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## A Multi-disciplinary Overview of Chagas in Periurban Peru

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### Abstract

There are between 8 and 11 million cases of American Human Trypanosomiasis, commonly known as Chagas disease, in Latin America. Chagas is endemic in southern Peru, especially the Arequipa region, where it has expanded from poor, rural areas to periurban communities. This paper summarizes the findings of four studies in periurban Arequipa: on determinants of disease-vector infestation; on prevalence, spatial patterns, and risk factors of Chagas; on links between migration, settlement patterns, and disease-vector infestation; and on the relationship between discordant test results and spatially clustered transmission hotspots. These studies identified two risk factors associated with the disease: population dynamics and the urbanization of poverty. Understanding the disease within this new urban context will allow for improved public health prevention efforts and policy initiatives.

Discovered in 1909 by Brazilian physician Carlos Chagas, American Human Trypanosomiasis is a chronic and potentially life-threatening illness found throughout Latin America (Moncayo, 2003). Indeed, it is estimated that there are between 8 and 11 million cases in Mexico and Central and South America (Centers for Disease Control [CDC], 2009). Chagas disease, as it is most commonly known, is endemic in southern Peru, especially in the region of Arequipa. Once thought to be limited to poor, rural areas, the disease is now appearing in the periurban communities that surround Arequipa City, the capital of the region (Cornejo del Carpio, 2003).

Understanding the urbanization of Chagas disease will allow public health and medical professionals to better combat the further transmission of the disease.

After providing an overview of Chagas and introducing the scope of the disease in Latin America, this paper will summarize the findings of four recent studies conducted in periurban districts in Arequipa. Ultimately, this paper seeks to identify the risk factors associated with Chagas infection in Arequipa's periurban communities.

### What is Chagas Disease?

Chagas, like other neglected tropical diseases, is generally found among marginalized populations in poor countries. Indeed, individuals infected with the disease tend to earn lower incomes, suffer from chronic malnourishment, have lower educational levels, and live in poor-quality housing (Franco-Paredes et al., 2007). The disease not only stems from poverty, but also perpetuates the so-called “cycle of poverty.” Since Chagas symptoms manifest themselves in the most economically productive members of the population, the disease renders many unable to sustain a livelihood (Moncayo, 2003; Franco-Paredes et al., 2007; Tarleton, Reithinger, Urbina, Kitron, & Gürtler, 2007).

According to the World Health Organization, Chagas disease causes more morbidity and mortality than any other parasitic disease in the Western Hemisphere (World Health Organization [WHO], 2002). Up to 11 million individuals in Latin America are infected with the disease, and it is estimated that the disease accounts for a loss of 670,000 disability-adjusted life years annually (WHO, 2004; CDC, 2009). Moreover, the Inter-American Development Bank calculated that the economic burden of Chagas was five to ten times higher than malaria (Inter-American Development Bank [IADB], 2002). Though historically endemic to rural areas, within the past two decades, Chagas disease has become increasingly urbanized and is now found in cities throughout the Americas (WHO, 2002; Bastien, 1998).

#### *Transmission*

Chagas disease primarily occurs through vector-borne transmission by various species of triatomine bugs. In the transmission process, the protozoan parasite *Trypanosoma cruzi* (*T. cruzi*) is transferred to a human or other mammal through the feces of the triatomine insect vector. Typically, the feces enter through the insect bite wound or through the host’s mucus membranes (Kirchoff, Weiss, Wittner, & Tanowitz, 2004). Known as the “kissing bug” because it usually bites the host’s face, the triatomine insect is the main Chagas vector in the Southern Cone of South America (Bastien, 1998; CDC, 2009; Dias, Silveira, & Schofield, 2002). Furthermore, it is highly synanthropic, or ecologically associated with humans (Zeldon & Rabinovich, 1981; Cohen & Gurtler, 2001).

