

## DETECTION OF HUMAN INTESTINAL PROTOZOA BY USING MULTIPLEX ALLELE SPECIFIC POLYMERASE CHAIN REACTION (MAS-PCR)

In New Damietta City

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### ABSTRACT

Enteric protozoa continue to be the most commonly encountered parasitic diseases causing significant morbidity and mortality in developing regions of the world affecting millions of people. This study assessed the use of Multiplex Allele Specific Polymerase Chain Reaction (MAS-PCR) assay and microscopy for detection and identification of common pathogenic protozoan parasites in New Damietta city of North Delta region, Egypt. During Jun 2013 until Sept 2013, fresh stool samples were obtained from 249 patients up to 65 years of age attending the internal clinic of the Damietta University Hospital and those visiting their general practitioner (GP) of outpatient clinics because of gastrointestinal symptoms. Stool samples collected was preserved at -200C for DNA extraction whilst the remaining was preserved in sodium acetate-acetic acid formalin and concentrated using the formol-ether technique for microscopic examination. DNA extracts were analyzed with the multiplex allele specific Polymerase Chain Reaction (MAS-PCR) for pathogenic protozoan parasites. The diagnostic results obtained using a multiplex allele specific PCR for the detection of *E. histolytica/dispar*, *G. lamblia* and *C. parvum/C. hominis* were compared with these obtained by routine microscopy of faecal samples from patients. 69 samples were positive by MAS-PCR assays, 9 cases of *G. intestinalis* infection, 34 cases of *D. fragilis* infection, 3 cases of *E. histolytica* infection, 17 cases *E. dispar* and 6 cases of *Cryptosporidium* infection in the clinical samples. By microscopy, only 32 samples were positive for one or more of the enteric protozoa, 5cases of *G. intestinalis* infection, 9cases of *D. fragilis* infection, 13 cases of *E. histolytica* infection, and 1 cases of *Cryptosporidium* infection in the clinical samples. However, there are no cases of *E. dispar* observed. Mixed infections were detected in 4 samples. The sensitivities varied from 58% for *D. fragilis* to 47% for *E. histolytica*, 35% for *Giardia*, and 30% for *Cryptosporidium*, while the specificities also varied from 97% for *E. histolytica* to 99% for *D. fragilis* and 100% for *E. dispar*. No cross-reactivity was detected in stools samples containing various bacterial, viral, and other protozoan species. This present study showed relatively high rates of protozoa infections in the study patients. The study has also demonstrated that the multiplex real time PCR assay was more sensitive compared to microscopy in the diagnosis of the intestinal protozoa parasites and thus, molecular methods must be considered the diagnostic methods of choice for enteric protozoan parasites.

**Keywords:** Human intestinal protozoa, Stools specimens, Microscopy, Multiplex Allele Specific Polymerase Chain Reaction (MAS-PCR), Diagnosis.

### INTRODUCTION

Enteric protozoa continue to be the most commonly encountered parasitic diseases and to cause significant morbidity and mortality throughout developing regions of the world, affecting millions of people each year<sup>(36&60)</sup>. Numerous protozoa inhabit the gastro-intestinal tract of humans. The majorities of these protozoa are non-pathogenic, or only result in mild disease. Some of these organisms can cause severe disease under certain circumstances. For example, *Giardia lamblia* can cause severe acute diarrhea which may lead to a chronic diarrhea and nutritional disorders; *Entamoeba histolytica* can become a highly virulent and invasive organism that causes a potentially lethal systemic disease<sup>(36)</sup>. Apicomplexa and microsporidia species can cause severe and life-threatening diarrhea in AIDS patients and other immunocompromised individuals<sup>(32&51)</sup>.

Laboratory diagnosis of these protozoan parasites for many years has relied on the traditional microscopic examination of stool samples. This is regarded as the gold standard when performed by an

experienced and a highly skilled microscopist. However, the sensitivity and specificity of the microscopic technique has been found to be rather low<sup>(44&50)</sup>. It is laborious and requires long professional training and may present false positive and negative results. The principal limitation of this method is its inability to differentiate closely related species and heterogeneity within species, as it is often difficult to differentiate cysts of the pathogenic from the non-pathogenic intestinal protozoa<sup>(11)</sup>.

To optimize parasite detection and identification, other diagnostic methods have been developed such as the Immunofluorescence (IF), Enzyme-linked immunosorbent assay (ELISA), culture and subsequent differentiation by isoenzyme analysis and the Polymerase Chain Reaction (PCR). These have been introduced as alternative methods that are more sensitive and specific, however, these applications also have some limitations<sup>(56)</sup>.

Recently, more specific and sensitive alternative PCR methods have been introduced for all of these parasitic infections<sup>(45&58)</sup>. However, the

incorporation in a routine diagnostic laboratory of these parasite-specific methods for diagnosis of each of the respective infections is time-consuming and increases the costs of a stool examination. Traditionally parasites have been identified by simple microscopy, serologic and PCR methods<sup>(25&48)</sup>.

The traditional PCR protocols require further processing of the amplicon, which is time-consuming and prone to false-positive results due to possible cross-contamination. In an effort to improve on the PCR protocol, the multiplex allele specific PCR has been developed which is able to circumvent the problems associated with the traditional PCR and the other detection methods.

This method allows specific detection of the amplicon, discriminating between *E. histolytica*, *E. dispar*, *G. lamblia*, and *C. parvum* in a single assay by binding to one or two fluorescence-labeled probes during PCR.<sup>(48)</sup>

A Multiplex Allele Specific Polymerase Chain Reaction (MAS-PCR) was developed for the simultaneous detection of intestinal protozoa infections in stool samples, it is capable of detecting the minimum amounts of organisms required to cause disease and the presence of multiple protozoan species in a single clinical sample<sup>((61&66)</sup>. This improves the diagnosis of parasitic diarrheal infection, hence patient management<sup>(76)</sup>. The multiplex PCR also included an internal control to determine efficiency of the PCR and detect inhibition in the sample. The assay was performed on species-specific DNA controls and a range of well-defined stools samples, and it achieved 100 percent specificity and sensitivity. The use of this assay in a diagnostic laboratory would provide sensitive and specific diagnosis of the main parasitic infections and could improve patient management and infection control<sup>(23)</sup>.

*Cryptosporidium* is an important diarrhea-causing parasitic protozoan found in both humans and animals<sup>(1&19)</sup>.

PCR-based methods has been shown to be sensitive and specific for the detection of *C. parvum* in clinical specimens and environmental samples<sup>(62,73,&75)</sup>. PCR-RFLP and PCR followed by DNA sequencing analysis have been described as reliable approaches for the distinction of *C. hominis* from *C. parvum* (formerly known as *C. parvum* genotypes 1 and 2, respectively)<sup>(37,52&53)</sup>. Nevertheless, they are time-consuming and labour-intensive, making them

inadequate for a rapid diagnostic response during outbreak investigations.

A Multiplex Allele Specific Polymerase Chain Reaction (MAS-PCR) with specific primers and probes represents an alternative to conventional PCR for increasing the speed of sample analysis while decreasing the potential risks for contamination of the laboratory environment with amplicons<sup>(23)</sup>.

