DOI: 10.1111/tmi.13915

SYSTEMATIC REVIEW

Oral transmission of Chagas disease from a One Health approach: A systematic review

Alejandra López-García | **Juan A. Gilabert**

Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, Complutense University of Madrid, Madrid, Spain

Correspondence
Juan A. Gilabert, Department of Pharmacology and Toxicology, Faculty of Veterinary Medicine, Complutense University of Madrid, Avda. Puerta de Hierro, s/n. 28040 Madrid, Spain.
Email: jagilabe@ucm.es

Abstract

Objective: To analyse acute Chagas disease (CD) outbreaks through a qualitative systematic review and discuss the determinants for its prevention and control.

Methods: Review of studies in which clinical cases of oral transmission were confirmed by parasitological and/or serological tests that included an epidemiological investigation of sources of infection, vectors and reservoirs.

Results: Thirty-two outbreaks (1965–2022) were analysed. The main foods involved in oral transmission outbreaks are homemade fruit juices. Different species of vectors were identified. Reservoirs were mainly dogs, rodents and large American opossums (didelphids).

Conclusion: Under a One Health approach, environmental changes are one of the factors responsible of the rise of oral transmission of CD. Entomological surveillance of vectors and control of the changes in wild and domestic reservoirs and reinforcement of hygiene measures around food in domestic and commercial sites are needed.

KEYWORDS
Chagas disease, infection transmission, One Health, *Trypanosoma cruzi*

INTRODUCTION

American trypanosomiasis or Chagas disease (CD) is a zoonotic disease, endemic in 21 countries of Central and South America. Its etiological agent is the hemoflagellate protozoan parasite *Trypanosoma cruzi* (*T. cruzi*), which is transmitted mainly through hematophagous vectors of the subfamily *Triatominae*, commonly known as *kissing bugs* or *vinchucas*.

All *Triatominae* species are potentially able to transmit *T. cruzi* to humans, but the genera *Triatoma*, *Rhodnius* and *Panstrongylus* are the most epidemiologically relevant vectors of CD. They become infected by feeding on the blood of an animal with circulating *T. cruzi* parasites in the form of trypomastigotes. When ingested, they evolve into epimastigotes in the stomach and into infective metacyclic trypomastigotes in the large intestine. When the vector feeds on a healthy animal, it releases these trypomastigotes in its faeces near the site of the bite, so that they can penetrate through the wound or even an intact mucous membrane, such as the ocular conjunctiva. Once inside the host, trypomastigotes invade cells and differentiate into intracellular amastigotes that multiply by binary fission. These amastigotes can be differentiated back into trypomastigotes and be released into the bloodstream [1].

In the Americas, CD shows an annual incidence of 30,000 new cases average, 12,000 deaths per year, and approximately 9000 newborns become infected during gestation. It is estimated that around 70 million people in the Americas live are exposed to and at risk of contracting CD. The disease is extremely complex because the *T. cruzi* parasite can maintain its biological cycle in a large number of vector and reservoir species and has several transmission routes [2]. Although the most relevant route of transmission to humans is vectorial (>80% of recorded infections), numerous outbreaks of infection by oral transmission have been described in countries where CD is endemic [3, 4]. Vectorial transmission only occurs in countries where the triatomines are endemic or present. Another route of transmission in humans that also depends on the presence of vectors is oral transmission through food and drink contaminated with faeces from

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triatomines. The parasite can also be transmitted by vertical transmission (2%–6% of newborns) due to transplacental congenital infection by pregnant mothers that can transmit the parasite at any stage of infection and at any time during pregnancy, including delivery. Other routes of transmission are blood transfusion (around 10% of cases), organ transplantation, biomedical laboratory accidents and handling of infected animals or the ingestion of their raw meat [1, 5].

