Impact Involving the Community in Entomological Surveillance of the *Triatoma Infestans* Vectorial Control

Luciana Abrahan (✉ lucianaabrahan@conicet.gov.ar)

Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR),
Provincia de La Rioja, UNLAR, SEGEMAR, UNCa, CONICET, Anillaco, La Rioja, Argentina.

<https://orcid.org/0000-0003-2651-4969>

Maria José Cavallo

Centro de Investigaciones y Transferencia de Catamarca

Ivana Amelotti

Centro Regional de Investigaciones Científicas y Transferencia Tecnológica de La Rioja (CRILAR),
Provincia de La Rioja, UNLAR, SEGEMAR, UNCa, CONICET, Anillaco, La Rioja, Argentina.

Research

Keywords: Triatomines, kissing bugs, Chagas disease, community participation

Posted Date: August 10th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-55505/v1>

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Abstract

Background

Vectorial transmission is the principal way of *Trypanosoma cruzi* infection, the parasite that cause Chagas disease. In Argentina, *Triatoma infestans* is the principal vector, for this reason, vector control is the main strategy for the prevention of this illness. Provincial Program of Chagas La Rioja (PPCHLR) carries out entomological evaluation of domiciliary units (UD) and spraying those where *T. infestans* are found. The lack of government funds generated low visit frequency of PPCHLR, especially in areas with a low infestation that they were not prioritized. For this reason, seeking possible alternatives to complement control activities are necessary. Involving householders in entomologic evaluation would be a control alternative. The major objective was to determine the cost of entomological evaluation with and without community participation.

Methods

For entomological evaluation with community participation, 434 DU corresponding to nine localities of Castro Barros Department (CBD) were selected in November 2017. *T. infestans* infestation of DUs selected was determined involving the community in triatomines detection. Each householder was trained in the insect collection that were kept in labelled plastic bags and recovered after two weeks to analyse *T. cruzi* presence in laboratory. For entomological evaluation without community participation, PPCHLR data collected in February 2017 over 359 DU of CBD were used. Entomological evaluation costs with and without community participation over DU visited number, over DU evaluated number, and over DU sprayed were calculated and compared between methodologies. In addition, DU evaluated number out DU visited number was compared. The infestation in the area was 13.8%, with relative risk differences by zones.

Results

The results showed that the triatomines did not show evidence of *T. cruzi* infection. Costs in relation to DU visited, to those evaluated and to those sprayed, were lowered with community participation ($p < 0.05$). In addition, a greater number of DU evaluated in relation to those visited as well as greater surface were covered with community participation.

Conclusion

The participation of the community in the infestation survey is more efficient, allowing the spraying to be focused on infested houses and thus reducing costs and intervention times by PPCHLR.

Background

Chagas disease continues to be an important public health problem in Latin America where it is estimated that there are between 6 and 7 million people infected with the *Trypanosoma cruzi* parasite, the causative agent of this disease [1]. In Argentina, it is assumed that there are between one to three million

people who could have this disease, although there are currently no official data on the number of people infected or at risk of *T. cruzi* infection [2].

This parasite can be transmitted through different ways, although in 80% of cases it is through vector transmission, that is, by contact with triatomines, so the control of this infestation is the main strategy for the prevention of the illness.

In Argentina, *Triatoma infestans* is the triatomine species with the greatest epidemiological importance, given its ability to inhabit within and on houses periphery. La Rioja province is endemic for Chagas disease, considered of medium risk in the transmission of this disease by *T. infestans* [3]. Provincial Program of Chagas La Rioja (PPCHLR) works on entomological evaluation and insecticide spraying in positive houses to eliminate *T. infestans* infestation, without considering householder denouncement, ensuring that the negative houses do not receive treatment. For entomological evaluation of houses, the PPCHLR staff moves from the Capital city to the different departments and returns to them depending on political decisions over economic resources derivation. For this reason, PPCHLR focalizes surveillance in departments with a high infestation. Castro Barros Department (CBD) is located to the northeast of La Rioja province. This department was evaluated by PPCHLR in 2009 and in 2013, showing a domestic infestation less than 12% and the last chemical intervention was registered in 2013 (PPCHLR, unpublished data). The low frequency in vector control intervention in CBD in part, it is a consequence of a lower *T. infestans* infestation in relation to others that have been a priority for PPCHLR, such as, San Martin Department [4, 5]. It is known that higher intervention interval favors the risk of *T. infestans* populations' recover [6]. At the same time, the community demand vector control activities due to the frequent *T. infestans* presence. Therefore, in this area, community participation in entomological surveillance would be an essential tool given this complex scenario but the cost of this type of control activity needs to be evaluated. Entomological surveillance carried out by the householders has been described by several authors [e.g.7,8,9,10]. In Los Llanos riojanos, our working group confirmed the importance of incorporating community participation in entomological evaluation of houses [11].

