Chagas disease in Northeast of Brazil: Findings from a systematic review of literature

RESUMO
Entre as doenças infecciosas relacionadas à pobreza, a doença de Chagas é uma doença que afeta cerca de 6 a 8 milhões de pessoas na América. Seu agente etiológico é o protozoário Trypanosoma cruzi, que é transmitido por vetores hematofágos da subfamília Triatominae (Reduviidae). No Brasil, a transmissão vetorial diminuiu nos últimos anos. No entanto, é de extrema importância monitorar e controlar constantemente os vetores desta doença, pois ainda é possível encontrar focos naturais de triatomíneos em todas as regiões geográficas do país. O Nordeste do Brasil é a região onde a doença de Chagas ocorre endêmica e apresenta grandes surtos de transmissão e ainda possui o maior número de vetores capturados no Brasil, representando mais de metade do total atribuído ao país. Além disso, o Nordeste continua sendo uma das regiões mais pobres do país, com um grande número de casas que proliferam triatomíneos. Considerando a importância da região Nordeste para o panorama da doença de Chagas no Brasil, este artigo faz uma revisão sistemática da literatura (RBS) para analisar aspectos do ciclo de transmissão de T. cruzi, em relação às espécies de triatomíneos, Chagas e mamíferos envolvidos em estudos que contemplam a região Nordeste do Brasil e seus estados.

Descriptors

Sources of funding: No
Conflict of interest: No
Date of first submission: 2017-01-17
Accepted: 2018-02-26
Publishing: 2018-05-11

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ABSTRACT
Among the infectious diseases related to poverty, Chagas' disease is a disease that affects about 6 to 8 million people in America. Its etiologic agent is the Trypanosoma cruzi protozoan, which is transmitted by hematophagous vectors of the Triatominae (Reduviidae) subfamily. In Brazil, vectorial transmission has declined in recent years. However, it is of utmost importance to constantly monitor and control the vectors of this disease, because it is still possible to find natural foci of triatomines in all geographic regions of the country. The Northeast of Brazil is the region where Chagas disease occurs endemically and has large outbreaks of transmission and still has the highest number of vectors captured in Brazil, accounting for more than half of the total attributed to the country. In addition, the Northeast continues to be one of the poorest regions of the country, with a large number of houses that proliferate triatomines. Considering the importance of the Northeast region for the panorama of Chagas' disease in Brazil, this article makes a systematic review of the literature (RBS) to analyze aspects of the transmission cycle of T. cruzi, in relation to triatomine species, Chagas and the mammals involved in studies contemplating the Northeast region of Brazil and its states.
INTRODUCTION

Among infectious diseases related to poverty, Chagas disease is an illness that affects about 6 to 8 million people in America (1). The etiological agent of Chagas disease is the protozoan parasite Trypanosoma cruzi which is transmitted by hematophagous vectors of the subfamily Triatominae (Reduviidae). Despite the vector-borne transmission of Chagas disease see declining in recent years, it is important that Brazil maintains constant surveillance operation and control of vectors of this disease because it is still possible to find natural foci of triatominae in all geographic regions of the country (2).

Northeast of Brazil is the macroregion where Chagas disease has more endemic occurrence. And their different physiographic subregions contain several species of triatominae (3). This region has an important highlight because it features large foci of transmission and still has the largest number of vectors captured in Brazil, representing almost 70% of total assigned to the country. In addition, Northeast region remains as one of the poorest regions of the country, with large amount of houses which proliferate triatominae, is the epicenter of dispersion of two species of unwieldy control (Triatoma brasiliensis and Triatoma pseudomaculata) (4).

Recently, the study of (5) showed that Northeast region still has the largest number of cases, as well as the higher rate of prevalence of Chagas disease in Brazil, despite the various measures for vector control. Authors also pointed to a large predominance of published studies on seroprevalence relative to the State of Piauí, suggesting a low and nascent literature on carriers of Chagas disease in remaining states of the region.

Northeast region has an important characteristic for the cycle of Chagas disease, because it presents major foci of transmission and still has the largest number of triatominae captured in Brazil, representing almost 70% of the total assigned to the country. In addition, Northeast region remains as one of the poorest regions of the country, with large amount of houses which proliferate triatominae, is the epicenter of dispersion of two species of unwieldy control, Triatoma brasiliensis and Triatoma pseudomaculata (4).

