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DIFFERENTIATION OF ENTAMOEBA HISTOLYTTICA/ENTAMOEBA DISPAR BY PCR AND THEIR CORRELATION WITH HUMORAL AND CELLULAR IMMUNITY IN INDIVIDUALS WITH CLINICAL VARIANTS OF AMOEBIASIS

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Abstract. To correlate a particular state of immunity with Entamoeba spp., we used colorimetric PCR to differentiate E. histolytica from E. dispar in individuals with amoebiasis and to associate its presence with the clinical profile, including humoral and cellular immune responses to E. histolytica. Our results showed high levels of antibody in acute amoebiasis and elevation of IL-4 production, a cytokine related to Th2 profile, associated with E. histolytica. In chronic amoebiasis, even with anti-E. histolytica seropositivity, intestinal symptoms were associated with E. dispers in all the cases, without differences in level of antibodies, BTI, CD4+/CD8+ ratio, INF-γ, and IL-4. Among asymptomatic carriers, E. dispar was more frequently found; however, identification of E. histolytica in two asymptomatic carriers associated with high levels of INF-γ, a cytokine related to Th1 profile, demonstrate the importance of making specific diagnosis of Entamoeba spp., to establish the clinical and epidemiological behavior in both intestinal and extra-intestinal amoebiasis.

INTRODUCTION

Amoebiasis continues to be a significant worldwide health problem. It has been estimated that 500 million individuals are infected with the causal agent Entamoeba histolytica and of these, 40 million would develop invasive disease, causing at least 100,000 deaths a year, most of these are secondary to the extra-intestinal complications like hepatic abscesses.1,2

In accordance with epidemic studies carried out in different parts of the world, the seroprevalence found in some communities of developing countries ranges from 5% to 55%.3–7 In 1988, the National Serologic Survey in México showed a seroprevalence of 8.41% for the whole country, highlighting the State of Puebla with 14.98%.8

The epidemiological analysis of the relationship between the prevalence of infected individuals and the number of cases with invasive amoebiosis made by E. Brumpt in 1925,9 and confirmed by Walsh in 1961,10 showed that the disease is present in approximately 10% of people with cysts of E. histolytica in feces. This fact suggested the existence of two species of E. histolytica to explain the epidemic behavior of amoebiasis in the world.10,11

Studies during the last 30 years have confirmed the existence of two morphologically indistinguishable species of Entamoeba. E. histolytica, the pathogenic species and E. dispers, the non-pathogenic species. Recent acceptance by the scientific community of these two different species has had an important impact on our understanding of clinical amoebiasis.2

Diverse methods exist to differentiate pathogenicity and virulence from Entamoeba spp., most of them requiring the isolation and culturing of the microorganism.12–16 Recently, Aguierre and others reported the amplification by PCR of specific segments of DNA, and the use of specific probes to allow for the differential diagnosis of pathogenic and non-pathogenic Entamoeba spp. in feces.17

Usually, the identification of specific antibodies against antigens of E. histolytica does not correlate with resistance to the infection or with protective immunity.18 However, detection of seric antibodies is a useful procedure in the diagnosis of invasive extra-intestinal amoebiasis, but not in the intestinal forms, where it is not feasible to distinguish asymptomatic carriers from patients with amoebic dysentery, especially in endemic areas where antibody titer is not enough to diagnose acute intestinal amoebiasis.19

Mosmann and Coffman have shown that specific Th1/Th2 cytokine profiles depend on the subpopulation of CD4+ T lymphocytes.20 These subpopulations participate in the regulation of the immune response induced by infection with Leishmania spp. in animal models,21 and the data has been confirmed with other pathogenic agents.22–24 During invasive amoebiasis, decrease of CD4+ cells, increase of CD8+ cells, as well as decrease in in vitro proliferation of T lymphocytes against amoebic antigens have been described.25 Also an immunosuppressive state has been observed on delayed cutaneous hypersensitivity against amoebic antigens. On the other hand, high levels of Interferon-γ (IFN-γ) (profile Th1) are associated with a higher cytotoxic effect of macrophages against trophozoites of E. histolytica.26,27 Additionally, studies in a murine model suggest that the induction of the Th1/Th2 profile is dependent on specific peptides of E. histolytica.28