This work was originated within a greater project in response to the community's demand to our research team that reside in CBD. The main objectives of this work were: to estimate departmental *T. infestans* infestation with community participation; to evaluate the infestation risk in different zones of the department and to determine the cost of vectorial control activities with and without community participation.

Methods

Study area:

CBD is located to northeast of La Rioja province, Argentina. Its departmental head is the Aminga locality, distant 95 km of the capital city. It is located in the biogeographic region of Monte Desert. The population

density is around 3 inhabitants / km². It is a rural population, concentrated in 10 villages that function as an oasis due to the availability of surface water. Total population of CBD is 4268 inhabitants [12].

About domestic infestation, between 2009 and 2013 ranged between 1.18% and 9.87% (PPCHLR, unpublished data). Each house with their peridomestic structures was defined as domiciliary unit (DU).

Entomological evaluation with community participation:

The infestation by *T. infestans* was evaluated by passive collection method on the selected DUs. This methodology includes the monitor DU infestation carried out for the householders [11]. A total of 434 DU corresponding to nine localities of CBD (Fig. 1) were selected considering the total number of DU in each locality (Table 1), covering the total area.

To this end, inhabitants of the selected DU received a detailed explanation of the study and were invited to participate. Inhabitants that accepted the invitation were trained in triatomines identification and careful collection to avoid the risk of accidental infection. Each participating family received plastic bags labelled with the DU identification code. Each passive collection lasted two weeks between November and December 2017 (between delivery and collection of the plastic bags). At the same time, health agents from local hospitals worked alongside householders.

The collected bags were transferred to the laboratory where species, gender and developmental stage [13] were determined and *T. cruzi* detection was performed in rectal material. For this analysis, the faecal samples were examined fresh in a drop of physiological solution in an optical microscope at a magnification of 400x for approximately 15 minutes (25 fields). After this analysis, the insects were deposited in the CRILAR Triatomines collections. *T. infestans* presence registered in each DU was notified to PPCHLR for pyrethroid insecticide treatment.

DU visited is defined as that DU selected in which householder was given bags for insect collection, previously trained.

DU evaluated was defined as that DU in which householder gave us bags with or without material. DU closed was defined as that DU in which householder was not present at bags collection moment.

Entomological evaluation without community participation

Rural houses in La Rioja Province are evaluated by PPCHLR brigades. The entomological evaluation, in these cases, is carried out only by trained personnel, PPCHLR technicians whose travel from capital city to perform triatomines search for a limited time and to use dislocating agent (tetramethrin 2%). This search is interrupted when insect is found in houses or until an hour of capture effort is completed. If an infestation is detected, the same technician teams performs the DU insecticide application. In each PPCHLR intervention, the infestation status and treatment of each georeferenced DU are registered. This type of control was defined as vertical intervention.

In February 2017 intervention, 359 houses localized in Aminga (one of ten localities of department), were evaluated and those positive for *T. infestans* were sprayed. In 2013, the latest departmental intervention was carried out by PPCHLR, that is, without community participation (PPCHLR unpublished data).

DU evaluated was defined as that DU in which householder was present and approved entomological evaluation while DU visited is defined as all DUs, included those in which householder was not present at the moment of entomological evaluation was carried out by PPCHLR technicians.