Another transmission route for Chagas disease is by blood transmission. Until recently, few countries screened donor blood for the *T. cruzi* parasite, and infectivity risk for individuals who received contaminated blood was estimated to be as high as 20% (WHO, 2002). Ten South American and three Central American countries now screen all blood donations (WHO, 2002). Transfusional transmission presents a challenge to both endemic and non-endemic countries. Chagas-infected migrants unknowingly transport the disease to Europe and the United States, where blood was not routinely screened for

*T. cruzi* until 2007 (WHO, 2002; Bern, Montgomery, Katz, Caglioti & Stramer, 2008; Piron et al., 2008; Bastien, 1998).

Chagas may also be transmitted congenitally—from mother to fetus—or through organ transplantation, as well as through the consumption of *T. cruzi*-contaminated foods or liquids (Benchimol Barbosa, 2006; Gurtler, Segura, & Cohen, 2003; Dorn et al., 2007; Tarleton et al., 2007). These transmission routes, however, are less common.

### ***Symptoms and Signs***

Though the severity and course of the disease affect individuals differently, there are generally two stages of Chagas disease, acute and chronic, both of which can be dangerously asymptomatic. Indeed, most cases never come to the attention of a physician. Persisting for the first few weeks or months of infection, symptoms in the acute stage include body aches, loss of appetite, fever, fatigue, headache, rash, diarrhea, and vomiting. The liver, spleen, and glands may also become enlarged. The most identifiable sign of acute Chagas infection, however, is Romana's sign, in which the eyelid and face swell. While most symptoms are resolved over time—acute Chagas disease is rarely fatal to otherwise healthy adults and children—the infection will persist if left untreated (CDC, 2009). Chronic Chagas, thus, ensues.

During the chronic stage of Chagas, the disease remains asymptomatic, though it is relatively common for individuals to develop cardiac and digestive problems. Indeed, between 20 to 30% of Chagas-infected individuals suffer from such diseases as cardiomyopathy (enlarged heart), arrhythmia (varied heart rate or rhythm), cardiac arrest, megacolon (enlarged colon) and megaesophagus (enlarged esophagus) (Bastien, 1998; CDC, 2009). Chronic Chagas disease is particularly dangerous because many individuals are unaware of the infection until major complications occur. Population screenings are therefore important for early detection and treatment (Bern, Montgomery, & Herwaldt, 2007).

### ***Treatment***

Test results for Chagas disease are sometimes inconclusive due to discordant testing outcomes. Confirmation of the disease requires that an individual test positive on two or more serological tests, which generally include a screening and confirmatory test (WHO Expert Committee, 2000; Bern et al., 2007). An individual, for example, may test positive for Chagas during the initial screening but negative in the confirmatory testing. In such a case, current public health policy usually considers the results to signal a false positive, and the individual is not typically offered treatment (Leiby et al., 2000). The lack of optimum diagnostic tests complicates the epidemiological understanding of the disease, as well as its clinical management.

There are two treatment options for Chagas disease: parasitic and symptomatic treatment. Parasitic treatment involves the actual killing of the *T. cruzi* parasite and is generally most effective after initial infection and during the acute stage (CDC, 2009). Nevertheless, anti-parasitic treatment has been found to be efficacious in infected children in the intermediate stages of the disease and has even been shown to slow disease progression in adults (Andrade et al., 1996; Viotti et al., 2006). However, anti-parasitic treatment does “lack optimal efficacy” (WHO, 2000). Furthermore, the treatment is known to have severe side effects, and doctors consequently limit its use. Anti-parasitic drugs, moreover, are expensive for many Chagas-infected individuals, though many governments do subsidize the cost of treatment (Ministerio de Salud del Perú [MINSA], 1998; WHO, 2002; Levy et al., 2009).

Symptomatic treatment for chronic Chagas requires long-term care to manage the cardiac and digestive ailments that develop in later stages of the disease. Such treatment, however, is often expensive and requires medical infrastructure that may not exist in the country or may be inaccessible to the poor (WHO, 2002).