The asymptomatic/symptomatic clinical state in individuals infected with E. histolytica could be explained by the combination of cytokines that reflect the Th1/Th2 profile and the recent acceptance of the two different, pathogenic and non-pathogenic species. In the present work we use colorimetric PCR to differentiate E. histolytica from E. dispers, to establish correlation between the humoral and cellular immune responses in individuals with clinical variants of amoebiasis coming from an urban community of the state of Puebla, México.

MATERIALS AND METHODS

Study population. The study was carried out in an urban community of the municipality of Puebla, located in the southeast region of México, at an altitude of 1,800 meters and surrounded by high volcanoes. Human population is about 2 million; 60% of them living in an appropriate environment for
the transmission and development of the disease. The estimated seroprevalence in the state, according to the 1988 National Serologic Survey, was 14.98%, 8

**Study subjects.** Informed consent was obtained from all humans participating and from parents or legal guardians of minors. The study group was composed of 47 individuals. The diagnosis of the clinical variant of amoebiasis was accomplished by a meticulous clinical study together with parasitological examination.

The cohort of Acute Intestinal Amoebiasis (AIA) (eleven patients), was clinically diagnosed with colic, tenesmus, trophozoites of *Entamoeba* spp., mucus and/or blood in feces, as well as anti-amoebic antibodies by ELISA (positive serology). Thirteen individuals formed the cohort of Chronic Intestinal Amoebiasis (CIA), showing positive serology, presence of cysts of *E. histolytica/dispar*, and symptoms of alternating diarrhea-constipation with manifestations of abdominal distension, colic, and tenesmus. Thirteen subjects formed the cohort of Asymptomatic Carriers (AC) with positive serology, shedding of cysts of *Entamoeba* spp., and absence of clinical evidence of disease. The Control Group (CG) was formed by 10 asymptomatic individuals with absence of parasite cysts in feces verified by PCR. Blood samples were collected and serum fractions stored at −20°C until used.

**Parasitological diagnosis.** The morphologic identification of the parasite was carried out by coproparasitoscopic analysis employing a direct method in cases of semi-liquid or liquid feces, or by the modified Ritchie's assay in cases of formed feces. 29 Samples containing cysts or trophozoites of *E. histolytica* and/or *E. dispar*, were diluted in PBS, aliquoted, and stored at −20°C until used. The molecular diagnosis was made by Colorimetric PCR as described. 32 The DNA from *E. histolytica* HM1-IMSS and from *E. dispar* clone 53 33 was used as a positive control.

**Detection of antiamoebic antibodies in human sera by ELISA.** This procedure was performed as described, 32 using 10 μg/mL of *E. histolytica* total extract and human sera at a 1:100 dilution. The cut off value for the ELISA test was an O.D of 0.032 ± 0.009.

**Isolation of peripheral blood lymphocytes.** Lymphocytes were purified from peripheral blood by the Ficoll-Hypaque (Sigma, St. Louis, MO) method. 32 Cell viability was verified by the trypan blue exclusion test. Cells adjusted to 3.6 × 10^6 in 100 μL of diluent for T cell proliferation assays. 2 × 10^6 cells in 200 μL of diluent for T CD4+/CD8+ determination.

**T cell proliferation assays.** Lymphocytes (220 × 10^3) were cultivated in a 96 well plate, stimulated with phytohemagglutinin (PHA) (1:250), and amoebic total extract 25 (100 μg/mL) at 37°C for 5 days. Proliferation of T cells against antigen or PHA was measured by [3H]-thymidine (1 μCi per well, 6.7 Ci/mmol; Amersham) incorporation after 18 hr. Cells were harvested on glass fiber filters, and incorporated radioactivity was measured by liquid scintillation in a Beckman Instrument (LS5801). Blast transformation index (BTI) was obtained according to Savanat, 1973 34; BTI = log cpm stimulated cells/log cpm control cells.