Considering the importance of Northeast region for the panorama of Chagas disease in Brazil, this article makes a systematic literature review (RBS) in order to analyze aspects of the transmission cycle of T. cruzi, with regard to species of triatominae, epidemiology of Chagas disease and the mammalian hosts involved from studies that have considered Northeast region of Brazil and its states.

METHODOLOGICAL ASPECTS

This study was carried out by means of RBS, which according to (6), is characterized by a comprehensive literature search of all potentially relevant papers and the use of explicit and repeatable criteria of selection, inclusion and exclusion of papers for review. In this technique of scientific research, the selected works are analyzed from different categories and their results are synthesized and interpreted.

Among various research techniques, RBS is the only one that enables the analysis of a wider range of publications and so to make a general overview of more important scientific production, in this case, about Chagas disease in Northeast region of Brazil, in particular in the State of Ceará. From this research technique it seeks to identify important characteristics related to Chagas disease such as: most common sites of investigation, prevalence of disease, types of hosts, main vectors and their biological and ecological characteristics.

In this study, one chose to make a RBS known as qualitative, i.e it does not include statistical analyses of the empirical evidence found. The analysis was made from a thematic synthesis and description of the papers analyzed (7–8).

The systematic review conducted was divided into the following phases:

Phase 1 - Guidelines for search: It was used as the basis of searching for papers Portal de Periódicos da Capes (Journal Portal from Coordination of Improvement of Higher Education Personnel (Capes)), since this portal encompasses national and international databases of most relevance to the subject (Biomed, Scielo, Medline/PubMed, thesis and dissertation database from
Capes, among others). That choice has reduced the search time and at the same time allowed the access to all publications held and indexed in the major databases. It was also sought papers via Google Scholar, in order to make sure that important publications on the subject would not be deleted. The combination of the following keywords was used in Portuguese and English, respectively: “chagas disease” “Northeast region of Brazil” and “Chagas disease” “northeast region of Brazil”. These search criteria to papers have been applied throughout the text, including title, keywords and abstract, to search as many papers as possible. In total in 150 publications were found in journal portal from Capes. On Google Scholar 3330 results were found (adding Portuguese and English), however only publications that contained up to 20 page were analyzed, because as Google itself (2015) informed, the most useful and important references (full text, type of publication, frequency it was quoted in other academic publications, etc.) are contained on the first watch pages of this search tool, totaling 114 references found. It has been used a total of 264 publications for the analysis.

Phase 2 - Inclusion and exclusion Criteria for publications: The first criterion to be checked was the availability of the file on the web, in which all references that were only quotation and/or were not found online were discarded. Then references selected in accordance with the form of publication were checked, considering only those which were papers published in journals, excluding references such as books, research reports and papers in the annals of event. After the reading, data was organized on Excel, such as the title, abstract, purpose, authorship, place of study and methodology, and from there, those publications that were only of literature review, those that were not analyzing directly Northeast region of Brazil and those that did not have chagas disease as a central focus of the article, by verifying the existence of at least one of the words: vector, reservoir, host or Trypanosoma cruzi were withdrawn. Finally, it was noticed that some references were repeated and selected papers decreased even more. In total 172 references were excluded at this phase, totaling 92 papers for analysis. Figure 1 shows the application of these criteria and the selection.

Phase 3 - Reading and analysis of selected papers: Selected papers were read and the aspects of Chagas disease that were being analyzed, the methodology used and the main results achieved were identified. Further, 43 references that were different from purpose of analysis of this research.

Figure 1: Schematic presentation of the elaboration steps for systematic review
Phase 4 - Synthesis of results found: Finally, the 49 references were read and the main findings were organized according to investigation themes to facilitate understanding of the data. The following themes were created: Triatominae, which addresses papers involving aspects of biology and ecology of vector insects related to dynamics of disease transmission. Trypanosoma cruzi that includes papers related to the etiologic agent showing results of geographical distribution and classification. And finally, Epidemiology in which the works related to various aspects of the dynamics of transmission of Chagas disease, the clinical forms and data on mortality of Chagas disease in Northeast of Brazil.

3. MAJOR FINDINGS AND DISCUSSIONS

3.1. Descriptive analysis of papers included

Regarding publication time of the papers, it was observed that there is a large amount of publications on the subject in recent years. The highest concentration of selected papers was published after the year 2000 (62 papers analyzed), especially in the last five years (30 papers have publication date between 2010 and 2015).