The protozoan *T. cruzi* occupies the tenth position in the list of most important foodborne parasites [6]. Oral transmission is considered the ancestral form of transmission of the parasite as it is the most common form of infection between animals and vectors, which has allowed the maintenance of *T. cruzi* in nature. However, since the discovery of CD, infection to humans has occurred predominantly through vectorial, vertical transmission and organ transplantation or blood transfusion, leaving oral transmission and the rest of the routes in the background. This has changed in recent decades, since of the more than 1000 acute cases of CD that occurred during the first 10 years of this century, up to 70% were related to oral transmission with a case-fatality rate of 1% [3, 4]. Thus, human infection by *T. cruzi* is arguably re-emerging as a foodborne disease, which must be analysed through a new multidisciplinary perspective to understand all its human, animal and environmental factors. The main objective of addressing zoonotic diseases with a One Health approach is to know and prevent epidemiological risks, considering the influence of factors relating to human, animal and environmental health in a determined social and economic context. Therefore, the complexity of zoonotic diseases forces us to the need for a paradigm shift from disease-centred interventions towards a more holistic and interdisciplinary coordinated approach [7].

This work analyses, from a One Health approach, the situation of infection with *T. cruzi* by oral transmission from a systematic review of publications on documented and proven outbreaks, to know the sources of infection involved, the domestic and wild vectors and reservoirs present in the foci of infection and how to address the epidemiological risks associated with oral transmission of CD.

METHODS

The systematic review followed the standard systematic review procedures of Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] (www.prisma-statement.org). The review used the following guidelines: (a) a database-based search to identify potentially relevant articles, (b) evaluating the relevance of articles, (c) quality assessment, and (d) extraction of data. These processes are summarised in the Figure 1.

The bibliographic search was conducted in the SCOPUS, PubMed, and SciELO databases and based on combinations of the following keywords: 'Chagas disease' OR 'Trypanosoma cruzi', AND 'acute disease', 'transmission oral', 'disease outbreak'. Only reports in English, Spanish and/or Portuguese with a publication date posterior to 1965 and full text available were included.

Only studies in which clinical cases of oral transmission were confirmed by parasitological and/or serological tests

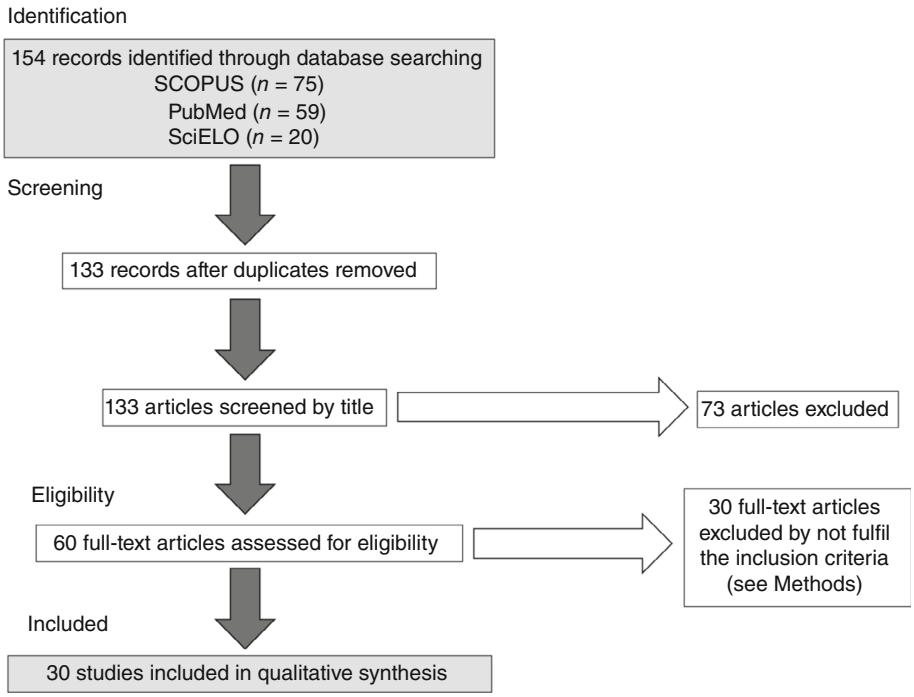

FIGURE 1 The PRISMA flow chart diagram. This flow of information shows the different phases of this systematic review (adapted and modified from Moher et al. [8]).

