but could also be associated with another pathogen or condition. Indeed, as only those samples in which diarrhea was reported were examined by mZN for coccidia, this sample was only investigated by molecular means. Therefore, the kappa index does not provide a good representation regarding the similarity of the methodological aspects for Cryptosporidium detection as only the microscopy-based investigation included this symptom in the methodological algorithm. It should be noted that due to the lack of analysis of the samples for other (e.g., bacterial or viral) pathogens, we cannot exclude that these may have been responsible for the symptoms in at least some of the patients.

Regarding the other three protozoa investigated in this study, Entamoeba spp. were identified by microscopy (E. dispar/histolytica), but as there were no positive results in the multiplex PCR for E. histolytica, it is assumed that all the microscopy-positive results actually indicated E. dispers. Again, similar findings were reported in the study from the study in Côte d’Ivoire (Becker et al., 2015). Furthermore, a previous study from Cienfuegos Province, Cuba using microscopy and an in-house duplex qPCR found that of E. histolytica/dispar infections identified by microscopy, the majority were due to E. dispers (Núñez et al., 2001). Given that E. dispers is considered a non-pathogenic commensal and E. histolytica is an important pathogen that can cause, in addition to intestinal symptoms, an invasive, severe, extra-intestinal disease, there seems little point in using a diagnostic method that cannot distinguish between pathogenic and non-pathogenic species. Although various articles (e.g., Hamzah et al., 2016; Lau et al., 2013) suggest that the World Health Organization endorsed PCR as the method of choice way back in 1997 (WHO, 1997), reading of this document does not actually indicate this. However, it does state that confirmation of the two distinct species is a major accomplishment. Thus, it is clear that using a technique that distinguishes between these species is important and of clinical relevance.

As tools for molecular detection of Blastocystis spp. were not used, infection with this protozoan was only identified using traditional microscopy-based methods; the rate of occurrence was lower than previously reported in Cuba (14%–38%) (Núñez et al., 2003; Cañete et al., 2012). In the current study, Blastocystis spp. infection was only identified in association with other protozoal infections, and therefore it was not possible to determine whether there was an association with a particular symptom spectrum. Indeed, given that Blastocystis is often found more commonly in healthy individuals than those with gastrointestinal complaints, the potentially pathogenic role of this parasite in human infections remains controversial (Clark et al., 2013; Andersen and Stensvold, 2016). Nevertheless, a recent retrospective study from Switzerland involving a large number of patients found a correlation between Blastocystis spp. detection and abdominal pain, but not diarrhea or other symptoms, and, as in our study, also noted a high degree of coinfection (Legeret et al., 2020). Furthermore, some isolates of Blastocystis, notably ST7, have been associated with disruption of the gut microbiota, potentially resulting in a pathogenic effect (Yasón et al., 2019). Investigation of Blastocystis sub-types was not in the remit of the present study.

Although D. fragilis was detected in 16 samples by PCR, this parasite was not detected by microscopy, neither as trophozoites nor as the cyst form, which was first identified a few years ago (Stark et al., 2014). Indeed, it was noted by Stensvold and Nielsen (2012) and others that other concentrations would not be expected to be appropriate for detecting D. fragilis trophozoites, although may have enabled identification of cysts. In general, even when staining is used, identification of D. fragilis in stool samples is considered difficult; the trophozoite stage can easily be misidentified because their staining is pale and their nuclei may appear similar to those of Endolimax nana or Entamoeba hartmanni (https://www.cdc.gov/dpdx/dientamoeba/index.html).

Furthermore, other investigations of this PCR setup have indicated that the forward primer and probe are non-specific (Verweij et al., 2020). Furthermore, some isolates of Blastocystis, notably ST7, have been associated with disruption of the gut microbiota, potentially resulting in a pathogenic effect (Yasón et al., 2019). Investigation of Blastocystis sub-types was not in the remit of the present study.

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Investigations and discussion on the use of real-time PCR assays for D. fragilis (Gough et al., 2019) have indicated contentious issues regarding both detection and potential pathogenicity of D. fragilis (some of which also should also be considered for other protozoan parasites, including those discussed here such as Giardia, Cryptosporidium, and Blastocystis). The authors (Gough et al., 2019) suggest that multiple false positives may occur, and they recommend a specific assay (Genetic Signatures EasyScreen) as a screening tool, and also amplicon sequencing, neither of which are appropriate for our laboratory and situation. As Cq values in our study were relatively early (23.5–29.5) and the detection was probe based, we feel confident that these were not false positives, taking into account the information presented by (Gough et al., 2019). However, it should be noted that the analytical performance of the PCR method used (Stark et al., 2006) was not investigated here. Furthermore, other investigations of this PCR setup have indicated that the forward primer and probe are non-specific (Verweij et al., 2007), and further optimization would be necessary before considering implementation into our current diagnostic lab routines. Sequencing of positive amplicons (although quite short at only 77 bp) could provide further strength to the study, but was not possible. Reports of D. fragilis in Cuba are scant, as permanent stains of fixed fecal smears are not routinely implemented and therefore this is the first report of this parasite identified by molecular tools in Cuba. However, with Blastocystis, the pathogenic and clinical role of D. fragilis infection is controversial. Although gastrointestinal symptoms associated with D. fragilis infection have been described in the literature, it is also identified in healthy subjects without abdominal symptoms (Wong et al., 2018). Due to the low number of patients in our study, the frequency of co-infections with other protozoa, and the absence of information on infections with bacterial or viral pathogens, it is difficult to draw any firm conclusions regarding D. fragilis as an etiological agent of gastrointestinal symptoms. However, the association we identified between infection with D. fragilis and symptoms of abdominal pain and flatulence, but not diarrhea, suggest the possible role of this agent in these symptoms and indicate the need for larger, more focused studies to investigate this aspect in greater depth. Indeed, some previously reported case histories describe similar associations of D. fragilis infection with abdominal pain and flatulence (e.g., Halkjær et al., 2015; Norberg et al., 2003). Thus, this study indicates that this protozoan should not be ruled out in the differential diagnosis of gastrointestinal disturbance caused by intestinal parasitic infections.

5. Conclusions

Our study supports implementation of molecular tools into the parasitology diagnostic laboratory, even in under-resourced settings. Such tools are particularly important for detecting protozoa that are challenging to identify by microscopy (e.g., D. fragilis). Molecular tools are also essential for distinguishing between morphologically identical species that are of differing clinical relevance (e.g., E. histolytica and E. dispers).

Although often more sensitive than microscopy, the disadvantages of excess sensitivity of molecular methods should, as previously noted, also be taken into account. In addition, the value of maintaining competence and experience in microscopy techniques in the diagnostic laboratory should not be overlooked.

Thus, in our experience, molecular and traditional techniques have overlapping, but complementary, roles in diagnosing protozoan infections resulting in clinical manifestations in patients.

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Transparency declarations

There are no conflicts of interest to declare.

Ethical statement

The study was approved by the Ethics Commission of IPK and the Pediatric Hospital William Soler (Project Code: 20009).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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