As expected, and being of interest of this research to analyze the production involving the Northeast of Brazil, all selected papers directly or indirectly involved some state of this region. It was noted that the states with highest production on the subject were: Ceará (22 papers), Bahia (12 references) and Pernambuco (7 papers). Other states also appeared in productions such as Paraíba, Sergipe and Maranhão. Other references were comparisons and included data from more than one state in Northeast, totaling 11 references. The remainder involved the analysis of various states of Brazil including some of the Northeast (17 papers). These findings showed the importance of Ceará to field of research on Chagas disease among Northeast, which is the focus of most studies in Brazil.

Regarding division of references and the themes of analysis, it might be observed that most papers were related to the theme Triatominae followed by papers which address the subject Epidemiology of the disease (Figure 2).

The analysis of authors of included papers revealed a large concentration of publications to few researchers. Only eight researchers had their names tied in more than 60 references analyzed, i.e., 75% of the selected works. Regarding this group, the researcher, who published the large number of papers, published 11 papers in partnership with other authors, followed by the researcher who published 10 papers, two researchers (9 papers), another one (6 papers), and three of them (5 papers). It is interesting to observe that about 15 researchers published 3 to 4 selected papers, 33 researchers published in partnership two of the selected works and the remainder only one. This shows that possibly the subject analyzed has several senior researchers with a great academic productivity, either via their own researches or from academic guidelines. On the other hand, the analysis also points out to a big production among young researchers.

Figure 2: Percentage distribution of papers found in accordance with the subject analyzed

Source: Self elaboration based on papers analyzed.

3.2. Analysis of papers by subject area

3.2.1 Triatominae

The dissemination of Chagas disease in Brazil was related to the introduction of Triatoma infestans, in the 19th century, which together with Triatoma brasiliensis and Panstrongylus megistus were sorted as primary vectors of the disease.

Although, at the end of the 1980s, there is evidence of a possible eradication of T. infestans and a
reduction in household densities of *T. brasiliensis*, *P. megistus*, *Triatoma pseudomaculata* and *Triatoma sordida*, possibly because of the effectiveness of Government's control programs, the constant record of native vectors, even though those secondary, of Chagas disease is reported in various localities of the municipalities in Northeast of Brazil (9).

A large Triatominae survey conducted between 1975 and 1980 recognized *T. brasiliensis*, *T. pseudomaculata* and *Rhodnius nasutus* as native species from caatinga; *T. infestans* the main vector in Northeast of Brazil, given the high degree of domiciliation and anthropophily and *T. pseudomaculata* as the species more prevalent. *T. sordida*, *P. megistus* have also occurrence in Northeast region of Brazil (10).

More focal studies further indicate the occurrence of *Triatoma rubrofasciata* and *Rhodnius neglectus* in Urban areas of Jaguaruana, in the State of Ceará, more specific in the municipalities of Russas and Jaguaruana, Ceará, indicating an active colonization of this species with greater ability to intradomicile over the coexistence of more than one species in artificial ecotopes (22). Investigation of artificial ecotopes such as piles of bricks, roof tiles, wood, chicken coops and pens of goats demonstrated the prevalence of *T. pseudomaculata* and *T. brasiliensis* in the peridomicile environment. However, chicken coops covered with dried leaves from palm trees showed a prevalence of *R. nasutus* (20-21). In region of Cariri, South of the State, the majority of specimens of *T. pseudomaculata* was captured in peridomicile environment (22). It is likely that the low degree of domiciliation is due to the use of insecticides in the annual campaigns of control of Chagas disease in the region (23).

In Sergipe, only *T. brasiliensis* was captured in intradomicile and peridomicile. The record of nymphs from species of *T. brasiliensis* and *T. pseudomaculata* indicated an active colonization of this location (18).

In locations of Sergipe colonies of *P. megistus* were found and main artificial ecotopes at peridomicile were chicken coops, pens, bunkers and styyes (21). *T. pseudomaculata*, *T. brasiliensis* and *P. lutzi* species more widely distributed in the State of Pernambuco (12).

*T. brasiliensis* stands out in Northeast semi-arid for being widely distributed in the region and because it colonizes dwellings in several municipalities. Despite the high susceptibility of *T. brasiliensis* to insecticides such as deltamethrin (26), a high capacity of reinfestation of Chagas disease in Northeast of Brazil: Findings from a ...
dwellings after sprinkling of insecticides was seen in this species, making the chemical control hard enough\cite{27}.