TABLE 1 Main characteristics of oral transmission outbreaks of Chagas disease identified from the systematic review comprising the references included in the Annex 1 (1965–2022).

COUNTRY zone, state/department	Year	Cases	Deaths	Source of infection	Vector	Reservoir	References (Annex 1)
VENEZUELA		239	12 (5.0%)				
Chacao, Caracas	2007	103	1	Guava juice	*P. geniculatus*	*Rattus rattus*	1, 2
Chichiriviche de la Costa, Vargas	2009	89	5	Guava juice	*P. geniculatus*	NI[a]	3
Rubio, Táchira	2010	6	1	Contaminated food	*P. geniculatus*	NI	4
El Bordo, Mérida	2012	5	1	Contaminated fruits	*P. geniculatus*; *T. maculata*; *R. prolixus*; *E. mucronatus*	*D. albiventris*; *Mus* spp., *Rattus rattus*	5
La Macarena, Mérida	2015	9	4	Contaminated food	*R. prolixus*	*Canis lupus familiaris*	6
Puerto Nuevo, Táchira	2018	27	0	Fruit ice cream	NI	NI	7
BRASIL		197	16 (8.1%)				
Estrêla, Rio Grande do Sul	1965	17	6	Contaminated food	*P. megistus*	*D. marsupialis*	8
Catolé do Rocha, Paraíba	1986	26	1	Sugarcane juice	*T. brasiliensis*; *T. pseudomaculata*; *P. megistus*	*D. albiventris*	9
Mazagão, Amapá	1996	17	0	Acai juice	*P. geniculatus*; *R. pictipes*	*D. marsupialis*; *Marmosa* spp.	10
Belém, Pará	2000	11	0	Contaminated drink	NF[b]	NI	11
Navegantes, Santa Catarina	2005	24	3	Sugarcane juice	*T. tibiamaculata*	*D. aurita*; *D. albiventris*; *Marmosa* spp.	12
Barcarena, Pará	2006	11	0	Acai juice	NF	NI	13
Ibipitanga, Bahia	2006	6	0	Sugarcane juice	*T. sordida*	NI	14
Macaúbas, Bahia	2006	7	2	Contaminated water	*T. sordida*	*Didelphidae*	14, 15
Aratuba y Redenção, Ceará	2006	8	2	Vegetable soup (contaminated post cooking)	*T. brasiliensis*; *P. lutzi*	*D. albiventris*; *Monodelphis domestica*; *Trychomis laurentius*; *Rattus rattus*	16
Breves, Pará	2007	12	0	Contaminated food	NF	NI	17
Bagre, Pará	2007	13	0	Contaminated food	NF	NI	17
Santa Isabel do Rio Negro, Amazonas	2010	17	0	Acai juice	NI	NI	18
Marcelino Vieira, Rio Grande do Norte	2016	18	2	Sugarcane juice	*T. brasiliensis*; *T. pseudomaculata*	*Cavia aperea*	19, 20
Manaos, Amazonas	2017	10	0	Acai juice	NI	NI	21
COLOMBIA		110	9 (8.2%)				
Lebrija, Santander	2008	10	2	Mandarin orange and soursop juice	*P. geniculatus*; *R. pallescens*	*D. marsupialis*	22, 23
Bucaramanga, Santander	2009	5	1	Mandarin orange juice	*P. geniculatus*; *R. pallescens*	*D. marsupialis*	22, 23
Piedecuesta, Santander	2009	5	0	Contaminated food	*P. geniculatus*	*D. marsupialis*	22, 24
San Vicente de Chucurí, Santander	2010	3	0	Contaminated food	*P. geniculatus*; *R. pallescens*	*D. marsupialis*	22, 24
Girón, Santander	2010	5	0	Contaminated food	*Triatominae*	*D. marsupialis*	22, 24

(Continues)

TABLE 1 (Continued)