### ***International Initiatives to Combat Chagas***

Several Chagas-endemic countries in Latin America have combined efforts to combat the disease. Together with the Pan American Health Organization, the Ministries of Health from Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay launched the Southern Cone Initiative to Control/Eliminate Chagas (INCOSUR) in 1991. Peru later joined the Initiative. INCOSUR aimed to coordinate triatomine elimination campaigns through clearly defined objectives and quality control (Schofield & Dias, 1999; Silveira, Umezawa, & Luquetti, 2001; Dias, Silveira, & Schofield, 2002). Each country finances and manages its Chagas-control campaigns, and meet annually to share information, methods, and lessons learned (Skolnik, 2008). Many of the anti-Chagas programs to date include systematic and repeated sprayings of insecticide, as well as rebuilding or improving homes with materials inhospitable to triatomine insects (Silveira et al., 2001).

In general, INCOSUR has been successful. Indeed, between 1992 and 2001, 2.5 million homes were sprayed, which most likely contributed to the halting of disease transmission in Chile and Uruguay, as well as parts of Argentina, Brazil, and Paraguay. Additionally, the number of new cases in South America fell from 700,000 in 1983 to 200,000 in 2000, and the number of annual deaths was halved to 22,000 (Skolnik, 2008). Transfusional and congenital transmissions have also declined due respectively to donor screening at blood banks and early detection programs (Silveira et al., 2001; Skolnik, 2008).

## **Chagas Disease in Peru**

It is estimated that 192,000 Peruvians are infected with Chagas disease, which is endemic to southern Peru and to areas in the north of the country (PAHO, 2006; Remme et al., 2006). The northern regions of Cajamarca, San Martin, Ucayali, and Amazonas are home to 13 triatomine species that can be infected by the *T. cruzi* parasite (CubaCuba, Abad-Franch, Roldan Rodriguez, Vargas Vasquez, Pollack Velasquez, & Miles, 2002). These species are domiciliary, peridomiciliary, and wild, and they present an interesting opportunity for research into the eco-epidemiology of villages in the Amazon Basin. Due to a lack of current epidemiological and entomological data, however, these regions are not included in control programs (CubaCuba et al., 2002). This paper will focus only on the Chagas-endemic areas in southern Peru.

Approximately 80% of all cases in the south of the country occur within the region of Arequipa, though the disease has been reported in Tacna, Moquegua, Ayacucho, Ica, and Apurimac. *Triatomine infestans*, the sole vector of Chagas disease in southern Peru, thrive between 10 to 3,075 meters above sea level and are found between 13.0 to 19.0 degrees latitude south, rendering the area a perfect environment for infestation (Cornejo del Carpio, 2003).

Compared to individuals in Bolivia, another Chagas-endemic country, Peruvians have relatively poor immunological response to infection. Indeed, when two types of rapid tests were performed on specimens from the two countries, the Bolivian samples were 87.5% sensitive with Stat-Pak and 90.7% sensitive with Trypanosoma Detect, both with 100% specificity. Peruvian specimens, however, showed a much lower sensitivity: 26.6% to 33.0% with Stat-Pak, and 54.3% to 55.2% with Trypanosoma. Both also had specificities below 98%. These results may be caused by the difference in parasite heterogeneity. Moreover, they could signal a major difference in immunologic response by location (Verani et al., 2009).

The Peruvian Ministry of Health (MOH) has made concerted efforts to interrupt Chagas transmission. In 2002, the MOH launched the Project to Control Chagas Disease or *Proyecto de Control de la Enfermedad de Chagas*, the objective of which was to use a spray-based approach to eliminate the triatomine vectors in 18,000 houses in Arequipa (MINSA, 2005). Unlike other INCOSUR-affiliated vector-control campaigns, which primarily targeted rural areas, the MOH initiative was concentrated in periurban districts (Levy et al., 2009). A similar model has been adopted in Chagas-endemic areas in northern Peru, and the MOH is receiving technical and financial support from the Pan American Health Organization and the Canadian International Development Agency (MINSA, 2005).