The causative agent of amebic colitis and liver abscess is *E. histolytica*<sup>(54)</sup>. The non pathogenic parasites *E. dispar* and *E. moshkovskii* are more common and identical in appearance to *E. histolytica*<sup>(29)</sup>. *E. dispar* and *E. histolytica* are morphologically identical and phylogenetically closely related<sup>(71)</sup>. Both of *E. histolytica* and *E. dispar* are able to colonize humans but only *E. histolytica* is able to cause invasive disease (colitis and extraintestinal manifestations)<sup>(47)</sup>. Tissue destruction is not seen with *E. dispar* in vivo. Earlier a panel of researchers concluded that colonization with *E. dispar* has never been documented to cause invasive disease in humans therefore the parasite does not necessitate treatment<sup>(69)</sup>. *Giardia* is a binucleated flagellated protozoan and these parasites can be found in mammals and other animals, including reptiles and birds<sup>(41)</sup>. *G. lamblia* is the most commonly isolated intestinal parasite throughout the world. Prevalence rates of 20-40% are reported in developing countries, especially in children<sup>(20)</sup>. There are two distinct genotypes of *G. lamblia* that infect humans, commonly referred to as assemblages A and B. Molecular analyses have shown the genetic variance between the two assemblages to be greater than that used to delineate other species of protozoa<sup>(24)</sup>.

*Dientamoeba fragilis* is a pathogenic protozoan parasite that infects the mucosa of the large intestine, causing gastrointestinal disease in humans. Diagnosis of *D. fragilis* relies on direct visualization of the trophozoites in stained fixed fecal smears by light microscopy. *D. fragilis* may be difficult to distinguish from nonpathogenic protozoa<sup>(24, 14&57)</sup>.

The objective of this work is to detection and identification of common pathogenic protozoan parasites in New Damietta city of North Delta region in faecal samples of patients and to compare the prevalence of *E. histolytica*, *G. lamblia* and *C. parvum* using microscopy and multiplex allele specific PCR diagnostic methods. Also, to compare the test performance characteristics of microscopy and MAS-PCR to an expanded gold standard in the

diagnosis of protozoa parasites in faecal samples of patients with gastrointestinal symptoms.

## MATERIAL AND METHODS

### Study area.

The Damietta University Hospital is a major hospital serving New Damietta City and other parts of Damietta government of North Delta, Egypt. The hospital's coverage population is approximately 100,000 people. The laboratory department and molecular biology unit of the hospital offers diagnostic as well as research services.

### Study population.

All 175 symptomatic (70.30%) and 74 asymptomatic (29.70%) population up to 65 years old and permanently residing in New Damietta City who attend the internal Clinic of the hospital were included in this study and fulfilled the inclusion criteria i.e. Attending the internal clinic of the Damietta University Hospital visiting their general practitioner (GP) of outpatient clinics because of gastrointestinal symptoms and these who attended the clinic for their normal checkups. The age of the patients range from 0–65 years (median 33 years).

The group examined contained significantly fewer children aged <15 years. Fecal specimens ( $n = 249$ ) submitted to the Department of parasitology and molecular biology unit, Faculty of Medicine (Damietta) at University Damietta Hospital. Specimens from outpatients were collected and submitted to the laboratory as a fresh specimen for investigation from Jun 2013 until Sept 2013, along with a portion mixed with sodium acetate-acetic acid-formalin (SAF) preservative<sup>(65)</sup>.

### Sample processing.

Labeled sterile containers with a collecting spoon were provided to all the cases and evaluation of clinical and socioeconomic condition of cases was done at clinic.

Stools sample was collected from each case. The Fresh stool samples were transported to the laboratory immediately for analysis. Stool samples (0.2g) were kept in a labeled 2.0ml Eppendorf tubes and frozen at -20°C without preservative for molecular analysis. The remaining portions of the stools were preserved in Sodium-acetate acetic acid formalin solution (SAF) for microscopy and the formol-ether concentration method. The concentrate (sediments) was divided into two portions. One portion in a 15ml Falcon tube was stained with Lugol's iodine. Smear preparation of the other portion on clean dry 76mm x 26mm microscopy slide was stained with the modified Ziehl–Neelsen stain<sup>(23)</sup>.

### Microscopy.

Unpreserved samples were investigated for trophozoites and cysts by microscopy of iodine-stained wet-mount preparations of a formalin–ether concentrate<sup>(8)</sup>.

Sodium acetate acetic acid formalin-preserved samples were first screened by iodine-stained direct smears. Parasite-like structures were confirmed by microscopy of Modified Ziehl–Neelsen staining for the detection of *Cryptosporidium* was performed and examined by oil immersion microscopy ( $\times 1000$  magnification)<sup>(46&27)</sup>

### DNA extraction.

DNA were extracted and purified using the QIAamp DNA Stools mini kit (Qiagen, Hilden, Germany). The extraction was done according to the manufacturer's protocol and according to<sup>(58&69)</sup>.

In brief, 100  $\mu$ L of faecal suspension was added to 2 mL of lysis buffer and incubated at room temperature for 10 min, after which an internal control (Phocin herpes virus-1 (PhHV-1);  $c. 6000$  copies/sample) and 50  $\mu$ L of magnetic silica particles were added. The mixture was mixed and incubated for 10 min at room temperature. After centrifugation for 2 min at 1500  $g$ , the supernatant was removed by aspiration and the pellet of silica–nucleic acid complexes was resuspended and washed in three washing buffers. Each washing step was conducted for 30 second on step 1 of the miniMAG instrument, with the exception of wash buffer 3 (15 s on step 1), after which the fluid was removed by aspiration. DNA was eluted in 100  $\mu$ L of elution buffer for 5 min at 60°C on a thermo shaker (Eppendorf, Hamburg, Germany) at 1400 rpm. The extracted DNA was stored at -20°C.

### MAS-PCR.

Multiplex Allele Specific Polymerase Chain Reaction PCR assay was performed on DNA eluates from all the stools samples using the Corbett Rotor Gene 6000 (Corbett life sciences, Australia) from the high-copy-number, ribosomal DNA-containing *Amoeba*, *Giardia*, *D. fragilis* and *Cryptosporidium* episomes with the following specific primers (Widmer *et al.*, 2000).

*E. histolytica*, Ehd239F(5'ATTGTCGTGGCCTCCTA ACTCA3'), Ehd88R(5'GCGGACGGCTCATTATAAC A3'), *E. dispar* were: Ed 15-GAAGAAACATTGTTTCTAAATCCA-3(18S)G. *Giardia*-80F(5'-GACGGCTCAGGACAACGGTT3'), *Giardia*127R(5'TTGCCAGCGGTGTCCG3'); *Cryptosporidium* spp., CrF (5'CGCTTCTCTAGCCTTTTCATGA3'), CrR(5'CTTCACGTGTGTTTGCCAAT3'), and *Crypto*(TexasRed5'C

CAATCACAGAATCATCAGAATCGACTGGTATC 3'D.fragilissamplesDF3(5'GTTGAATACGTCCCTG CCCTTT3')andDF4(5'TGATCCAATGATTTCACCG AGTCA-3') Oligos were designed from the region of maximum mismatch in the 18S rRNA and ITS-2. (Novati *et al* 1996; Som *et al* 2000).

Amplification conditions were: denaturation at 94°C for 1 min, annealing at 45°C for *E. histolytica* specific primers and 40°C for *E. dispar* specific primers, followed by extension at 72°C for 1 min. The amplification was carried out for 30 cycles in a DNA Thermal cycler (MJ Research, USA) PCR was performed in 25-µL volumes containing PCR buffer, 5 mM MgCl<sub>2</sub>, 2.5 µg of bovine serum albumin, 12.5 pmol of forward primer annealing to both *E. histolytica*, *E. dispar*, 6.25 pmol of *E. histolytica*-specific reverse primer (CP-HR) and 6.25 pmol of *E. E. dispar* C-specific reverse primer (CP-CR).