Climatic Variables

To verify the climatic conditions in the study area and based on equipment availability, three data loggers (HOBO U10 / 003 Onset Computer Corporation, Bourne, MA, USA), each of them were placed in Pinchas, Anillaco and Santa Vera Cruz localities. Temperature (°C) and relative humidity (%) were recorded at 15-minute intervals between 7:00 p.m. and 10:30 p.m., corresponding to the moment of the peak active dispersion for *T. infestans* [14, 15, 16].

Costs with and without community participation

When householders participated (December 2017), cost was constituted by the sum of the expenses incurred by PPCHLR (fuel and travel wage) and inputs used (brochures and gloves). When householders did not participate (February 2017), cost was only constituted by the expenses incurred by PPCHLR.

The cost over DU visited number, over DU evaluated number and in relation to DU sprayed number were calculated for each methodology.

The insecticide and spraying machine costs were simplified since they were the same for each methodology. In both cases, the supplies to carry out spraying were provided by National Chagas Program.

Data analysis:

A DU was recorded as “infested or positive” when at least one *T. infestans* individual was found in the DU. The percentage of infested DU was calculated over total evaluated DU and expressed as “DU infestation”. For the spatial analysis, firstly a descriptive infestation analysis by locality was performed. Secondly, the geographically aggregated localities (= cluster) was identified and with significantly greater or lower infestation compared to the average, that is, positive DU number observed in cluster is significantly greater (or less) than expected number. Moreover, the relative risk of each locality included in conglomerate was estimated, indicating how many times the proportion of positive DU for *T. infestans* within the locality is higher in relation to those observed in the cluster. Risk was estimated based on amount of positive DU observed in each locality over amount of expected DU in all cluster localities [17]. Analysis was performed using the SaTScan program (v. 9.4.4.), considering the locality as the analysis unit. Relative risks greater than 1 indicate a greater number of positive DU than those expected in the locality.

In addition, as possible explanatory factors for differences in *T. infestans* infestation among zones, environmental variables were compared between clusters by a non-parametric Kruskal-Wallis test using the Infostat program [18].

For cost analysis, data were compared between methodologies using Chi-Square of Infostat program [18].

Results

A total of 81.6% DU were evaluated (354/434) due to the fact that 18.4% of DU were closed at sample collection moment. The general infestation by *T. infestans* in the study area was 13.8%. The infestation varied between 0 and 50% among localities (Table 2).

Table 2
Infestation by *T. infestans* estimated by passive collection in Castro Barros Department, La Rioja.

Locality	DU evaluated	DU closed ^a	DU Infestation% (CI 95)	DU sprayed ^b
San Pedro	12	4	8.33 (0.44–40.25)	2
Santa Vera Cruz	13	3	0 (0–28.34)	0
Anjullon	36	6	0 (0–12.00)	0
Los Molinos	27	8	14.81 (4.86–34.61)	2
Anillaco	84	26	8.33 (3.7–16.95)	6
Aminga	73	26	5.48 (1.77–14.16)	4
Chuquis	41	3	12.19 (4.58–27.00)	4
Pinchas	52	3	38.46 (2.56–52.99)	18
Agua Blanca	16	1	50 27.99–72.00)	8
^a DU closed at the moment of bags collection				
^b DU sprayed by PPCHLR with householder approval				

The 89.8% of total infested DU detected by householders were sprayed by PPCHLR technicians with pyrethroid insecticide (Table 2). Householders collected 70 specimens of *T. infestans*, none with presence of *T. cruzi* infection. Figure 2 shows the low nymph number that were collected, the majority being adult insects. The abundance between localities could not be compared because collection time per householders is not standardized.