COUNTRY zone, state/department	Year	Cases	Deaths	Source of infection	Vector	Reservoir	References (Annex 1)
Aguachica, César	2010	11	0	Contaminated food	*R. pallescens*; *P. geniculatus*; *E. cuspidatus*	*D. marsupialis*	24
Turbo, Antioquia	2010	11	1	Contaminated water	*P. geniculatus*	*Caluromys lanatus*	25
Paz de Ariporo, Casanare	2014	40	2	Contaminated food	*R. prolixus*	*D. marsupialis*; *Canis lupus familiaris*	26, 27
Restrepo, Meta	2014	4	0	Contaminated drink	*P. geniculatus*; *R. pictipes*	*Didelphidae*; *Canis lupus familiaris*	27
El Roble, Sucre	2019	16	3	Contaminated water	*R. pallescens*; *E. mucronatus*	NI	28
BOLIVIA		14	0 (0.0%)				
Guayaramerín, Beni	2010	14	0	Patawa juice	*R. robustus*	NI	29
FRENCH GUIANA		8	0 (0.0%)				
Cayenne	2005	8	0	Bacaba	NI	NI	30

Note: Genera abbreviations for triatomine vectors (in alphabetical order): *E.* (*Eratyrus*), *P.* (*Panstrongylus*), *R.* (*Rhodnius*), *T.* (*Triatoma*). Genera abbreviation for reservoirs: *D.* (*Didelphis*).
[a]NI: not investigated, the study did not search for the vectors or reservoirs involved.
[b]NF: not found, the vectors involved were not found or identified from the epidemiological research carried out in the study.

that included an epidemiological investigation of sources of infection, vectors and reservoirs were considered.

The initial search resulted in 154 articles. The studies were selected for qualitative synthesis if they met all of the following inclusion criteria: (i) only descriptive studies of outbreaks of oral transmission of CD, (ii) only studies in which an epidemiological investigation was carried out looking for possible sources of infection, vectors and/or reservoirs involved (at least some of them) and (iii) whose clinical cases were confirmed by parasitological and/or serological tests.

The final selection included the 30 studies (Annex 1) discussed in this review from which the following data: type of study, year of epidemic outbreak, location, number of total cases, number of deaths, cause of death, tests used for diagnosis, symptoms, possible source of infection, possible vectors and reservoirs involved, type of search for them and other specific characteristics of each outbreak were considered. These were studies with clinical cases of oral transmission presenting positive parasitological and/or serological tests, and epidemiological investigation of sources of infection, vectors and reservoirs although in the majority of cases the parasite was not detected in the initial source of infection. Other-related articles that arose during the search, including bibliographies from selected papers were reviewed and added as additional information sources (see References).

RESULTS AND DISCUSSION

The location (country and zone, state/department), year of the outbreak, the number of cases and deaths reported, the potential sources of infection involved, and the main vectors and reservoirs present in the foci of infection from the publications selected from the systematic review are summarised in Table 1.

We found 32 outbreaks of CD due to oral transmission of *T. cruzi* comprising 568 cases and 37 associated deaths. The average mortality of the evaluated outbreaks was 6.51% (and 3.45% in the three largest outbreaks). In seven outbreaks, the cause of death was declared as myocarditis with acute cardiac failure.

The geographical distribution of the outbreaks (Figure 2) was: 14 in Brazil (refs. 8–21, Annex 1), 10 in Colombia (refs. 22–28, Annex 1), 6 in Venezuela (refs. 1–7, Annex 1) and 1 each in Bolivia (ref. 29, Annex 1) and French Guiana (ref. 30, Annex 1). Almost 60% of the outbreaks were reported between 2006 and 2010. The first orally transmitted outbreak of CD occurred in 1965 and was reported in 1968.

In all evaluated studies, oral transmission was confirmed considering the epidemiological, environmental and health characteristics of the epidemic outbreak. However, in 13 out of 32 outbreaks, the source of infection could not be fully identified, mainly because of the difficulty of collecting food samples for analysis given the long delay between the occurrence of cases and the beginning of investigations.