**CD4+/CD8+ ratio.** Determination of CD4+/CD8+ ratio was carried out by flow cytometry using Simultest CD4+/ CD8+ kit (Becton-Dickinson). Briefly, 1 × 10^6 lymphocytes in 100 μL were mixed with 20 μL of the respective monoclonal antibody, incubated 15 min at room temperature, washed with PBS/BSA, and centrifuged 10 min at 2,000 × g. The pellet was resuspended in 2% p-formaldehyde and the cell suspension read in a flow cytometer. Reference values for normal individuals ranges from 0.6 to 2.2.

**Cytokine assays.** For quantitative determination of IL-4 and INF-γ cytokines, ELISA kits (Genzyme Diagnostics, Predicta®) were used. Supernatant from lymphocyte cultures was incubated with mouse monoclonal antibodies against human IL-4 or INF-γ adsorbed on the bottom of 96 well plates, and then 50 μL of the sample diluter were added per 50 μL of sample. Biotinylated IgGs against IL-4 or INF-γ were incubated for 1 hr at room temperature to perform a sandwich ELISA. After 5 washes, 100 μL of peroxidase labeled streptavidin was added and the plate incubated for 15 min at 37°C. After 5 washes, 100 μL of substrate were added, incubated at room temperature (18–24°C) for 20 min, then 100 μL of 1 N H2SO4 were added to each well to change the color from blue to yellow. Plates were read in a spectrophotometer at 450 nm.

**Statistical analysis.** The statistical evaluation was carried out using the Mann-Whitney U-test. Values of P < 0.05 were considered statistically significant. The results in Table 2 are presented as ± one standard deviation. The results in Figure 1–3 are presented as mean ± SE.

**RESULTS**

**Study population.** Forty-seven individuals were included in a longitudinal and prospective study (cohorts study). All of them were evaluated by parasitological, clinical, and immunological criteria at the moment of diagnosis, at one month, and at three months after diagnosis. Due to ethical criteria, the control group (CG) was evaluated only at the moment of diagnosis to have references values. Twenty-two were men (46.8%) and 25 women (53.1%). Age analysis showed that 95% of the individuals were between 2 and 40 years old. Selection according to the clinical variant showed that 16% of the clinical cases were acute, 46% were IA, and 4% were chronic (Table 2). Among the patients that agreed to the study, 11% were men and 29% were women. Age, clinical symptoms, and diagnosis time, and at one and three months after diagnosis. The statistical evaluation was carried out using the Mann-Whitney U-test. Values of P < 0.05 were considered statistically significant. The results in Table 2 are presented as ± one standard deviation. The results in Figure 1–3 are presented as mean ± SE.

**Identification of *E. histolytica/E. dispar* by colorimetric PCR.** Control Group samples (10 out of 47) were negative by coproparasitoscopic analysis (CPS), and also by PCR. From the remaining 37 positive samples by CPS, only 29 were positive by colorimetric PCR for *E. histolytica* and/or *E. dispar* (Table 1). Based on PCR results, the clinically defined cohorts were further divided into subsets according to the presence or absence of *E. histolytica/E. dispar* (Table 2).

**Immunological parameters.** Antibody levels, BTI, CD4+/ CD8+ ratio, IL-4, and INF-γ levels for the clinically defined cohorts, and the PCR defined subsets were determined at diagnosis time, and at one and three months after diagnosis.
Asymptomatic carriers of Entamoeba histolytica/E. dispar (data not shown). Among the different groups and subsets, compared with CG at the different times did not show significant differences compared with CG (data not shown).

-profile was defined by INF-γ levels at the time of diagnosis and at three months were significantly different between CG and AIA (Figure 2), and also titers compared with those in the cohorts of CIA, AC, and CG. Neither AIA cohort (Figure 3) nor those individuals from the subset infected with E. histolytica/E. dispar in individuals with clinical variants of amoebiasis.