Biochemical and molecular studies showed the existence of four distinct sub species of *T. brasiensis*: *T. brasiliensis*, *T. melanica*, *T. macromelasoma* and *T. juazeiro*\cite{28-29}. Under the epidemiological point of view, population *brasiliensis* stands out because of its greater geographical distribution, variety of ecotopes and highest rate of natural infection by *T. cruzi*\cite{30}. The mapping of the potential distributions of the populations of *T. brasiensis complex*, allowed suggest a stable distribution\cite{31}.

Food source studies in Triatominae indicated the birds as the main food source of *Triatoma pseudomaculata*, in localities of Cariri, State of Ceará\cite{22}. However, in Vale do Jaguaribe, North of Brazil, *T. brasiensis*, *T. pseudomaculata* and *R. nasutus* were more related to goats and rodents\cite{32}. Positivity for blood proteins of dog's blood and hemolymph from blaberidae (cockroaches) allowed the conclusion that the species *T. pseudomaculata* feeds on animals that live in anthropic environment\cite{22}.

Table 1 shows the distribution of triatominae species by State in Northeast of Brazil, according to the food source and type of ecotopes.

Panstrongylus lutzi was very eclectic with observation of several food sources. In addition, the occurrence of mixed feeds suggests that the species runs between wild and peridomicile environments and it may present high rate of infection with *T. cruzi*\cite{15}. On the other hand, several studies have reported the participation of man in the food chain of triatominae, highlighting the relevance of maintaining the entomological surveillance system efficiently, in addition to the awareness and education of people involved\cite{22-15-32}.

Rate of natural infection with trypanosomatids similar to *T. cruzi* on triatominae captured in municipalities of Piauí and Ceará ranged according to the

<table>
<thead>
<tr>
<th>Species</th>
<th>State</th>
<th>Food source</th>
<th>Ecotopes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>R. nasutus</em></td>
<td>Ceará, Pernambuco</td>
<td>bird, marsupial, rodent, goats, hemolymph</td>
<td>O.martiana, M.vinifera, Astrocaryum, chicken coops, cattle sheds, lofts, pile of roof tiles</td>
</tr>
<tr>
<td><em>T. pseudomaculata</em></td>
<td>Ceará, Pernambuco, Piauí</td>
<td>bird, canine, human, lizard, bovine, goat, hemolymph, porcine, marsupial</td>
<td>bird's nest, chicken coops, cattle sheds, piles of roof tiles</td>
</tr>
<tr>
<td><em>T. tibiamaculata</em></td>
<td>Bahia</td>
<td>bird, rodent, marsupial, ruminant</td>
<td>S.I.*, Intradomicile</td>
</tr>
<tr>
<td><em>T. brasiensis</em></td>
<td>Ceará, Pernambuco, Piauí</td>
<td>Human, goats, rodent, marsupial</td>
<td>S.I.*, Intradomicile, chicken coops, cattle sheds, stone walls, pile of roof tiles, pile of wood</td>
</tr>
<tr>
<td>Triatoma sordida</td>
<td>Bahia, Pernambuco</td>
<td>S.I.*</td>
<td>S.I.*, Home Unit**</td>
</tr>
<tr>
<td>Triatoma lenti</td>
<td>Bahia</td>
<td>S.I.*</td>
<td>S.I.*, Home Unit**</td>
</tr>
<tr>
<td>P. megistus</td>
<td>Sergipe, Pernambuco</td>
<td>S.I.</td>
<td>S.I.*, Chicken coop, cattle shed, barn, warehouses,</td>
</tr>
<tr>
<td>P. geniculatus</td>
<td>Bahia</td>
<td>S.I.</td>
<td>S.I.*, Intradomicile</td>
</tr>
<tr>
<td><em>P. lutzi</em></td>
<td>Ceará, Pernambuco</td>
<td>bird, marsupial, rodent, tatu, bovine, human, equine, feline</td>
<td>Tree trunks, Intradomicile and peridomicile (chicken coops, cattle sheds, pile of wood and roof tiles)</td>
</tr>
<tr>
<td><em>R. prolixus</em></td>
<td>Maranhão</td>
<td>S.I.</td>
<td>S.I.*, O.martiana, Intradomicile</td>
</tr>
<tr>
<td><em>R. neglectus</em></td>
<td>Maranhão, Pernambuco</td>
<td>S.I.</td>
<td>C.cerifera, O.martiana, Intradomicile</td>
</tr>
<tr>
<td><em>R. pictipes</em></td>
<td>Maranhão</td>
<td>S.I.</td>
<td>S.I.*, Intradomicile</td>
</tr>
</tbody>
</table>