Among the sources of infection, fruits and plants were prominent: acai (*Euterpe oleracea*) and sugarcane

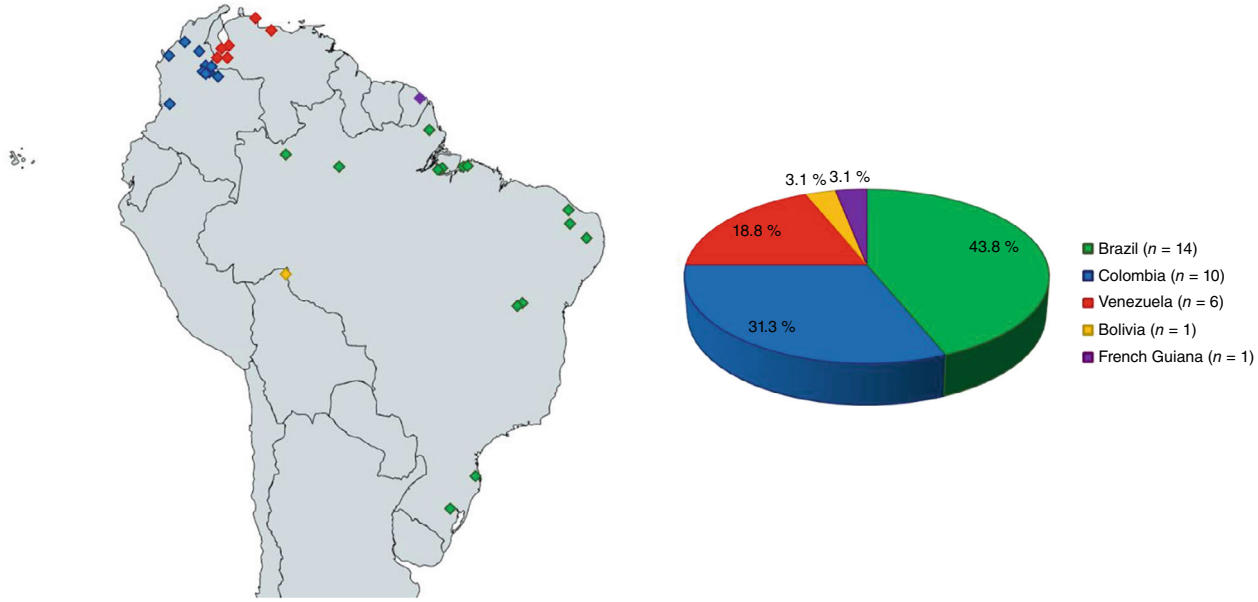

FIGURE 2 Geographical distribution and percentage by country of orally transmitted outbreaks of Chagas disease compiled from the systematic review described in this work. Left: Geographical distribution of outbreaks coloured by country. Right: Percentage of outbreaks by country. The total number of outbreaks by each country is indicated between parentheses.

(*Saccharum* spp.) in Brazil, guanabana or soursop (*Annona muricata*) and mandarin orange (*Citrus reticulata*) in Colombia, guava (*Psidium guajava*) in Venezuela, *majo* or patawa (*Oenocarpus bataua*) in Bolivia and *milpesillo* or bacaba (*Oenocarpus bacaba*) in French Guiana.

Vectors were identified in 24 of 32 (75%) outbreaks. *Panstrongylus geniculatus* was the most common vector in Colombia (in 7 out of 10 outbreaks) and in Venezuela (in 4 out of 5 outbreaks), *Rhodnius pallescens* was also common in Colombia (in 5 out of 10 outbreaks). In Brazil, the vectors were different species of the genera *Triatoma* and *Panstrongylus*, while in Bolivia the only vector identified was *Rhodnius robustus*. No entomological research was conducted in the French Guiana outbreak. In 25% of the outbreaks, no vectors were found or identified and in 40% of outbreaks, no reservoirs were investigated; didelphid marsupials and rodents were the main species identified.