The population studied was young (80% younger than 20 years old), and came from urban and suburban areas of the municipality of Puebla, México, an entity of 2 million inhabitants. The seroprevalence of 14.98% reported for the state of Puebla is relatively high compared with other parts of México but comparable to those reported for other cities in developing countries such as South-Africa, Brazil, India, and Bangladesh.

Infection with E. histolytica/E. dispar in endemic areas frequently coexists with other protozoa and helminths; therefore, to avoid the interpretation biases observed in previous investigations we included in the study only those cases infected with E. histolytica/E. dispar. By following them during three months, beginning at the moment of diagnosis, we were able to evaluate the behavior of different forms of the disease over time. The cohort of AIA comprised the cases of apparent amoebic dysentery referred from a suburban clinic over a 2-year period. The parasitological diagnosis consisted on the finding of trophozoites associated with the presence of mucus and/or blood, a widely used method effective in the diagnosis of AIA, in accordance with recommendations of the World Health Organization (1997). Parasites were later confirmed as E. histolytica by colorimetric PCR standardized using spiked samples. This procedure is apparently 100% specific but not 100% sensitive when applied to stored fecal samples (Shire and Ackers, unpublished observations). Thus, whereas a positive result confirms the diagnosis, a negative one does not exclude it; therefore, an adequate sample storage and conservation procedure is of great importance. Based on PCR results, the clinically defined cohorts were further subdivided.

It should be noted that even before applying PCR, in 90% of the cases the doctor’s clinical suspicion of amoebic dysentery was not corroborated, demonstrating a clinical over-diagnosis of AIA. It has been reported that, patients diagnosed with amoebic dysentery are frequently infected with Shigella dysenteriae and Shigella flexneri, or other different pathogens including enteroinvasive Escherichia coli, Salmonella spp., and Campylobacter jejuni.

The production of antibodies is the main immunological manifestation of invasive amoebiasis in humans, although its presence is not associated with resistance to infection or with protective immunity. Their utility is accepted in cases of extra intestinal invasive amoebiasis, but not in the intestinal form. In contrast with reports from other groups, in this study the cohort of AIA showed significantly higher antibody titers compared with those in the cohorts of CIA, AC, and CG, both at the moment of diagnosis and one month later; values had returned to control levels by three months. The humoral immune response observed with the different groups was obtained using total extract of E. histolytica trophozoites as the antigen. The possibility to use E. dispar instead of E. histolytica as the antigen, for those cases where PCR was positive for E. dispar, may change the results obtained so far.

**TABLE 1** Determination of Entamoeba histolytica/E. dispar by colorimetric PCR in individuals with clinical variants of amoebiasis

<table>
<thead>
<tr>
<th>Clinical variant</th>
<th><em>PCR + E.h.</em></th>
<th><em>PCR + E.d.</em></th>
<th>Negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute intestinal amoebiasis</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Chronic intestinal amoebiasis</td>
<td>0</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Asymptomatic carriers</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Control group</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>20</td>
<td>18</td>
<td>47</td>
</tr>
</tbody>
</table>

* = Identification of Entamoeba histolytica by PCR. ** = Identification of Entamoeba dispar by PCR.

Discussion

The recognition of E. histolytica and E. dispar as different species, has provided important insights into the epidemic behavior of amoebiasis in the world, and has had important epidemiological and clinical implications. The existence of asymptomatic carriers of E. histolytica, has raised doubts about the proportion of individuals infected who are truly at risk of invasive amoebiasis, and questions the human host factors, that favors this apparently commensal-like relationship with E. histolytica.

A mixture of symptomatic and asymptomatic cases is frequently observed in infections by pathogenic agents. Although some elements of the microorganisms such as virulence, inoculum size, exhibition routes, etc., affect the subsequent manifestations of the infection, undoubtedly host factors contribute in a substantial way in the outcome of the host-parasite relationship. Among these factors, the CD4+/CD8+ ratio and a specific cytokine profile, characteristic of subpopulations of CD4+ T lymphocytes, seem to play an important role. In the present study, we examined the importance of humoral and cellular immunity in the outcome of the relationship between the host and E. histolytica/E. dispar.
TABLE 2