### **A Multi-disciplinary Overview of Chagas in Periurban Southern Peru**

In southern Peru, as the disease moves into previously Chagas-free periurban and urban areas, the epidemiology and ecology are adapting to the new context and are not



yet entirely understood. The following four studies were carried out in various communities of periurban Arequipa, Peru, and are mapped in Figure 1. Though distinct in their methodologies and themes, each contributes key information to understanding the dynamics and risk factors of Chagas disease in a periurban setting. Before reviewing the studies, it is important to understand the context in which they were conducted.

### *Arequipa*

Located in southern Peru, the department of Arequipa borders the departments of Puno, Ica, Ayacucho, Moquegua, Apurímac, and Cuzco, as well as the Pacific Ocean (see Figure 1). Between 2001 and 2008, the region's economy grew an average of 7.8% a year, and the region has a comparatively low rate of poverty—23.8%—to the national average of 36.3% (Instituto Nacional de Estadística e Informática [INEI], 2002-2008; INEI, 2007). Accordingly, Arequipa enjoys relatively high human development indicators compared to the rest of the country. Life expectancy for men and women in the department is 73.0 and 77.8 years, respectively, while national life expectancy is 70.5 for men and 73.5 for women. At 17.3 deaths per 1,000 births, infant mortality is lower than the national rate of 18.5 (INEI, 2007). Furthermore, a little more than half—53.2%—of the population has some form of health insurance, compared to only 41.8% nationally (INEI, 2008).

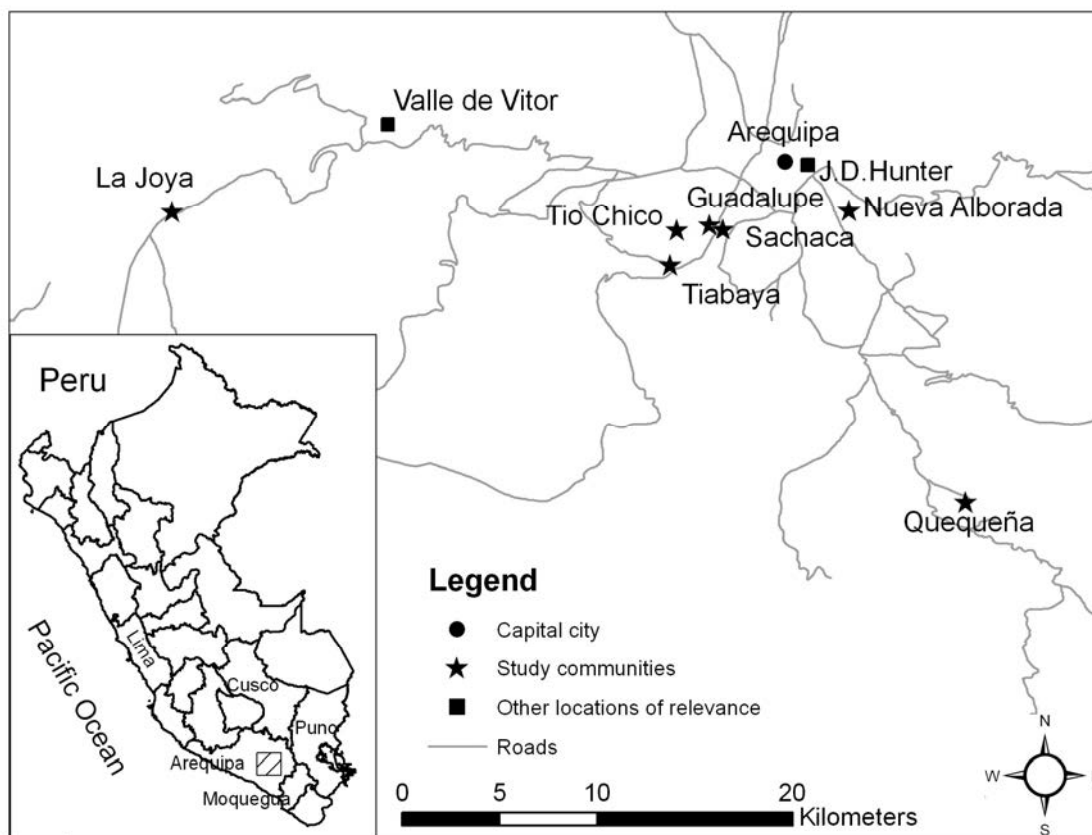


Figure 1. Map of the city of Arequipa and surrounding communities and study sites.