**PCR amplification and detection.** Amplification reactions were performed in 25-µL volumes containing PCR buffer (Hotstar mastermix; Qiagen, Venlo, The Netherlands), 5 mM MgCl<sub>2</sub>, 2.5 µg of bovine serum albumin (Roche Diagnostics, Almere, The Netherlands), 3.125 pmol each of the *E. histolytica*- and *G. lamblia*-specific primers, 12.5 pmol of the *Cryptosporidium*-specific primer, 1.25 pmol of VIC-labelled MGB-*Taqman* probe (Applied Biosystems, Warrington, UK) for *E. histolytica*, 2.5 pmol of FAM-labelled double-labelled probe (Biolegio, Nijmegen, The Netherlands) for *G. lamblia*, 2.5 pmol of Texas-red-

labelled double-labelled probe for *Cryptosporidium*, and 5 µL of template DNA. For MAS-PCR, the following items were placed on the deck of the liquid-handling system: a strip tube containing step 1 multiplexed primers was placed in the thermal cycler; a gene disc containing lyophilized step 2 primers was placed in a loading block; and oil (for covering PCR mixtures), master mix, and water tubes (all supplied in a kit form) were placed in a reagent block. The samples were directly added to the strip tube in the thermal cycler. Software templates for all reactions were performing. Amplification was detected following electrophoresis in agarose 1% w/v gels stained with ethidium bromide.

**Control group**

Control DNA extracted from an infected clinical sample was used as a positive control for the PCR assays. This control group underwent DNA extraction and MAS-PCR as described above.

**Data analysis.**

Statistical analyses were performed using SPSS v.11.0.1 (SPSS Inc., Chicago, IL, USA).

**RESULTS**

More than seventy percent (70.30%) of the cases who provide stool samples were symptomatic. The ages of study cases ranged from 5 months to 65 years. The mean ages of the symptomatic and asymptomatic were 33 years. Socioeconomic and clinical characteristics of study cases were shown in (Table 1).

**Table 1: Socioeconomic and clinical characteristics of study cases.**

Socioeconomic and health care behavior No. (%)	Housing & Waste disposal No. (%)	Water supply & water contact No. (%)	Clinical symptoms No. (%)	Stool consistency No. (%)
Low 105 (42.3)	Modern building 219 (87.9)	Piped 185 (74.3)	Anemia 19 (7.6)	Firm 90 (36.1)
Moderate 90 (36.1)	Primitiv building 21 (8.4)	River Nile 45 (18.7)	Diarrhea 78 (31.3)	Loose 66 (26.5)
High 24 (9.6)	Sewage disposal 9 (3.6)	Shallow wells 19 (7.6)	Nausea & Vomiting 62 (24.8)	Mucoid 78 (31.3)
consultation for treatmnt 30 (12.4)	Well with chamber disposal 0 (0.0)	Deep wells 0 (0.0)	Headach e, fever, fatigue, pallor & Weight loss 90 (36.1)	Blood stained 15 (6.2)

A total of 69/249 samples(table 3&4) were positive by MAS-PCR assays detected 9 cases of *G. intestinalis* infection, 34 cases of *D. fragilis* infection, 3 cases of *E. histolytica* infection, 17 cases *E.dispar* and 6 cases of *Cryptosporidium* sp. infection in the clinical samples. MAS-PCR showed 100% sensitivity and specificity.

With microscopy, only 32/249 samples(table 2&4)were positive for one or more of the enteric protozoa. Microscopy detected only 5cases of *G. intestinalis* infection, 9cases of *D. fragilis* infection, 13 cases of *E. histolytica* infection and 5 cases of *Cryptosporidium* sp.

Mixed infections of pathogenic and non-pathogenic protozoa, *Entamoeba coli*, *Entamoeba hartmani*, *Endolimax nana*, were detected in 4 samples.

However, there is no cases of *E.dispar* observed. It should be

noted that microscopy cannot differentiate the nonpathogenic, morphologically identical *E. dispar* from the pathogenic *E. histolytica*.

Out of the 13 microscopy-positive *E. histolytica* samples, compared to the PCR methods, only 3were true *E. histolytica* positives.

When microscopy (Figures1-3)was compared to molecular method (Figures 4-7) , the sensitivities varied from 58% for *D. fragilis* to 47% for *E. histolytica*, 35% for *Giardia*, and 30% for *Cryptosporidium*, while the specificities also varied from 97% for *E. histolytica* to 99% for *D. fragilis* and 100% for *E.dispar*. None of the control samples run by MAS-PCR produced a product. No cross-reactivity was seen with the other organisms. A total of 249 fecal samples results included in the study were summarized in Table 4.

**Table 2: Infection rate of protozoa in study cases by microscopy**

Parasites	Total N=249 n (%)	Symptomatic N =175 n (%)	Asymptomatic N =74 n (%)	P value
<i>Entamoeba histolytica/ dispar</i>	13(5.2)	3(1.8)	10(13.6)	<0.097
<i>Giardia lamblia</i>	5(2.0)	3(1.8)	2(2.7)	<0.001
<i>Cryptosporidium species</i>	5(2.0)	4(2.3)	1 (1.4)	<0.999
<i>Dientamoeba.fragilis</i>	9 (3.7)	5(2.9)	4(5.4)	<<0.996

**Table 3: Infection rate of protozoa in study cases by MAS-PCR**

Parasites	Total N=249 n (%)	Symptomatic N =175 n (%)	Asymptomatic N =74 n (%)	P value
<i>Entamoeba histolytica/ dispar</i>	20(8.0)	3(1.8)	17(22.9)	<0.0001
<i>Giardia lamblia</i>	9(3.7)	7(4.0)	2(2.7)	<0.001
<i>Cryptosporidium species</i>	6(2.4)	3(1.8)	3 (4.1)	<0.969
<i>Dientamoeba.fragilis</i>	34 (13.7)	23(13.1)	11(14.9)	<<0.997

**Table 4: summarized results included in the study**

Parasites	PCR Total N=69 n (%)	Sympto TotalN=32 n (%)	Microscopy n (%)
<i>Entamoeba histolytica</i>	3(1.2)	1(3.1)	5(2.0)
<i>Giardia intestinalis</i>	9(3.6)		5(2.0)
<i>Cryptosporidium sp.</i>	6(2.4)		5 (2.0)
<i>Entamoeba dispar</i>	17(6.9)		0 (0.0)
<i>Dientamoeba fragilis</i>	34 (13.6)		9 (3.6)
Mixed Infection	0 (0.0)	4(1.8)	

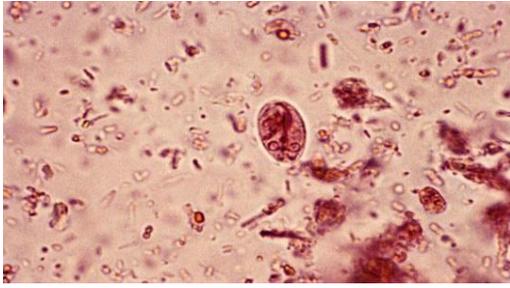


FIG (1) Lugol's iodine stained *Giardia spp* cyst and trophozoite in stool of infected human