Subsets according to PCR diagnosis of *Entamoeba histolytica*/E. dispers and its correlation with immunological parameters at the moment and three months after diagnosis

<table>
<thead>
<tr>
<th>Clinical variant</th>
<th>AIA</th>
<th>CIA</th>
<th>AC</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ELISA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.149 ± 0.053*</td>
<td>0.069 ± 0.038</td>
<td>0.093 ± 0.057</td>
<td>0.069 ± 0.033</td>
<td>0.125 ± 0.033</td>
</tr>
<tr>
<td>INF-IL-4</td>
<td>31.91 ± 4.31*</td>
<td>27.76 ± 1.54</td>
<td>29.07 ± 3.49</td>
<td>29.53 ± 3.68</td>
</tr>
<tr>
<td>INF-γ</td>
<td>11.56 ± 3.95</td>
<td>8.04 ± 0.22</td>
<td>11.13 ± 5.85</td>
<td>11.40 ± 3.22</td>
</tr>
</tbody>
</table>

At moment of diagnosis

| ELISA            | 0.067 ± 0.041 | 0.071 ± 0.018 | 0.092 ± 0.043 | 0.082 ± 0.056 |
| INF-IL-4         | 11.41 ± 8.36  | 9.58 ± 0.22   | 9.18 ± 0.97   | 9.89 ± 2.53   |
| INF-γ            | 39.44 ± 7.35* | 37.82 ± 2.13  | 27.98 ± 5.44  | 30.76 ± 4.05  |

At 3 months after diagnosis

Interestingly, the two patients assigned to the AIA cohort on clinical grounds but in whom PCR demonstrated *E. dispers* presented lower antibody levels compared with patients with AIA and *E. histolytica*.

Regarding cell-mediated immunity the work of Savant,4, Ortiz,26 and later Salata49 have observed a poor lymphocyte response measured by BTI in circulating T lymphocytes. On the other hand, Ganguly and others,96 demonstrated a decrease in the number of T lymphocytes circulating in the blood of patients with amoebic hepatic abscess. In our investigation, the proliferation of T cells measured by BTI was low. This differs from the results of Ortiz, Harris, Segovia, and Diamanstein51–54 who found a proliferative response to amoebic antigens from lymphocytes of patients with amoebic hepatic abscesses. Moreover, Velásquez and others,55 observed proliferation of peripheral blood mononuclear cells of a patient with amoebic hepatic abscess against a 170 kDa recombinant protein. In our case we used a total extract of *E. histolytica* and Talamás-Rohana and others,28 have reported that whole extract might contain growth inhibiting factors, explaining in part the results obtained by other authors,34,48,49 as well as the low levels of blast transformation found in all the clinical variants tested in this study, including the CG.

Salata and others49 have showed a decrease of CD4+ helper T cells and an increase of CD8+ cells in patients with amoebic hepatic abscess. In our study the patients with invasive amoebiasis showed values for the CD4+/CD8+ ratio that were lower than those reported previously. Suppression of the cellular immune response has been observed during the infection by protozoan parasites, including *Leishmania donovani*26 and *Trypanosoma cruzi*.23 There is also evidence that the response of T cells is systematically suppressed during the acute illness due to *E. histolytica*, as has been observed in animal models57 and in patients with amoebic hepatic abscess.29 Serum from *E histolytica*-infected gerbils58 and immune sera from patients59 selectively suppress T cell proliferation by inhibiting IL-2 and IFN-γ production. Previous studies have shown that in infections caused by pathogens that induce immunosuppression in the host, such as *L. donovani*,26 *HIV*,59 and *T. cruzi*,23 the outcome of the relationship could be regulated by CD4+ helper T cells with different pattern of cytokines. Protective immunity would be associated with Th1 cells that produce INF-γ and IL-2, whereas Th2 cells, which produce immunosuppressive IL-4 and IL-10, could facilitate the survival and dissemination of the parasite generating tissue damage and the appearance of the disease.60