Eight provinces—Arequipa, Camaná, Caravelı, Castilla, Caylloma, Condesuyos, Islay, and La Union—constitute the department of Arequipa. The region’s population is largely urban with 71.3% of *Arequipenos* living in Arequipa City, the capital. Most commonly known as “Arequipa,” the regional capital is Peru’s second-largest city with a metropolitan area of 904,931 residents organized into 29 districts (INEI, 2009). The city sits at the foot of an inactive volcano in the southwestern Andes and has an altitude of 2,328 meters above sea level (INEI, 2008). The most populated districts of the city form the metropolitan area, and some urban zones have population densities of up to 30,000 residents per km<sup>2</sup>. Between 2000 and 2004, the metropolitan area experienced a total of 2.4% population growth, and by 2015, Arequipa is expected to be home to 1,061,582 people. Two of the metropolitan districts, Cayma and Jacobo D. Hunter, are predicted to grow at an annual rate of 11.2% and 10.0%, respectively (Swiss Contact, 2005). A subsequent section of this paper will reveal that a high population density is a risk factor for Chagas disease.

Arequipa has always been an industrial, agricultural, and commercial hub, as well as an administrative center. Consequently, the city has been attractive to rural-to-urban

migrants seeking better economic opportunities. Since the 1950s, Arequipa has been the “focal point” of migration in southern Peru. In the past, rural-to-urban migrants typically migrated first to the center of the city. However, due to high rents, overcrowding, and a desire for a place of their own, more recent migrants moved to the peripheral agricultural lands and founded squatter settlements in sparsely populated areas. Indeed, by 1956, there were already 12 shantytowns, or *pueblos jóvenes*, with 13,000 inhabitants sprouting around the city’s periphery (Schuurman, 1986). More formal settlement dates, however, range from 1970 to 1995, though these shantytowns continue to be established (Bayer et al., 2009).

Once established, these *pueblos jóvenes* began to serve as reception points for new migrants, especially those with ties to friends or family already residing in the area, as people tend to concentrate according to similar regional backgrounds (Schuurman, 1986). Though Chagas has typically been characterized as a “rural disease,” transmission cycles of disease are well established in some urban *pueblos jóvenes* on the outskirts of urban Arequipa (Levy et al., 2006; Bowman et al., 2008).

### ***Periurban T. cruzi-infected Triatoma Infestans in Arequipa***

Chagas has traditionally been characterized as a rural disease, and as a result, there is little epidemiological information about disease transmission in urban areas. Levy et al. (2006) thus sought to fill this knowledge gap by conducting a study to identify determinants of triatomine infestation and population density in Guadalupe, a district in periurban Arequipa. Additionally, in order to examine the risk for potential Chagas transmission by these vectors in the community, the authors examined triatomines for *T. cruzi* parasites (Levy et al., 2006).

The study, “Periurban *Trypanosoma cruzi*-infected *Triatoma infestans*, Arequipa Peru,” was carried out in coordination with the first phase of the MOH’s vector control program between November 15 and December 8, 2004 (Levy et al., 2006). During the first round of the campaign, the MOH sprayed 374 houses and peridomestic structures in Guadalupe using a deltamethrin-based insecticide. Field staff then spent one person-hour per structure collecting triatomines from individual rooms and animal enclosures, as well as noting the construction materials of each space. An adult from each household responded to a survey concerning insecticide usage, cleaning practices, and potential triatomine infestation (Levy et al., 2006). The data were then examined for two outcome variables: presence of *Triatoma infestans* and insect population density, which was calculated by the number of insects collected in one hour. Each outcome was independently analyzed for rooms in human and animal structures (Levy et al., 2006).