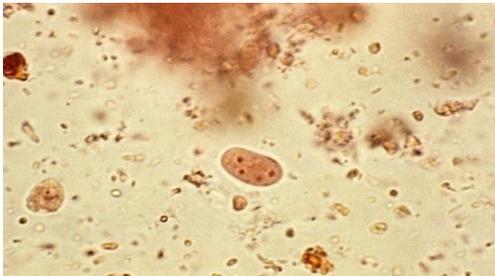


FIG (2) Lugol's iodine stained *Entamoeba spp.*cyst and trophozoite in stool of infected human

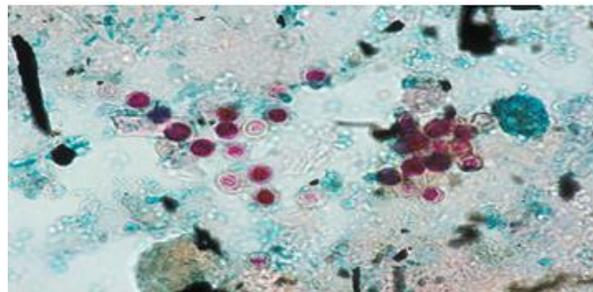
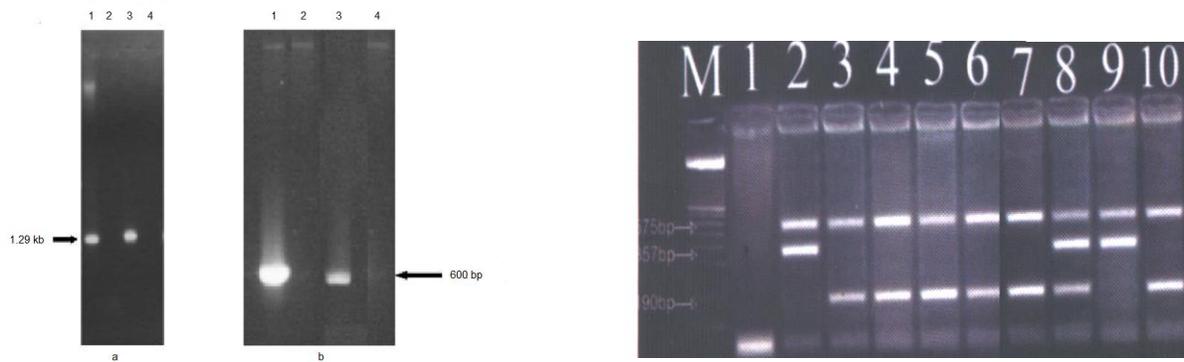


FIG (3): Acid fast *cryptosporidium* oocysts in diarrheal stool of infected human (Modified acid fast stains x1000)

Primers were designed from regions of maximum sequence divergence between *E. histolytica* and *E. dispar*. Primer sequences are given in 18S rDNA and ITS-2 is shown in figure 1. The primer pair (1 + 3) in which one primer was derived from 18S rDNA and the second from ITS-2 amplified the expected 1.29 kb fragment when the *E. histolytica*-specific primer was used with *E. histolytica* DNA but not with *E. dispar* DNA.

Similarly, the *E. dispar*-specific primer pair amplified the 1.29 kb fragment only from *E. dispar*

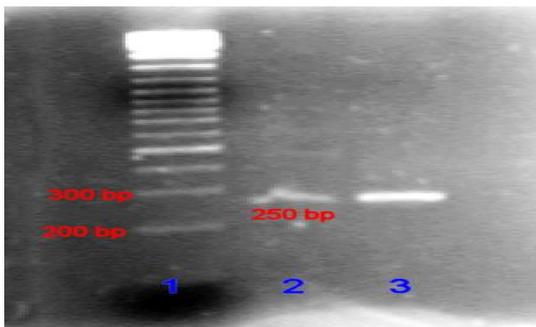
DNA (figure 4A). Since the *E. dispar* DNA used in this study showed absolutely no amplification with the *E. histolytica* primer pair (figure 4A, lane 4), the possibility of any contamination was ruled out. The cloned *EcoRI* fragments of *E. dispar* rDNA were also tested for amplification with *E. histolytica*-specific and *E. dispar*-specific primer pairs derived from 18S rDNA (primer pairs 1 + 2). Both fragments amplified the expected 600 bp band only with the *E. dispar*-specific primer pairs (figure 4B).



**Figure 4 (a & b):** PCR amplification of total genomic DNA of *E. histolytica* (lanes 1 and 2) and *E. dispar* (lanes 3 and 4) with *E. histolytica*-specific primer pairs. Amplified products were separated by electrophoresis through 1% agarose gels for 6 h at 0.8 V/cm.

**Figure (5):** Agarose gel electrophoresis for the products of the multiplex PCR targeting gene of *Cryptosporidium* spp

M 1 2 3 4 5 6 7 8 9 10



**Figure (6):** Agarose gel electrophoresis for the products of the multiplex PCR targeting gene of *Dientamoeba* spp

**Figure (7):** Agarose gel electrophoresis for the products of the multiplex PCR targeting gene of *Giardia* spp

## DISCUSSION

*E. histolytica*, *G. intestinalis*, *Cryptosporidium*, and *D. fragilis* are the four most important and commonly occurring diarrhea-causing parasitic protozoa<sup>(63)</sup>. Therefore, it is essential that correct diagnosis be made, as all four protozoa can be successfully treated with a range of antiprotozoal drugs<sup>(31)</sup>. Infection with *these* parasites is rare, but its high morbidity and, in particular, mortality make accurate diagnosis crucial<sup>(6)</sup>.

The Multiplex Allele Specific Polymerase Chain Reaction (MAS-PCR) assay for the detection of *Cryptosporidium*, *Dientamoeba*, *E. histolytica/dispar*, and *G. intestinalis* presented here provides an additional diagnostic tool for the rapid, sensitive, and specific detection of these enteric protozoa<sup>(23&66)</sup>. The intestinal parasite with the highest prevalence in Delta region is *D. fragilis*

followed by *Entamoeba histolytica*, *Giardia lamblia*<sup>(16&50)</sup>. About 40–50 million people develop clinical amoebiasis each year, resulting on up to 100 000 deaths<sup>(72)</sup>. In the present study a total of 13(5.2%) *Entamoeba histolytica/dispar* prevalence was observed by microscopy but *Entamoeba histolytica* and *Entamoeba dispar*-specific DNA amplification using the multiplex allele specific polymerase chain reaction identified only 3(1.2%) *E. histolytica* cases and revealed a considerably higher prevalence of *Entamoeba dispar* 17(9.6%). This observation compares well with results obtained in a similar study conducted in northern Ghana by<sup>(68&70)</sup>, that showed a high prevalence (9.8%) of *E. histolytica/dispar* complex by microscopy and 8.8% of *Entamoeba dispar* but only one case of *Entamoeba histolytica* by PCR. These results agree with Samuel Ekuban<sup>(15)</sup>; in North

District of the Ashanti Region. In consonance with other studies<sup>(33)</sup>. This study showed a high prevalence of *Giardia lamblia* in asymptomatic cases. This suggests that *Giardia lamblia* infection either presents sub-clinically or the protozoa have limited pathogenicity. Analysis of 722 faecal DNA samples by Hove *et al.*,<sup>(24&31)</sup> in the Netherland revealed that a prevalence rate of 9.3% of *G. lamblia* by PCR, as compared to 5.7% by microscopy. From a total of 480 patients and apparently healthy Egyptian selected, the prevalence rate of *G. lamblia* infection detected by concentration-sedimentation method was 11.0 %<sup>(17&26)</sup>