![FIGURE 1. Anti-*E. histolytica* antibodies levels. Sera from each group were evaluated by ELISA using the same serum dilution (1:100). AIA: Acute Intestinal Amoebiasis; CIA: Chronic Intestinal Amoebiasis; AC: Asymptomatic Carrier; CG: Control Group.](image1)

![FIGURE 2. Determination of seric IL-4 levels. Sera from each group were evaluated by ELISA. AIA: Acute Intestinal Amoebiasis; CIA: Chronic Intestinal Amoebiasis; AC: Asymptomatic Carrier; CG: Control Group. IL-4: Seric levels expressed in pg/mL. Reference value: 27.59 ± 2.81 pg/mL. *P < 0.05 (Mann-Whitney U test, compared with CG).](image2)
Recent evidence\(^{61-63}\) suggests an important role for IL-10, but not for IL-4 in the Th2 response. However, as has been proposed by others,\(^{64-67}\) we analyzed IL-4 and IFN-\(\gamma\) as indicators of Th2 and Th1, respectively. These subpopulations may in part explain the behavior observed in the cohorts of patients with invasive amoebiasis and asymptomatic carriers, considered in this study. The first group presented significantly high levels of IL-4 (Th2 profile) at the moment of the diagnosis, associated with the presence of the pathogenic species \textit{E. histolytica} (determined by PCR), and returning to normal levels, compared with CG, at three months post-therapy. Regarding the cohort of untreated asymptomatic carriers, the two individuals infected with \textit{E. histolytica} presented high levels of IFN-\(\gamma\) at the moment of diagnosis, maintaining these levels for the following three months, without alteration in the other evaluated parameters, (levels of antibodies, BTI, CD4+/CD8+ ratio). The nine AC patients infected with \textit{E. dispar} were not different from the CG in any immunological parameters and it is tempting (although the numbers are very small) to attribute asymptomatic carriage of pathogenic \textit{E. histolytica} to a powerful Th1 response not seen in those who succumbed to amoebic dysentery.

It is recognized that the chronic abdominal pain and intestinal alterations are symptoms experienced by 15% of apparently healthy people.\(^{68}\) In endemic areas such as México, this type of condition is frequently diagnosed as chronic intestinal amoebiasis. The etiology of CIA has not been settled and clear-cut differences between this disease and the syndrome of irritable bowel have not been defined.\(^{69,70}\) Infection in all the cases where it could be determined in the cohort of CIA, (characterized by abdominal distension, colicky pain, tenesmus, alternating diarrhea and constipation, and positive serology) was due to \textit{E. dispar}. Studies carried out in India,\(^{71}\) Panama,\(^{72}\) Puerto Rico,\(^{73}\) and Honduras\(^{74}\) have shown that the typical abdominal symptoms of CIA were observed more frequently in individuals negative for amoeba in feces.\(^{75}\) On the other hand, individuals with diagnosis of CIA treated with anti-amoebic drugs showed no improvement of symptoms.\(^{76}\)

In this study, the identification of the non-pathogenic \textit{E. dispar} in all the cases of patients classified as CIA, does not provide evidence for a causal relationship between infection and symptoms. This suggests reconsideration of the existence of this type of clinical variant of amoebiasis.

In general, our results show that invasive amoebiasis, induced by the presence of \textit{E. histolytica} could be partly explained by the levels of the IL-4 associated with a Th2 cytokine profile. Resistance to the invasive form of the illness in asymptomatic carriers of \textit{E. histolytica} may be explained by the high levels of IFN-\(\gamma\) associated with a Th1 cytokine profile, as found in this investigation.

The identification of \textit{E. histolytica} in asymptomatic carriers demonstrates the importance of routinely making a species-specific diagnosis in view of the participation of the asymptomatic carriers of \textit{E. histolytica} in the establishment and maintenance of a pathogenic cycle of extra-intestinal amoebiasis in endemic regions.

To have elements to better understand the clinical-epidemiological pattern of amoebiasis, it will be necessary to perform longitudinal studies with a larger number of patients to analyze all the immunological parameters which participate in the pathogenic process associated with \textit{E. histolytica} infection.

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