Human health

Almost 60% of the outbreaks were recorded between 2006 and 2010, coinciding with the years in which oral cases started to increase significantly [4, 9, 10]. Until 2004, cases of acute CD associated with the consumption of contaminated food were scarce [11], and therefore under-reported.

Two types of epidemic outbreaks can be differentiated in people who develop symptoms simultaneously and who are related in a certain space and time by sharing certain foods. On the one hand, 90% of outbreaks occurred in family settings with an average of 11 people affected, so they can be considered small outbreaks in family environments. On the other hand, there have been three major outbreaks, two in Venezuela with 103 and 89 people infected in schools in 2007 and 2009, respectively, and one in Colombia, with 40 people infected in a restaurant in 2014.

In symptomatic patients, the main symptoms were prolonged fever, headache and muscle pain and no signs of the parasite's entrance route (unilateral palpebral oedema or Romagna's sign or inflammatory reaction or inoculation chagoma in the bite area) were observed discarding a vectorial transmission. In 40% of outbreaks, the initial symptoms were confused with those of other endemic infectious diseases, thus delaying a definitive diagnosis and treatment, which is more effective the earlier it is.

The mortality percentages in the oral transmissions outbreaks were quite variable (0%–44%), and similar to those reported in a previous study (8% and 35%) [12]. No fatal cases were found in 16 of 32 (50%) outbreaks. The lethality (case-fatality rate = 1%) in symptomatic cases is similar to that from other routes of infection [4] and may be due to the high prevalence of cardiac complications together with the absence of a successful early diagnosis and/or an adequate treatment.

Acai and sugarcane were the source of infection in 8 of 14 outbreaks in Brazil, which is the world's largest producer, consumer and exporter of acai fruit [11]. These berries have become popular globally and are currently the most commercialised Amazonian fruit in the Brazilian and international markets. A study of the presence of DNA from *T. cruzi* showed that it could be detected in a 20% of acai samples [13]. Hence it is essential to implement hygienic measures and food quality controls in the commercial chain.

Experimental contamination has shown dependence on the type of food and also the refrigeration to which it is subjected. In fruit juices, *T. cruzi* can survive at room

temperature up to 72 h in mandarin orange juice and 24 h in guava juice; in soursop juice it can survive up to 48 h at room temperature and up to 384 h under refrigeration [9]. Since handmade juices are usually consumed within a few hours of preparation, there is a risk of infection due to the use of fresh fruits if they are not subjected to pathogen elimination.

So far, four pathways of food infection with *T. cruzi* have been described:

- Contamination of food with triatomine faeces, as identified in 26 of the 32 outbreaks. Infective metacyclic tripomastigotes access the host by its digestive system and have been demonstrated in experimental studies with fruits, vegetables and beverages intentionally contaminated with metacyclic tripomastigotes obtained from the rectal ampoule of *Rhodnius prolixus*, demonstrating its survival and infective capacity [14].
- Accidental consumption of whole triatomines along with food. It is possible in outbreaks involving artisanal juices when the fruit is crushed and may accidentally grind insects too.
- Contamination of food with secretions from the anal glands of certain reservoir animals containing epimastigotes and metacyclic trypomastigotes [15] and identified in 15 of the 32 outbreaks.
- Consumption of raw or undercooked meat and/or blood from infected animals [16]. This was not detected in any of the evaluated outbreaks, but could be a source of infection maintenance in wild animals.

In addition, indirect contamination may occur through cooking utensils or equipment and during the transport, processing or distribution of food [11]. It is therefore essential, especially in community establishments, to implement hygienic and health inspection measures such as:

- Parasitological quality certification throughout production and marketing for products with a high potential transmission risk.
- Risk assessment of outbreaks from oral transmission by products exported over long distances.
- Hygiene and food safety campaigns: promoting basic cleaning and disinfection, how to avoid cross-contamination, and perhaps prohibition of unpasteurized artisanal juices and fruits, especially in schools or street markets.
- Development of community education programs to inform about the risk posed by food consumption in certain areas such as street sales to both locals and tourists.