The primers used in the current study were aimed at detecting *Cryptosporidium parvum* (type II). This is because *C. parvum* is known to infect almost all mammals, including humans, and is a major pathogen of calves. Humans are infected with *C. parvum* in a zoonotic cycle<sup>(28)</sup>. In this study 5.6% by PCR of symptomatic and asymptomatic recruited cases were found to be infected with *Cryptosporidium parvum*. The overall prevalence of 4.4% and 4.9% by PCR and microscopy respectively. This study has demonstrated that *C. parvum* infection is predominantly common among children and is detected more frequently from symptomatic children than asymptomatic indicating that children with diarrhoea and/or vomiting are more likely to be infected with the protozoa<sup>(28&45)</sup>. This is consistent with a previous study in Egypt by Abdel-Messih *et al.*,<sup>(2)</sup>. However these findings contradict the findings of<sup>(21)</sup> in Keny and<sup>(3)</sup> in Accra who indicated that *Cryptosporidium* infections were highest among children and adult. Classically, diagnosis of *Giardia*, *Cryptosporidium* and *E. histolytica* infections is achieved by microscopical examination of faecal samples<sup>(22)</sup>. However, microscopy has several important disadvantages: (i) correct identification depends greatly on the experience and skills of the microscopist; (ii) sensitivity is low, and therefore examination of multiple samples is needed; (iii) *E. histolytica* cannot be differentiated from the non-pathogenic *Entamoeba dispar* simply on the basis of the morphology of cysts and small trophozoites; and (iv) in settings with relatively large numbers of negative results<sup>(66-70)</sup>. Although molecular methods such as PCR have proven to be highly sensitive and specific for the detection of *E. histolytica*/*E. dispar*, *G. lamblia* and *C. parvum*/*C. hominis* infections<sup>(40)</sup>, their use in routine diagnostic laboratories is still very

limited<sup>(7&34)</sup>. The introduction of molecular methods has been hindered by time-consuming methods for the isolation of DNA from faecal specimens and the presence of inhibitory substances in such samples<sup>(18,42&43)</sup>. Furthermore, amplification of DNA was previously laborious and expensive, and cross-contamination among samples was a notorious problem. However, newly developed methods have greatly reduced these obstacles<sup>(20&67)</sup>. A multiplex PCR reduces labour time, reagent costs and the risk of cross-contamination, and offers the possibility of detecting multiple targets in a single multiplex reaction. A multiplex PCR has been described for the simultaneous detection of the three most important diarrhoea-causing parasites, i.e., *E. histolytica*, *G. lamblia* and *C. parvum*/*C. hominis*, and has demonstrated high sensitivity and specificity with species-specific DNA controls and a range of well-defined stool samples<sup>(66)</sup>. However, the role of this assay as a diagnostic tool in a routine clinical laboratory requires further evaluation with respect to large-scale screening and improved patient diagnosis<sup>(9&35)</sup>. This study highlights the lack of sensitivity that conventional staining techniques that are commonly used in most diagnostic laboratories provide for the diagnosis of these infections. The sensitivity of microscopy is as less as 60% and confounded with misleading results due to misidentification of macrophages as trophozoites, (polymorpho nuclear leukocytes) PMNs as cysts (particularly when lobed nuclei of PMNs break apart), and other *Entamoeba* species. It was also showed that the assay is the most sensitive method for differential detection of *E. histolytica* and *E. dispar* because it is able to detect as little as 0.2 pg for *E. histolytica* and 2 pg each for both *E. dispar* DNA, whereas a single round PCR assay can detect 9.5 pg of *E. dispar* and 19 pg of *E. histolytica*<sup>(68&70)</sup>. The main purpose of detection and differentiation of *E. histolytica* species in stools samples is the detection of the causative agent of amoebic dysentery. We showed that this multiplex PCR assay was capable of detecting nearly all of (17/20) the suspected *E. histolytica* cases and showed that some of them were actually positive for *E. dispar*, 17 cases of and only three cases of *E. histolytica*. The MAS- PCR was shown to possess a higher level of sensitivity (100%) for the detection of *E. dispar* in feces. This shows that our MAS- PCR is highly sensitive, capable of detecting target DNA at a copy number that the conventional microscopy unable to detect, agreement with<sup>(11,36&60)</sup>. On the basis of MAS- PCR assay, the number of

*E. histolytica* positive cases found in stools samples is about 3 times higher than *E. dispar*.

This result clearly indicates that the method used in diagnosis of amoebiasis could significantly affect estimates of the actual number of *Entamoeba* infections in North Delta supports that *E. dispar* infection is, in general, much more common than *E. histolytica* coincided with similar study in Netherlands by Hove<sup>(31)</sup>. Microscopy detected only 32/249 positive samples compared to 69/249 for the MAS-PCR assay. Compared to both assays, the sensitivity of microscopy ranged from 38% for *D. fragilis* up to 56% for *Cryptosporidium*. Previous studies by<sup>(55)</sup>, have produced similar findings. When comparing microscopy, conventional PCR, and PCR for the detection of *D. fragilis*, it was found that, compared to MAS-PCR, microscopy had a sensitivity of only 34%; this is similar to the 38% found in this study<sup>(56)</sup>. Detection of the other parasite-specific DNAs has also been shown to be more sensitive than microscopy, as it has for *Giardia* infections, for *Cryptosporidium* infections, and for amoebic infection with *E. histolytica*- and *E. dispar*-specific<sup>(23&49)</sup>. The present study revealed that significant numbers of *E. dispar* and *Cryptosporidium* infections remain undetected by microscopy in patients with gastrointestinal symptoms who consult their GP. Furthermore, the number of additional parasites detected with microscopy was shown to be limited in this population. Therefore, the introduction of MAS-PCR for the routine detection of diarrhoea-causing protozoa would improve the diagnostic efficiency of laboratories dealing with faecal samples from this patient group<sup>(5,23&66)</sup>.

The data indicate that the use of microscopy alone for general, routine parasitological diagnosis has limited diagnostic value. It appears that the rationale for developing and implementing molecular screening platforms, combined with microscopy-based and specialized analyses where appropriate<sup>(8,36&59)</sup>. In both the clinical samples and control samples tested the MAS-PCR for the detection of *Cryptosporidium*, *Dientamoeba*, *E. histolytica*, and *G. intestinalis* achieved a sensitivity and specificity of 100% Compared to previously published MAS-PCR assays targeting<sup>(36&38)</sup>. The same organisms, in all samples tested in which microscopy revealed the presence of *Cryptosporidium*, *Dientamoeba*, *E. histolytica*, and *G. intestinalis*, specific amplification was detected. However, MAS-PCR detected an additional

69 positive samples (6 *Cryptosporidium*, 34 *D. fragilis*,

17 *E. histolytica*, 3 *E. dispar* and 9 *Giardia*). The assay also was found not to cross-react with various other viral, bacterial, and protozoal fecal pathogens. The four samples previously suspected as mixed infection cases of *Entamoeba coli* with *E. histolytica* and positive by our MAS-PCR assay were confirmed that they were *E. coli* infections. Therefore, further development of molecular diagnosis for detection of other nonpathogenic *Entamoeba* species commonly found in humans, such as *E. coli* and *E. hartmanni*, will lead to specific identification and provide the true prevalence of these amoebae in epidemiological studies<sup>(12,13&58)</sup>. Because of the excellent specificity and sensitivity of MAS-PCR in this study, we propose its application as an alternative tool in routine diagnosis and in epidemiological studies of intestinal parasites. This method will provide more accurate epidemiological data and a greater understanding of infections with these parasites in humans<sup>(38,39,76&77)</sup>.