Note: *S.I. - No Information; ** Home Unit - set of domicile and peridomicile
Source: Self-elaboration based on papers
species of vector, capture ecotope and food source. In *T. pseudomaculata* captured in peridomicile, low rate occurred in Piauí and Ceará\(^{18-21}\). In contrast, triatominae captured in palm trees showed high rate of natural infection and the results of the food source showed a preference for blood of marsupials and birds \(^{16\text{-}18\text{-}17\text{-}21}\).

In Sergipe, *P. megistus* captured in peridomicile environment showed rate of natural infection with trypanosomatids quite high \(^{33}\). Triatominae in Pernambuco showed natural infection around 8%, and most of them were captured in intradomicile\(^{12}\).

Dog is likely to be involved in maintaining domestic cycle of *T. cruzi* in peri and intradomicile, once it has been identified as a source of food of *T. brasiliensis* found in intradomicile of localities from Piauí\(^{18}\).

Reinforcing this record, high seropositivity for *T. cruzi* in a rural area of Bahia was associated with the presence of dogs, cats and triatominae at home \(^{34}\) and in the municipalities of Ceará and Piauí dogs exhibit a high prevalence for *T. cruzi*\(^{35}\).

Table 2 lists the species of mammals positive for contact with *T. cruzi*.

### Table 2: Mammalian species positive for the presence of *Trypanosoma cruzi*, by place and date

<table>
<thead>
<tr>
<th>Mammal species positive for <em>T. cruzi</em></th>
<th>State</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ceará</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td>Maranhão</td>
<td>2015</td>
</tr>
<tr>
<td>Rattus rattus</td>
<td>Piauí</td>
<td>1992</td>
</tr>
<tr>
<td></td>
<td>Ceará</td>
<td>2012</td>
</tr>
<tr>
<td>Chiroptera</td>
<td>Piauí</td>
<td>1984</td>
</tr>
<tr>
<td></td>
<td>Maranhão</td>
<td>2015</td>
</tr>
<tr>
<td>Canis familiaris</td>
<td>Bahia</td>
<td>1978</td>
</tr>
<tr>
<td>Felis catus</td>
<td>Bahia</td>
<td>1978</td>
</tr>
<tr>
<td>Philander opossum</td>
<td>Maranhão</td>
<td>2015</td>
</tr>
<tr>
<td>Gracilinanus spp</td>
<td>Maranhão</td>
<td>2015</td>
</tr>
<tr>
<td>Tamandua tetradactyla</td>
<td>Piauí</td>
<td>1992</td>
</tr>
<tr>
<td>Euphactus sexcinctus</td>
<td>Piauí</td>
<td>1989</td>
</tr>
<tr>
<td>Phyllostomus hastatus</td>
<td>Piauí</td>
<td>1989</td>
</tr>
<tr>
<td>Phyllostomus discolor</td>
<td>Piauí</td>
<td>1989</td>
</tr>
<tr>
<td>Bolomys lasius</td>
<td>Piauí</td>
<td>1989</td>
</tr>
<tr>
<td>Marmosa agilisagilis</td>
<td>Piauí</td>
<td>1994</td>
</tr>
</tbody>
</table>

Source: Self-elaboration based on papers analyzed.

Furthermore, mammals captured in greater quantity and showing high rates of infection with *T. cruzi* in peridomicile were *Didelphis albiventris* e *Rattus rattus*\(^{21}\). In wild areas, rodent *Trichomys laurentius* proved to be a competent reservoir of *T. cruzi* and it is found in abundance in Serra da Capivara, Piauí\(^{35}\).

Presence of parasite in wild and peridomicile environments poses a real risk for the transmission of Chagas disease. Habits of the population as the use of dried leaves of palm trees on the roof and walls of houses also contribute to domiciliation of triatominae\(^{16\text{-}17}\).

It is ultimately important that measures related to vector control are not interrupted, with entomological surveillance \(^{33}\). The improvement of dwelling and chemical control are strategies proposed to control the
density of triatominae which transmit Chagas disease. Housing improvement has been applied in restricted areas of Brazil and apparently no systematic evaluation has been conducted concerning the effectiveness of this strategy. On the other hand, chemical control of triatominae populations has been extensively used in endemic areas of Brazil (23).