More health professionals educated and trained in the differential diagnosis of CD against other infectious diseases and in local epidemiological surveillance are needed. Where they exist, structured health systems for early diagnosis of malaria could be used, and technicians to improve environmental sanitation where necessary. Surveillance and prevention networks have been created in Brazil, Ecuador, Colombia, Guyana, French Guiana and Peru in addition to those of PAHO-WHO as a response to Chagas outbreaks of foodborne diseases [17].

Animal health

In some of the outbreaks, triatomines were not found in the domiciles, but CD is gaining relevance even in areas where the presence of domestic triatomines has not been reported. To identify the triatomine species involved, active searches for the vector were carried out inside the houses near the origin of the outbreak and in peri-domiciliary areas by trained local communities. There is a big difference in the vector transmission route between infection through the domestic cycle of the parasite, and oral transmission, where the wild cycle between triatomines and reservoirs becomes relevant.

Insecticide spraying campaigns in endemic countries since the 1990s [18] have significantly reduced the presence of the main vector-borne species (mainly *T. infestans*). The problem is that new species take their place due, in part, to the lack of an adequate entomological monitoring, control and surveillance after fumigation, which could be carried out by local communities after an adequate training. The most relevant findings regarding vectors were:

- In 50% of the 24 outbreaks with vector identification, the possible vector involved was *P. geniculatus*, native to wild areas, but certain biotic and abiotic factors have promoted its change to domestic habitats [19] where it feeds on domestic cycle reservoirs and can contaminate food with its faeces or urine secretions.
- The vectors of the genus *Rhodnius* (*R.*) were found in 46% of those outbreaks, being also predominantly wild triatomines, such as *R. prolixus*, found in Colombia and in Venezuela, its main ecotope are palm trees, native such as *Attalea butyracea* or exotic cultivation such as *Elaeis guineensis* (oil palm) with a high rate of infection by *T. cruzi* [20]. In the palms, the vector can contaminate fruits and moreover has a high domiciliation presence [21]. The vector *R. pallescens*, especially important in Colombia, has been found associated with the same species of palm trees within or on the periphery of rural communities and may have sporadic intrusions into homes. Another triatomine is *R. brethesi*, although it has not been confirmed in any outbreak of oral transmission, CD is considered as an occupational disease of workers of extraction of piassava fruits and fibres, during which individuals come into contact with this vector, as it inhabits palm trees such as *Leopoldinia piassaba* [22].
- Vectors of the genus *Triatoma* are especially relevant in Brazil and have been found in 6 of 8 outbreaks there. Thus, *T. brasiliensis* has been reported in the home interior and presents high rates of infection, both in the wild and in the peri-domestic environment [23]. As for *T. sordida*, it is considered a secondary vector in process

of domiciliation [24], occupying the space left free by *T. infestans* in the houses after vector control programs. According to Ribeiro et al. [25], all these vectors present in the areas of outbreaks of oral transmission present wild populations, making it difficult to eliminate them with insecticides.

- Therefore, new triatomine species mainly linked to the wild cycle have high rates of *T. cruzi* infection [21] and begin to come into contact with humans due to the environmental changes that destroy their natural ecotopes reducing their food animal sources as birds or mammals, and on the other hand, humans are colonising their wild habitats.
- In addition, the variety of triatomines causing outbreaks of oral transmission is much greater than that of those that transmit it by bite, since any triatomine can produce infection by defecating in food, whereas to infect through the skin, they need to have a rapid ejection reflex (one of the most important vectors in terms of oral transmission, *P. geniculatus*, however, does not usually infect by vector transmission due to its slow ejection reflex).

No cases of vector transmission have been described outside the Americas, but the spread of the disease to other continents (due to migration and vertical transmission) could pose a risk if accompanied by vector dissemination. Therefore, the potential geographical distribution under current climatic conditions of 11 triatomine species was investigated, revealing that suitable habitats exist for some of them in temperate areas of Portugal, Spain and Italy and Eastern Australia [26]. Climate change and transnational movements of goods and people could promote potential dissemination, and entomological monitoring programmes should be initiated.