In summary, Traditionally, microscopy has been the method of choice; however, for diagnosis of enteric protozoans, molecular methods are now considered the gold standard for diagnosis, given the excellent sensitivities and specificities achieved by molecular methods. Although PCR-based assays have been successfully used for all organisms, this assay to provide detection of the four different targets in one commercially available kit. This is study developed and evaluated a multiplex PCR (MAS-PCR) assay for the simultaneous detection and identification of *Cryptosporidium*, *D. fragilis*, *E. histolytica*, and *Giardia* in human fecal samples. In the future, the implementation of such multiplex assays will have a tremendous impact on routine diagnostic laboratories, as these parasite targets could be combined with both viral and bacterial causes of diarrhea. This would represent a major advance in the differential laboratory diagnosis of diarrheal diseases in general.

## REFERENCES

1. Alyousefi, M. A. K. ; Mahdy, Y. A. L. ;Lim, L. X. and Mahmud R .(2010): First molecular characterization of *Cryptosporidium* in Yemen. Parasitology .140: 729- 734.
2. Abdel-Messih I.A., Wierzba T.F., Abu-Elyazeed R., Ibrahim A.F., Ahmed S.F., Kamal K., Sanders J. and Frenck R. (2005) Diarrhea associated with *Cryptosporidium parvum* among young children of

- the Nile River Delta in Egypt. *J Trop Pediatr* 51, 154-159.
3. Adjei A.A., Armah H., Rodrigues O., Renner L., Borketey P., Ayeh-Kumi P., Adiku T., Sifah E. and Lartey M. (2004) *Cryptosporidium* Spp., a frequent cause of diarrhea among children at the Korle-Bu Teaching Hospital, Accra, Ghana. *Jpn J Infect Dis* 57, 216-219.
  4. Amar, C.; McLauchlin, J.; Pedraza-Diaz, S. and Nichols, G. L.(2001): Molecular epidemiological analysis of *Cryptosporidium* spp. in the United Kingdom: results of genotyping *Cryptosporidium* spp. in 1,705 fecal samples from humans and 105 fecal samples from livestock animals. *J Clin Microbiol.* 38:3984–3990.
  5. Ash, L. and Orihel, T. (1987): Collection and preservation of feces.: *a Guide to Laboratory Procedures and Identification*. Chicago: American Society of Clinical Pathologists.28:1-8.
  6. Blessmann, J. ;Buss, H. and Nu, P. (2002): Real-time PCR for detection and differentiation of *Entamoeba histolytica* and *Entamoeba dispar* in fecal samples. *J Clin Microbiol.* 40: 4413–4417.
  7. Boom, R.; Sol, C. and Weel, J. (2003): Detection and quantization of human cytomegalovirus DNA in faeces. *J Virol Methods.* 84: 1–14.
  8. Bruijnesteijn, v.; Coppentraet, L.E.; Wallinga, J.A.; Ruijs, G.J.; Bruins, M.J. and Verweij J.J. (2009):Parasitological diagnosis combining an internally controlled real-time PCR assay for the detection of four protozoa in stool samples with a testing algorithm for microscopy. *Clin. Microbiol. Infect.*15: 869–874.
  9. Caccio, S.; Spano, F. and Pozio, E. (2001): Large sequence variation at two microsatellite loci among zoonotic (genotype C) isolates of *Cryptosporidium parvum*. *Int J Parasitol.* 31: 1082–1086.
  10. Casemore, D. P.; Armstrong, M. and Sands, R. L. (1985): Laboratory diagnosis of *cryptosporidiosis*. *J Clin Pathol.* 38: 1337–1341.
  11. Chalmers R.M., Smith R., Elwin K., CliftonHadley F. A., and Giles M.(2010):Epidemiology of anthroponotic and zoonotic human cryptosporidiosis in England and Wales, 2004–2006. *Epidemiol. Infect.* 12:1–13.
  12. Clark ,C.G. and Diamond, L.S. (1997): Intraspecific variation and phylogenetic relationships in the genus *Entamoeba* as revealed by riboprinting. *Journal of Eukaryotic Microbiology.* 44(2):142–154.
  13. Clark, C.G. and Diamond, L.S. (2000): The Laredo strain and other ‘*Entamoeba histolytica*-like’ amoebae are *Entamoeba moshkovskii*. *Molecular and Biochemical Parasitology.* 46(1):11–18.
  14. Crotti, D. ; D'Annibale, M. L. ; Fonzo, G. ; Lalle, M. Caccio, S. M. and Pozio, E. (2005): *Dientamoeba fragilis* is more prevalent than *Giardia duodenalis* in children and adults attending a day care centre in Central Italy. *Parasite* 12:165-170.
  15. Ekou, J.; Nakavuma, J.L.; Erume, J. and Ocaido, M. (2012):PCR detection of *Entamoeba histolytica* in microscopically positive stool samples of hospital patients in Soroti ,Eastern Ughanda. *A. J. Clin. Exper .Microbiol.*14(1): 5-9
  16. El Shazly, A.M.; Soltan, D.M.; El-Sheikha, H.M.; Sadek, G.S. and Morsy, A.T. (2007): Correlation of ELISA coproantigen and oocysts count to the severity of cryptosporidiosis *parvum* in children. *J Egypt Soc Parasitol* 37(1): 107-120
  17. El-Naggar S.M., El-Bahy M.M., Abd Elaziz J. and El-Dardiry M.A. (2006) Detection of protozoal parasites in the stools of diarrhoeic patients using different techniques. *J Egypt Soc Parasitol* 36, 7-22.
  18. Espy, M.J. ; Uhl, J.R. and Sloan, L.M. (2003): Real-time PCR in clinical microbiology: applications for routine laboratory testing. *Clin Microbiol Rev.*19: 165–256.
  19. Fayer, R. (2004): *Cryptosporidium*: a water-borne zoonotic parasite. *Vet Parasitol.* 126: 37–56.
  20. Fraser, D. (1994) Epidemiology of *Giardia lamblia* and *Cryptosporidium* infections in childhood. *J Med Sci* 30: 356-361.
  21. Gatei, W.; Ashford, R. W.; Beeching, N. J.; Kamwati, S. K.; Greensill, J. and Hart, C. A. (2002):*Cryptosporidium muris* infection in an HIV-infected adult, Kenya. *Emerg Infect Dis.* 8: 204–206.
  22. Ghosh, S.; Debnath, A.; De Sil, A.S.; Chattopadhyay; D.J. and Das, P. (2002): PCR detection of *Giardia lamblia* in stool: targeting intergenic spacer region of multicopy rRNA gene. *Mol Cell Probes.* 14: 181–189.
  23. Giles, M.; Warhurst, D. and Webster, K. (2002): A multiplex allele specific polymerase chain reaction (MAS-PCR) on the di-hydrofolate reductase gene for the detection of *Cryptosporidium parvum* genotypes 1 and 2. *Parasitol.* 125:35-44.
  24. Girginkardesler, N. S. ;Coskun, I. ;Cuneyt, P. and Ertan, S. (1998): *Dientamoeba fragilis*, a neglected cause of diarrhoea, successfully treated with secnidazole. *Clin. Microbiol. Infect.* 9:110-113.
  25. Gool, T.; Weijts, R.; Lommerse, E. and Mank, T.G. (2003): Triple Faeces Test: an effective tool for detection of intestinal parasites in routine clinical practice. *Eur J Clin Microbiol Infect Dis.* 22: 284–290.
  26. Graczyk, T. K.; Cranfield, M. R. and Fayer, R. (1996): Evaluation of commercial enzyme immunoassay (EIA) and immunofluorescent antibody (FA) test kits for detection of *Cryptosporidium* oocysts of species other than *Cryptosporidium parvum*. *Am J Trop Med Hyg.* 54: 274–279.
  27. Hadfield, G.; Stephen, J.; Robinson, E. and Elwin, K. (2011):Detection and Differentiation of *Cryptosporidium* spp. in Human Clinical Samples by