The spatial analysis allowed to detect differences in the infestation with respect to average in the area. Three clusters in the area were identified. The first cluster called North Zone, presented an infestation of

0.02%, that is, less than the average in the area (Relative risk = 0.1; $p = 0.02$) and covered three localities, San Pedro, Santa Vera Cruz and Anjullón, with 61 DU and with a radius of 6.33 km centred on -28.66°S , -66.92°W . The second localities grouping in a cluster, called Centre Zone, presented an infestation of 0.07% also lower than expected (Relative risk = 0.37; $p = 0.04$) with two localities, Aminga and Anillaco, with 157 DU and with a radius of 4.68 km centred at -28.85°S , -66.93°W . The third cluster, called South Zone, with an infestation of 39.7%, higher than expected (Relative risk = 5.4; $p < 0.001$) that covered two localities, Agua Blanca and Pinchas, with 68 DU and a radius of 4.88, centred on -28.96°S , -66.99°W . (Fig. 3).

As possible factors that could influence the zonal infestation differences, temperature and relative humidity were compared among clusters. South Zone had a higher temperature than Centre Zone, and this, in turn, had a higher temperature than North Zone (H: 96.73, gl:2, $p < 0.0001$). In relation to relative humidity, South Zone showed lower humidity than Centre Zone, and this in turn showed lower humidity than North Zone (H: 59.51, gl: 2, $p < 0.0001$). Table 3 shows the median temperature and relative humidity.

Table 3
Median of temperature ($^{\circ}\text{C}$) and relative humidity (%) for each cluster
(Quartiles 1 and 3).

Cluster	Variable	Median	Quartile 1	Quartile 3
North Zone	Temperature	22.33	20.42	24.84
	Relative Humidity	52.53	42.67	62.44
Centre Zone	Temperature	26.68	25.42	28.16
	Relative Humidity	40.03	34.01	45.94
South Zone	Temperature	28.06	26.98	29.45
	Relative Humidity	35.82	30.64	38.38

When costs were compared between methodologies (Table 4), data showed a reduction in costs related to DU visited ($\chi^2 = 4.57$, $p < 0.0325$), to those evaluated ($\chi^2 = 24.64$, $p < 0.0001$) and to those sprayed ($\chi^2 = 13.22$, $p < 0.0003$) with community participation. Moreover, a greater number of DU evaluated in relation to those visited ($\chi^2 = 23.43$, $p < 0.0001$) as well as a larger surface covered (163.9 vs. 0.8 km^2) were obtained with community participation.

Table 4 Comparisons of indicators between methodologies in Castro Barros Department during 2017

Variables	Entomological Evaluation with Community Participation (Dec)	Entomological Evaluation by PPCHLR, without Community Participation (Feb)
Number of DU visited	434	359
Number of DU evaluated	354	109
Number of DU sprayed after evaluation	43	57
Surface evaluated (km ²)	163.89	0.796
Cost	1323.71	3809.90
Cost over the number of DU visited	3.05*	10.61*
Cost over the number of DU evaluated	3.74**	34.95**
Cost over the number of DU sprayed	30.78***	66.84***

* $\chi^2=4.57$, $p<0.0325$; ** $\chi^2=24.64$, $p<0.0001$; *** $\chi^2=13.22$, $p<0.0003$

Table 1 Description of the study area for each locality.					
Locality	Total number of DU ^a	Inhabitants number ^b	Altitude (masl)	Number of DU visited	Coverage (%) ^c
San Pedro	145	298	1507	16	11
Santa Vera Cruz	79	123	1323	16	20
Anjullon	242	418	1294	42	17.36
Los Molinos	166	244	1254	35	21
Anillaco	678	1573	1325	110	16.22
Aminga	359	833	1275	99	27
Chuquis	157	236	1323	44	28.03
Pinchas	262	390	1351	55	20.99
Agua Blanca	30	68	1470	17	56.7

1. Local hospitals database.
2. Instituto Nacional de Estadística y Censos. 2010.
3. Coverage is calculated as number of DU visited over DU total number.

Discussion

Vector control infestation is the main strategy for preventing Chagas disease. When vector control actions are carried out in a sustained and committed way over time, triatomines presence in houses is reduced and consequently, the risk of vector transmission decreased. However, in areas where the infestation is reduced, a paradox occurs as these areas lose surveillance priority and are visited less and less frequently, and their chemical treatments are postponed. This misconception produces a huge setback to achieve the main objective, which is the vectorial transmission interruption. For this reason, it is important to generate strategies that guarantee constant entomological surveillance, to control areas where a low domiciliary infestation allows *T. infestans* population return to infestation levels found before control actions. For CBD, entomological evaluation frequency is greater than three years and, at each visit, evaluation coverage is reduced due to political decisions that limit PPCHLR logistic and budget.