About 180 species of 25 mammal families have been described as potential reservoirs of *T. cruzi* [27–29]. In outbreaks by oral transmission, the main ones (70%) are different species of marsupial didelphids such as *Didelphis (D.) marsupialis*, *D. aurita*, *D. albiventris* and *Marmosa* spp., *Monodelphis domestica* or *Caluromys lanatus*, which are synanthropic reservoirs (supposing a link between the domestic cycle and the wild cycle) relevant, acting as reservoirs and vectors. The following species, with a 10% presence each, are dogs (*Canis lupus familiaris*), black rat (*Rattus rattus*) and rodents of the genus *Mus* spp. (mice) and the species *Trichomys laurentis* (Sao Lourenco punare) and *Cavia aperea* (Brazilian guinea pig). The dog is a domestic reservoir already identified in 1969 [30] and an important food source for triatomines but it can also ingest these insects or remains contaminated with their faeces, establishing vector and oral transmission routes. Due to its coexistence with people, it is a good sentinel animal to detect the circulation of the parasite in the domestic cycle in high-risk areas. In the domestic and peri-domestic cycle in urban environments, rats are the main reservoir, ahead of dogs and cats [27]. Other naturally infected reservoirs are wild rodents such as *Dasyprocta agouti* and *Trichomys apereoides*, especially in Venezuela [31], and *Echimys dasythrix* and *Akodon* spp. [32], although no outbreaks of oral transmission related to them have occurred so far.

Environmental health

Environmental changes affecting the ecology and ethology of vectors and reservoirs are particularly relevant and have contributed to the increase of cases of CD by oral transmission. They are all changing the behaviour, distribution and diversity of the *T. cruzi* cycle [27].

The most important environmental aspects include global warming, deforestation, reforestation with non-native or endemic plants, urbanisation of new areas or the construction of roads and other infrastructures, which are producing changes in the natural ecotopes of wild vectors and reservoirs, forcing them to move to new areas [16], even urbanised, coming into contact with people and domestic and peri-domestic species. For example, certain areas of the Amazon jungle suffer from increased population density and consequent urbanisation, accompanied by the introduction of intensive agriculture and monocultures reducing reservoirs biodiversity or forcing wild vectors into homes to find food. A good example is acai palm monocultures (increased by 99.6% between 2007 and 2016) [33] or palm trees (*Elaeis guineensis*) to obtain the palm oil that involves massive felling of trees, significant damage to the ecosystem and a rapid reduction of biodiversity.

In addition, large human migrations from rural areas to cities in recent decades have also contributed to the introduction of parasites in urban environments where they persist thanks to the presence of domestic and peri-domestic reservoirs. These urban environments also favour the arrival of some vectors attracted by the brightness of artificial lighting: at night some triatomines, such as *P. geniculatus*, are attracted by the internal and external house lights [34].

CONCLUSION

CD will be difficult to eradicate since the wild cycle will continue, allowing the circulation of *T. cruzi* by oral transmission. Thus, actions must focus on prevention and control. Coordinated collaborative and multidisciplinary strategies should be adopted for a One Health approach to CD, considering all the determinants that predispose individuals and reservoirs to contracting the disease, including animal (insects and reservoirs) and environmental aspects as well as human health and socio-cultural aspects.

ACKNOWLEDGEMENTS

The authors would like to thank our institution (Complutense University of Madrid) for covering the Article Publication Charges (APCs) through a CRUE-CSIC and Wiley Open Access Account.

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How to cite this article: López-García A, Gilabert JA. Oral transmission of Chagas disease from a One Health approach: A systematic review. Trop Med Int Health. 2023;28(9):689–98. https://doi.org/10.1111/tmi.13915

ANNEX 1

Bibliographic references included in the systematic review after applying inclusion and exclusion criteria (Figure 1; see Methods for details).

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