- Use of Real-Time PCR. *J Clin Microbiol.* 49(3): 918-24.
28. Hashim A., Mulcahy G., Bourke B. and Clyne M. (2006) Interaction of *Cryptosporidium hominis* and *Cryptosporidium parvum* with primary human and bovine intestinal cells. *Infect Immun* 74, 99-107.
  29. Haque, R., Ali ,K.M.; Clark, C.G.; Petri ,F. and WA, J.R. (1998): A case report of *Entamoeba moshkovskii* infection in a Bangladeshi child. *Parasitology International.* 47(3):201-202.
  30. Haque, R.; Roy, S.; Kabir, M.; Stroup, S.E.; Mondal, D. and Houpt, E.R. (2005) *Giardia assemblage A* infection and diarrhea in Bangladesh. *J Infect Dis.* 192: 2171-2173.
  31. Hove, R.T. (2007): Detection of diarrhoea-causing protozoa in general practice patients in The Netherlands by multiplex real-time PCR. *Clin. Microbiol. Infect.* 13: 1001-1007.
  32. Kappus, K.D.; Lundgren, R.G.; Juranek, D.D.; Roberts, J.M. and Spencer, H.C. (1994): Intestinal parasitism in the United States: update on a continuing problem. *The American Journal of Tropical Medicine and Hygiene.* 50(6):705-713.
  33. Klaus R., Ignatius R., Weitzel T., Seidu-Korkor A., Anyidoho L., Saad E., Djie-Maletz A., Ziniel P., Amoo-Sakyi F., Danikuu F., Danour S., Ochwemah R.N., Schreier E., Bienzle U., Stark K. and Mockenhaupt F.P. (2007) Acute childhood diarrhoea in northern Ghana: epidemiological, clinical and microbiological characteristics *BMC Infectious Diseases* 7, 1471-2334.
  34. Kohli, A.; Bushen, O.Y. and Pinkerton, R.C. (2008): *Giardia duodenalis* assemblage, clinical presentation and markers of intestinal inflammation in Brazilian children. *Transactions of the Royal Society of Tropical Medicine and Hygiene.* 102(7):718-725.
  35. Lewthwaite, P.; Gill, G.V.; Hart, C.A. and Beeching, N.J. (2005): Gastrointestinal parasites in the immunocompromised. *Curr Opin Infect Dis.* 18: 427-435.
  36. Lieshout, L. and Verweij, J.J. (2010): Newer diagnostic approaches to intestinal protozoa. *Curr. Opin. Infect. Dis.* 23: 488-493.
  37. McLauchlin, J.; Amar, C.; Pedraza-Diaz, S. and Nichols, G. L. (2000): Molecular epidemiological analysis of *Cryptosporidium* spp. in the United Kingdom: results of genotyping *Cryptosporidium* spp. in 1,705 fecal samples from humans and 105 fecal samples from livestock animals. *J Clin Microbiol.* 38:3984-3990.
  38. Monar, N. (2009): Diagnosis of parasitic diseases old and new approaches. *Infectious diseases vol(1) no.15*
  39. Morgan, U.; Weber, R.; Xiao, L.; Sulaiman, I.; Thompson, R. C.; Ndiritu, W.; Lal, A.; Moore, A. and Deplazes, P. (2000): Molecular characterization of *Cryptosporidium* isolates obtained from human immunodeficiency virus-infected individuals living in Switzerland, Kenya, and the United States. *J Clin Microbiol.* 38: 1180-1183.
  40. Morgan, U.M. and Thompson, R.C.A. (1998): PCR detection of *Cryptosporidium*: the way forward? *Parasitol Today.* 14: 241-245.
  41. Naelah, A. ; Alyousefi, M. and Mahdy, R. M. A. (2010): Molecular characterization of *Giardia duodenalis* in Yemen. *Experimental Parasitology* 2013; 134: 141-147.
  42. Ouattara, M.; Gue'ssan, N.A.; Yapi, A. and N'Goran, E.K. (2012): Prevalence and Spatial Distribution of *Entamoeba histolytica/dispar* and *Giardia lamblia* among School children in Agboville Area (Cote d'Ivoire). *PLoS Negl Trop Dis.* 4:1
  43. Pedraza-Diaz, S.; Amar, C. and McLauchlin, J. (2000): The identification and characterisation of an unusual genotype of *Cryptosporidium* from human faeces as *Cryptosporidium meleagridis*. *Microbiol Lett.* 189: 189-194.
  44. Petri, W.A.; Haque, R.; Lyerly D. and Vines, R.R. (2000): Estimating the impact of amebiasis on health. *Parasitol Today.* 16, 320-321.
  45. Pieniazek, N. J.; Bornay-Llinares, F. J.; Slemenda, S. B.; da Silva, A. J.; Moura, I. N.; Arrowood, M. J.; Ditrich, O. and Addiss, D. G. (1999). New *Cryptosporidium* genotypes in HIV-infected persons. *Emerg Infect Dis.* 5: 444-449.
  46. Robinson, G. (2010): Redescription of *Cryptosporidium mcuniculus* (Apicomplexa: Cryptosporidiida): morphology, biology and phylogeny. *Int. J. Parasitol.* 40:1539-1548.
  47. Romano, N.; Fakhrrrazi A.; Yvonne, A.; Jamaiah, I. and Rohela, M. (2010): Differentiating *Entamoeba histolytica*, *Entamoeba dispar* and *Entamoeba moshkovskii* using nested polymerase chain reaction (PCR) in rural communities in Malaysia. *Parasites and Vectors* 5: 187.
  48. Roy, S.; Kabir, M.; Mondal, D.; Ali, K.M.; Petri, W.A. and Haque, R. (2005): Real-time-PCR assay for diagnosis of *Entamoeba histolytica* infection. *Journal of Clinical Microbiology.* 43(5):2168-2172.
  49. Samie, A.; Bessong, P.O. and Obi, C.L. (2006): *Cryptosporidium* species: preliminary descriptions of the prevalence and genotype distribution among school children and hospital patients in the Venda region, Limpopo Province, South Africa. *Experimental Parasitology.* 114(4):314-322.
  50. Samn, K. A. M. ; Samn, A. A. M. and Abou El-Nour, M. F. (2012): A survey of *Giardia* and *Cryptosporidium* spp. in Rural and Urban community in North Delta, Egypt. *New York Science Journal* .5(3):49-54.
  51. Singh, A.; Houpt, E. and Petri, W.A. (2009): Rapid diagnosis of intestinal parasitic protozoa, with a focus on *Entamoeba histolytica*. *Interdiscip Perspect Infect Dis* .5:47-90.
  52. Spano, F.; Putignani, L.; Guida, S. and Crisanti, A. (1998). *Cryptosporidium parvum*: PCR-RFLP