Triatomine insects were present in both human dwellings and animal enclosures. In total, 5,398 triatomine insects were captured: 2,270 from households and 3,128 from animal enclosures or peridomestic structures. Over half (52.0%) of the 374 households in

the study were infested with triatomines and 72 (19.3%) sheltered *T. cruzi*-infected triatomines. Moreover, 107 (13.0%) of the 803 animal enclosures surveyed contained vectors and 31 (3.9%) were infested with parasite-infected vectors (Levy et al., 2006).

Keeping domestic animals in the yard or on the roof, as a food or income source, is not uncommon in Guadalupe, and at the time of the survey, 263 (70.0%) of households raised guinea pigs, dogs, rabbits, chickens, sheep, cats, turkeys, cows, or pigs. In general, sheep and guinea pigs were kept in adobe and stuccoed structures, respectively, while chicken-wire pens held rabbits. Data revealed multiple risk factors for triatomine infestation stemming from these animal enclosures. Chicken-wire pens, for example, were one-fifth as likely to test positive for triatomine infestation as corrals built partially or entirely out of adobe or stacked brick, which were significantly more likely to be infested. In terms of species-specific risk factors, guinea pig enclosures were 1.69 times more likely to have vectors and were associated with a 2.4-fold increase in triatomine population density compared to the density found in the enclosures of other pet species. Furthermore, a guinea-pig pen in a household's yard further increased the likelihood that the home would be infested with triatomine insects (Levy et al., 2006).

The risk of triatomine infestation in human dwellings increased for each additional person sleeping in the room. Indeed, the number of triatomines increased by 42% per additional person per room. Exclusively human-dwelling rooms had 5.2 times fewer triatomine insects than rooms in which animals—primarily dogs and cats—slept. Rooms that were fully stuccoed, moreover, had an infestation likelihood of less than one-third, while rooms constructed of brick or *sillar*—a volcanic stone common to Arequipa—were 1.6 and 1.8 times more likely, respectively, to house vectors. Based on the data, the important risk factors for triatomine infestation were: the number of individuals sleeping in a room, the presence of animals in the same room, and the materials used to construct the home or animal enclosure. Please refer to the original article by Levy et al. (2006) for further details. The environmental risk factors identified by the authors are closely linked to the poverty in the study sites and the numerous other *pueblos jóvenes* around Arequipa. In the studies described subsequently, these relationships continue to resonate.

### ***Chagas Disease Transmission in Periurban Arequipa***

Following the finding of parasite-carrying triatomine vectors in periurban Arequipa, an examination of rates of human infection in these areas ensued. Small studies in periurban communities in Arequipa have revealed Chagas seroprevalence in children ranging from 0.7% to 12.9% (Cornejo del Carpio, 2003). On a broader scale, however, little is known about the epidemiology of the disease in this urban setting. Thus, in order to determine the prevalence, spatial patterns, and risk factors of Chagas disease, Bowman et al. conducted a cross-sectional serosurvey in periurban Arequipa. While the main

target group was school-aged children, they also included a population survey of 1,053 individuals, which allowed for analysis of age-specific prevalence, as well as examination of how long vector-borne transmission of *T. cruzi* had been occurring in the community. Like Levy et al. (2006), “Chagas Disease Transmission in Periurban Communities of Arequipa, Peru” surveyed residents of Guadalupe but also included children from the nearby periurban districts of Tiabaya and Sachaca (see Figure 1) (Bowman et al., 2008).

The data collected during the MOH’s vector control campaign in 2004 and 2005 was used to estimate the proportion of households with both non-infected and *T. cruzi*-carrying triatomines. Based on their geography and demography, the communities were designated as “hillside shantytowns” (*pueblos jóvenes*) or “low-lying towns.” Blood samples were taken from study participants in order to determine seroprevalence for *T. cruzi*. Based on the relationship between age and seroprevalence, the authors compared two different transmission models. In the first model, it was assumed that the probability of infection increased linearly with the log of an individual’s age rounded to the next year. The second model hypothesized that the probability of infection increased linearly with the log of an individual’s age only if the age was greater than the unknown time since the initiation of transmission in their place of residence (Bowman et al., 2008).