3.2.2 Trypanosoma cruzi

The fewest references found were related to this theme. However, this theme is involved in a large number of papers surveyed, especially those related to triatominae theme when it is about rate of natural infection. The works found on this theme are quite recent and they still show an incipience in research of this area.

Studies indicate the occurrence of three lines of Trypanosoma cruzi circulating in the State of Rio Grande do Norte. TCI line only in humans, TCII in T. brasiiliensis and humans and TCIII line between T. brasiiliensis and P. lutzi (36).

TCI and TCII lines of T. cruzi run in wild triatominae of species T. tibiomaculata in localities of Salvador, Bahia (14) and small wild rodents in Serra da Capivara, Piauí (35). In Ceará, TCI line is present in T. brasiiliensis, T. pseudomaculata and R. nasutus in wild environments, peri and intradomicile in Vale do Jaguaribe, North of the State (37-38). In synanthropic mammals, TCI line is also present in D. albiventris and TCII line runs in R. rattus (21) (Table 3).

### Table 3: Lines of Trypanosoma cruzi of occurrence in Northeast of Brazil, hosts and year of isolation

<table>
<thead>
<tr>
<th>T. cruzi (DTU) line</th>
<th>Host</th>
<th>State</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCIII</td>
<td>T. brasiiliensis, P. lutzi</td>
<td>Rio Grande do Norte</td>
<td>2010</td>
</tr>
</tbody>
</table>

Source: Self-elaboration based on papers analyzed

Knowledge of distribution of lines is important to assess the impact of the genetic diversity of T. cruzi in endemic areas and its consequences to epidemiological and clinical aspects of Chagas disease (36-38-21-14).

3.2.3 Epidemiology

Although fewer reference was found, this theme is extremely important to study of Chagas disease, since it provides direct evidences about the population affected by the illness. A descriptive study between 1995 and 2008 showed that the number of hospitalizations for Chagas disease in the State of Pernambuco was representative enough, compared to national average of Brazil, a reduction in mortality of individuals due to Chagas disease in the country has been also observed (39). However, the analysis of the profile of blood donors from Hemocentro de Pernambuco showed a low prevalence for Chagas disease in donors, noting that the younger age group represented the smallest amount of reactive serology (40).

In a study in the municipality João Costa, Piauí, a high seropositivity was showed, and it is greater in individuals older than 59 years (41). In contrast, there seems to be evidence of active transmission of Chagas
disease in localities of Piauí, since the reduction in the number of positive tests in young people is an indicator of the effectiveness of prophylactic measures applied, which was not observed, and a high prevalence of positive serology in younger age groups (0 to 20 years) in localities of Piauí.\(^{18}\)

In Jaguaruana, State of Ceará a low prevalence in young age groups was registered. And especially for children under 10 years old infection to Chagas disease was not observed, suggesting the interruption of transmission possibly due to success of measures based on vector control \(^{21}\).

Regarding clinical manifestations of Chagas disease, megaesophagus and cardiomegaly were observed in indigenous patients in State of Piauí, with diagnostic confirmation through additional tests and positive parasitological survey \(^{42}\).

However, in Paraíba, radiographic study has shown the occurrence of megaesophagus and no case of cardiomegaly \(^{43}\). In this State, the prevalence of infection by \textit{T. cruzi} was 9.5\% with prevalence among women and progressive increase according to age in both genders \(^{43}\).

Chronic Chagasic cardiopathy was reported in both patients of Ceará \(^{44-45}\) and individuals from Piauí \(^{41}\). Once serological inquiries showed prevalence of Chagas disease similar between regions of caatinga from Piauí and Vale do Jaguaribe, Ceará \(^{46-44}\).

Records related to occurrence of acute Chagas disease were also analyzed in Bahia. An outbreak among individuals of a family, with two deaths was reported in Macaúbas. A probable source of infection was the ingestion of water contaminated by feces of triatominae \(^{47}\). Fever and dyspnea were the symptoms found in most patients with acute Chagas disease. Myocarditis was the most common and potentially serious finding in these patients \(^{48}\).

Still in Bahia, in addition to a serological survey, the analysis of variables such as age, gender, clinical and transfusion history, degree of relatedness of the population studied, also suggested the existence of vector-borne transmission of \textit{T. cruzi} in the region of Mulungu \(^{49}\).