- analysis of the TRAP-C1 (thrombospondin-related adhesive protein of *Cryptosporidium*-1) gene discriminates between two alleles differentially associated with parasite isolates of animal and human origin. *Exp Parasitol.* 90: 195–198.
53. Spano, F.; Putignani, L.; McLauchlin, J.; Casemore, D. P. and Crisanti, A. (1997). PCR-RFLP analysis of the *Cryptosporidium* oocyst wall protein (COWP) gene discriminates between *C. wrairi* and *C. parvum*, and between *C. parvum* isolates of human and animal origin. *FEMS Microbiol Lett.* 150: 209–217.
  54. Stanley, S.L. ; Jackson, T.F.; Foster, L. and Singh, S. (1998): Longitudinal study of the antibody response to recombinant *Entamoeba histolytica* antigens in patients with amebic liver abscess. *The American Journal of Tropical Medicine and Hygiene.* 58(4):414–416.
  55. Stark, D. J.; Barratt, T.; Roberts, D.; Marriott, J. and Ellis, J. (2010): Comparison of microscopy, two xenic culture techniques, conventional and real-time PCR for the detection of *Dientamoeba fragilis* in clinical stool samples. *Eur. J. Clin. Microbiol. Infect. Dis.* 29:411–416.
  56. Stark, D. N. ;Beebe, D. ;Marriott, J. ;Ellis, and Harkness, J. (2006): Evaluation of three diagnostic methods, including real-time PCR, for detection of *Dientamoeba fragilis* in stool specimens. *J. Clin. Microbiol.* 44:232–235.
  57. Stark, D.; Al-Qassab, S. E.; Barratt, J. L. N.; Stanley, K.; Roberts, T.; Marriott, J.; Harkness, D. and Ellis, J. T. (2011): Evaluation of Multiplex Tandem Real-Time PCR for Detection of *Cryptosporidium* spp. *Dientamoeba fragilis*, *Entamoeba histolytica*, and *Giardia intestinalis* in Clinical Stool Samples. *J Clin Microbiol.* 49(1): 257–262.
  58. Stensvold, C.R. (2013): Blastocystis :genetic diversity ,molecular methods and epidemiology *Tropical Parasitology .* vol(3) no.11
  59. Stensvold, C.R.; Lebbad, M. d. and Verweij J.J. (2011): The impact of genetic diversity in protozoa on molecular diagnostics. *Trends Parasitol.* 27: 53–58.
  60. Stensvold, R.C. and Nielsen, H.V. (2012): Comparison of microscopy and PCR for detection of intestinal parasites in Danish patients supports an incentive for molecular screening platforms. *J Clin Microbiol.* 50(2):540–1.
  61. Stephen, J.; Hadfield, G.; Robinson, E. and Elwin, K. (2011): Detection and Differentiation of *Cryptosporidium* spp. in Human Clinical Samples by Use of Real-Time PCR. *J Clin Microbiol.* 49(3): 918–24.
  62. Sturbaum, G. D.; Reed, C.; Hoover, P. J.; Jost, B. H.; Marshall, M. M. and Sterling, C. R. (2001): Species-specific, nested PCR-restriction fragment length polymorphism detection of single *Cryptosporidium parvum* oocysts. *Appl Environ Microbiol.* 67:2665–2668.
  63. Svenungsson, B.; Lagergren, A. and Ekwall, E. (2000): Enteropathogens in adult patients with diarrhea and healthy control subjects: a 1-year prospective study in a Swedish clinic for infectious diseases. *Clinical Infectious Diseases.* 30(5):770–778.
  64. Tanyuksel, M. and Petri, W.A. (2003): Laboratory diagnosis of amebiasis. *Clinical Microbiology Reviews.* 16(4):713–729.
  65. Troll, H.; Marti ,H. and Weiss, N. (1997): Simple differential detection of *Entamoeba histolytica* and *Entamoeba dispar* in fresh stool specimens by sodium acetate-acetic acid-formalin concentration and PCR. *Journal of Clinical Microbiology.* 35(7):1701–1705.
  66. Verweij , J.J., Roy, A. and Templeton K. (2004): Simultaneous detection of *Entamoeba histolytica*, *Giardia lamblia* and *Cryptosporidium parvum* in fecal samples using multiplex real-time PCR. *J Clin Microbiol.* 3: 1220–1223.
  67. Verweij, J.J.; Blotkamp, J.; Brienens, E.A.T.; Aguirre, A. and Polderman, A.M. (2000): Polymerase chain reaction for differentiation of *Entamoeba histolytica* and *Entamoeba dispar* cysts on DNA isolated from faeces with spin columns. *Eur J Clin Microbiol Infect Dis.* 5: 358–361.
  68. Verweij, J.J.; Oostvogel, F.; Brienens, E.A.; Nang-Beifubah, A., Ziem, J. and Polderman, A.M. (2003a): Short communication: prevalence of *Entamoeba histolytica* and *Entamoeba dispar* in northern Ghana. *Trop Med Int Health.* 8: 1153–1156.
  69. Verweij, J.J.; Polderman, A.M. and Clark, C. (2001): Genetic variation among human isolates of uninucleated cyst-producing *Entamoeba* species. *Journal of Clinical Microbiology.* 39(4):1644–1646.
  70. Verweij, J.J.; Schinkel, J.; Laeijendecker ,D. ;Van Rooyen ,M.A.A.; Van Lieshout, L. and Polderman, A.M. (2003b): Real-time PCR for the detection of *Giardia lamblia*. *Mol Cell Probes.* 17: 223–225.
  71. Visser, L.G.; Verweij, J.J.; Esbroeck, M.; Edeling, W.M.; Clerinx, J. and Polderman, A.M. (2006): Diagnostic methods for differentiation of *Entamoeba histolytica* and *Entamoeba dispar* in carriers: performance and clinical implications in a non-endemic setting. *International Journal of Medical Microbiology.* 96(6):397–403.
  72. W H O (2010): Working to overcome the global impact of neglected tropical diseases. First WHO report on neglected tropical diseases. 172 p.
  73. Webster, K. A.; Smith, H. V.; Giles, M.; Dawson, L. and Robertson, L. J. (1996): Detection of *Cryptosporidium parvum* oocysts in faeces: comparison of conventional coproscopical methods and the polymerase chain reaction. *Vet Parasitol.* 61:5–13.
  74. Widmer, G.; Akiyoshi, D.; Buckholt, M. A.; Feng, X.; Rich, S. M.; Deary, K. M. ;Bowman, C. A.; Xu, P. and Wang, Y. (2000): Animal propagation and genomic survey of a genotype 1 isolate of

- Cryptosporidium parvum*. Mol Biochem Parasitol .108 : 187–197.
75. Xiao, L.; Alderisio, K.; Limor, J.; Royer, M. and Lal, A. A. (2000): Identification of species and sources of *Cryptosporidium* oocysts in storm waters with a small-subunit rRNA-based diagnostic and genotyping tool. Appl Environ Microbiol. 66: 5492–5498.
76. Xiao, L.; Fayer, R.; Ryan, U. and Upton, S. J. (2004): *Cryptosporidium* taxonomy: recent advances and implications for public health. Clin Microbiol Rev. 17: 72–97.
77. Xiao, L.; Bern, C.; Limor, J.; Sulaiman, I.; Roberts, J.; Checkley, W.; Cabrera, L.; Gilman, R. H. and Lal, A. A. (2001): Identification of 5 types of *Cryptosporidium* parasites in children in Lima, Peru. J Infect Dis. 183:492–497.
78. The study was reviewed and approved by the ethics committee of the Investigational Review Board of the Parasitology Department, Faculty of Medicine, Al-Azhar University.