In this work, the impact of incorporating community participation in areas with a low domestic infestation that in general are neither focus of study nor priority to apply vector control actions is analysed. The low frequency with a vertical program cannot meet demand in areas where infestation risk is known to be low [5], causing the domestic vector persistence to continue and recovering populations among spraying

cycles [6]. Incorporating participatory approaches against vector-borne diseases has been shown to be important for control program sustainability [8, 10, 11, 19, 20]. However, there is still debate regarding the limitations of incorporating community participation in house surveillance circuit due to *T. infestans* presence reported in houses where it is not present, as positive false.

Specifically, in La Rioja province, it is assumed that a house is positive only when PPCHLR technicians corroborate *T. infestans* presence in DU. The theoretical vector control model would be annual intervention by specialized technicians who evaluate and spray houses. In fact, this logistical capacity does not exist. Given the actual situation, advantages and disadvantages of maintaining only vertical PPCHLR interventions in low infestation areas are necessary to be re-evaluated.

In this work, using field data collected in the same year and without modelling on indirectly estimated variables, two intervention types were compared, showing that costs in relation to DU visited, evaluated, and sprayed were lowered with community participation. In addition, a greater proportion of DU evaluated in relation to those visited as well as greater surface were covered with community participation.

Other studies have analysed the cost-effectiveness of different interventions types with similar results obtained in this work, although with completely different approaches that do not allow a direct comparison with our data. For example, in Mexico, the cost to evaluate entomologically a domicile, detecting *T. dimidiata*, was US\$70 for an infested house by carrying out an active search and only US\$10 when householders were involved [21]. Also, in Santiago del Estero (Argentina) a very complete analysis was carried out using variables related to costs considering community intervention, estimating that costs were reduced in surveillance phase. Cost-effectiveness was also analysed in attack phase, where householders sprayed own houses, although this situation created vector control quality problems in long term [10]. These latter results would not be comparable to our data since our focus is only on entomological surveillance and the spraying is only carried out by specialized personnel.

Despite methodological differences, there are many works showing a cost decrease when community collaborates in surveillance phase [8, 10, 11, 19, 20, 22]. In this work, we recommended that community intervention is only in surveillance phase to guarantee an early triatomines detection but the spraying function is always responsibility of personnel specifically trained for this task.

In order to control circuit function correctly, we proposed that householders inform about the *T. infestans* presence in their houses and notify to Municipality. The municipal referent verifies or not this species presence. If houses are *T. infestans* positive, personnel designated for this purpose spray them and surroundings. Although, in this particular context, our CRILAR medical entomology team participates in a social commitment, it is expected that this activity should be carried out routinely by health area staff or Chagas municipal referent implying that there would be no extra costs. In this way, technician work is optimized, focusing the spraying on positive houses already surveyed by sanitary agents, while, at the same time, reducing travel wage and fuel costs for the transfer of PPCHLR personnel to field. These economic resources would be designated to higher infestation areas without causing a triatomine increase in areas visited sporadically.

In addition to the cost reduction, *T. infestans* domestic infestation estimated with community participation allowed a spatially heterogeneous infestation detection in the north of La Rioja. These results coincide with those obtained in the south of La Rioja [4, 5, 11] and in other areas of Gran Chaco [23]. Within of La Rioja Province, *T. infestans* domestic infestation in CBD was lower than in Los Llanos riojanos (13.8 vs 21.4%) carried out with community participation [11]. In relation to infection risk, in CBD, triatomines did not show evidence of *T. cruzi* infection while in Los Llanos exist vectorial transmission risk of *T. cruzi* [5, 11].