Analysis of Table 4 leads to the conclusion that seroprevalence studies of Chagas disease per year was higher in the State of Piauí, followed by the Ceará. So, the study demonstrated that it found, from a systematic bibliographical review, a greater concentration of seroprevalence studies also to Piauí \(^{51}\).

| Table 4: Distribution of chronic cases of Chagas disease by State of Northeast and year of evidence |
|---------------------------------|-----------------|---------------------|
| **State (municipality)**        | IgG +           | **Year**            |
| Ceará (multiple municipalities) | 411             | 2005 to 2013        |
| Paraíba (multiple municipalities) | 489             | 1984 to 1985        |
| Bahia (Mulungu)                | 33              | 1998 to 1999        |
| Piauí (Oeiras)                 | 01              | 1975                |
| Piauí (Castelo)                | 01              | 1975                |
| Piauí (Bom Jesus do Gurguéia)  | 01              | 1975                |
| Piauí (João Costa)             | 205             | 2000                |
| Ceará (Jaguaruana)             | 21              | 2008                |
| Pernambuco (multiple municipalities) | 499             | 2002 to 2007       |
| Piauí (multiple municipalities) | 278             | 1975                |
| Piauí (Castelo do Piauí and Pedro II) | 123         | 1984 and 1985      |
| Ceará (Jaguaruana)             | 13              | 2012                |
| Piauí (Teresina)               | 02              | 1992                |
| Ceará (Russas)                 | 08              | 2008 and 2009       |

Source: self-elaboration based on papers analyzed.
FINAL CONSIDERATIONS

Given importance of Northeast region for the panorama of chagas disease in Brazil, this study sought to highlight and review the scientific literature on the subject in the region. It was evidenced that Ceará is the place with the highest concentration of studies, however, as well as verified for other States of the region, there is a clear concentration of studies in certain municipalities of a single State, which makes impossible to understand more comprehensively the disease in the region and in its different locations. In other words, despite the large volume of publications related to the epidemiological aspects of Chagas disease in Northeast of Brazil, it is evident the need for studies demonstrating the variability of these aspects in the various States and localities of the region.

By analyzing the aspects of the cycle of transmission of T. cruzi, it was verified that the most important species in Northeast region are T. brasiliensis and T. pseudomaculata because they are present in large number in peri and intradomicile environments in most of the studied municipalities. The marsupials are mammals that are important in maintaining the cycle of T. cruzi for being a link between wild and peri and intradomicile environments and because they are positive for this protozoan. And birds are proving to be important as a food source for triatominae, attracting them and keeping them close to men. On the other hand, studies directed to infection by T. cruzi infection in wild and home mammals were scarce. The investigation of these vectors would be interesting and necessary, in order to clarify and get more information about the transmission cycles of the parasite.

If on the one hand, the literature shows a high prevalence of infection by Trypanosoma cruzi in population of multiple municipalities of Northeast region, on the other hand, low rate in individuals under 10 years old suggests the reduction of active transmission by triatominae. Nevertheless, even if Brazil has demonstrated reduction in mortality, Chagas disease remains a serious public health problem, especially in Northeast of Brazil. Assim, it is evident in this systematic review that all the studies show that the Northeastern States should be prioritized for surveillance activities and triatominae control due to occurrence of several native species and high percentage of specimens in peri and intradomiciles in multiple municipalities from this region.

Thus, broader descriptive epidemiological studies provide important data to assess the risk of disease transmission and allow the evaluation of the effectiveness of the measures for vector control. However, the analysis of the data of publications obtained in this systematic review show specific, old and restricted data to certain areas and municipalities in the region, highlighting the need for obtaining a general and current profile concerning seroprevalence of Chagas disease in the northeastern region to assess the actual prevalence of individuals carrying T. cruzi.

It was possible to identify advances regarding knowledge of Chagas disease in the region, but also realize the main gaps for future investigations, namely: to map preferred ecotopes of vectors, their ecological aspects, assess the risks of domiciliation of indigenous vectors and the risk of maintaining infestation by vectors introduced. It is also identified lack of information about educational activities performed, because education is an important tool to ensure success in programs for prevention and eradication of diseases once they represent instruments for the maintenance of institutional control policies. These actions also contribute to strengthen work of entomological surveillance in areas where there is incidence of triatominae. Thus, contributing to more effective control actions in order to reduce the incidence of the disease.

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