Within CBD, southern zone presented the highest risk of infestation. Heterogeneity in the infestation risk could be associated to climatic conditions and peridomestic structures presence. Climatic conditions could explain differences in *T. infestans* infestation among zones due to southern zone presented higher temperature and lower humidity in relation to the other ones. These climatic conditions, especially the temperature, could allow an optimal growth of the species as was observed by other authors [23, 24, 25]. Another factor that could explain differential zonal differences was the presence of peridomestic structures due to those gave refuge and feeding sources for triatomines [26]. Supplementary data (Additional file 1: Table S1) showed that southern zone presented the highest peridomestic structure percentage (58%, $\chi^2 = 64.67$, $gl = 2$, $p < 0.0001$). All these results showed that there are several factors that promote *T. infestans* presence, particularly in this zone.

To understand the set of variables associated with infestation in the area help in design of entomological surveillance implementation. An orderly and efficient entomological surveillance system is necessary in rural areas far from the capital, since otherwise the feasibility of maintaining a successful chemical control diminishes. Knowing variables involve in the infestation risk is useful to estimate the most appropriate and economic routes carried out so as not to stop covering areas with the greatest vector transmission risk [23], increasing coverage and cost-effectiveness of interventions [27].

This work allowed to verify that involving community in entomological surveillance reduced costs, covered a greater surface, covered a greater proportion of DU evaluated, encouraged early infestation detection and is the first step in stimulating control interventions. Furthermore, it promoted an active and positive attitude in local population in relation to Chagas disease prevention. However, for this strategy to be effective, municipalities should carry out sustained surveillance work and chemical control interventions to prevent *T. infestans* populations from recovering after an application interval. Therefore, these actions must continue to be encouraged and, in addition, the authorities must be committed to giving a quick and effective response to householder demands.

Conclusion

Community participation is recommended in low infestation areas where a vertical control strategy difficult an adequate control frequency. This strategy is more efficient and profitable, increasing collection effectiveness, allowing the spraying to be focused on infested houses, and thus, reducing costs and intervention times by PPCHLR, integrating easily with other health programs.

Abbreviations

PPCHLR

Provincial Program of Chagas La Rioja

CBD

Castro Barros Department

DU

Domiciliary Unit

Declarations

Acknowledgements:

To C. Nieto for collaborating in the field and laboratory activities, to householders of Castro Barros department, to Health Center of Pinchas and Los Molinos and their sanitary agents, to the technicians of the Provincial Program of Chagas La Rioja, to C Gonzalez in surface estimation of the study, to L. Fiorelli for figure assistance, to V. Valentinuzzi for her support in general research aspects and for providing dataloggers. LA, MJC and IA are CONICET members.

Funding:

Financial support was received from Argentinean National Council for Scientific Research (CONICET), grant PUE 0125 and Argentinean National Agency of Science and Technological Promotion (FONCyT) grant PICT 2016-0512 to L.A.

The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article. Raw data are available from the corresponding author on reasonable request.

Authors' contributions

LA, MJC and IA carried out the field and lab works, conceptualized and designed the study. LA drafted the manuscript; carried out statistical analyses and provided financial support. MJC and IA carried out statistical analyses and helped draft the manuscript. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Competing interests

The authors have declared that no competing interests exist.

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Figures

Figure 1

Geographical localization of Castro Barros Department and localities evaluated with community participation in December 2017. SP: San Pedro, SVC: Santa Vera Cruz, ANJ: Anjullón, LM: Los Molinos, ANI: Anillaco, AMI: Aminga, CH: Chuquis, PI: Pinchas, AG: Agua Blanca.

Figure 2

Abundance of *T. infestans* by developmental stage and gender in localities evaluated with community participation.

Figure 3

Clusters of localities with high and low infestation by *T. infestans* in Castro Barros Department. Entomological evaluation with community participation in December 2017. Each circle represents cluster area and groups localities with similar *T. infestans* infestation. North Zone Cluster (Low infestation = 0.02%). Centre Zone Cluster (Low infestation = 0.07%). South Zone Cluster (High infestation = 39.7%). SP:

San Pedro, SVC: Santa Vera Cruz, ANJ: Anjullón, LM: Los Molinos, ANI: Anillaco, AMI: Aminga, CH: Chuquis, PI: Pinchas, AG: Agua Blanca.

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