Of the 1,615 children in the serosurvey, 75 or 4.7% had confirmed Chagas disease. A univariate analysis showed that there was a positive relationship between the likelihood of individual infection and the proportion of triatomine-infested houses in the community of residence. A multivariate analysis, moreover, concluded that Chagas-infection risk increased 12% per year of age and that children residing in hillside shantytowns were more likely to be infected with the disease than those in low-lying towns. Additionally, the data revealed that Chagas transmission had begun relatively recently in the community, which confirmed the study’s initial hypothesis that *T. cruzi* was introduced into periurban Arequipa within the last two decades. Please refer to the original article by Bowman et al. (2008) for further details. This study provides evidence of vector-borne transmission of Chagas disease to persons living in periurban Arequipa and further describes the differential risk of Chagas in the shantytown setting.

Three years prior to the community-based study, a hospital-based serological screening study was conducted in puerperal women by Mendoza-Ticona et al. (2005). Of 3,000 women screened for *T. cruzi* infection in three hospitals and four health centers around Arequipa, only 0.73% were confirmed seropositive for infection with the parasite. Higher prevalence was observed in more rural communities near the city of Arequipa. The authors did not observe any cases of congenital Chagas disease transmission, but these results were limited by the small sample size of babies born to infected mothers (Mendoza-Ticona et al, 2005).

### ***Chagas Disease, Migration, and Community Settlement Patterns***

Given that active human contagion of Chagas disease now exists on the outskirts of Arequipa, it is important to evaluate how the disease vector and parasite may have arrived to this periurban setting. Since the 1950s, migrants have come to Arequipa seeking better economic opportunities. Many of these migrants have been from Chagas-endemic areas. However, few studies have analyzed the relationship among migration, settlement patterns, and Chagas disease transmission. In “Chagas Disease, Migration and Community Settlement Patterns in Arequipa, Peru,” Bayer et al. (2009) conducted a qualitative study to explore the migration-disease transmission nexus. The study specifically concentrated on the links between migration, settlement patterns, and triatomine vector infestation in five peripheral communities (three of which are *pueblos jóvenes*).

A total of 94 individuals participated in the study, which consisted of focus groups and in-depth interviews. Focus groups used participatory methods, such as community mapping and timeline construction of both general and Chagas-related events, to explore the participants’ memories of the community demography, migration patterns, and the historical and current presence of triatomine vectors through activities. In-depth interviews examined personal stories relating to migration, animal rearing, Chagas disease, and the presence of triatomine insects. Population data, including the number of households in the community and insecticide application, was obtained from the MOH (Bayer et al., 2009).

The data revealed that males migrated more frequently than females with a median of 4 versus 3 lifetime moves and that most of these moves were among residents of *pueblos jóvenes*. Indeed, 80% of participants in these communities had moved to *pueblos jóvenes*, whereas 40% of participants from traditional and longer-established towns were migrants. Subsequent discussion revealed that as the *pueblo joven* settlements grew, the observed number of vectors did as well. The same scenario did not apply to the traditional towns, however. One of the traditional towns had remained virtually vector-free despite proximity to highly infested *pueblos jóvenes*. The other traditional town only began to experience memorable vector presence about 20 years ago, when its population became more mobile and new migrants seeking seasonal labor began to arrive (Bayer et al., 2009).

The superimposition of the MOH data revealed that the *pueblos jóvenes* had both several times the population density of the traditional towns and higher proportions of household infestation by triatomine vectors. For example, the *pueblo joven* of Guadalupe had a population density of 13,061 inhabitants per km<sup>2</sup> and a domiciliary infestation index (DII) of 45.6%, compared to the traditional town of Quequeña, with a population density of 1,738 and a DII of 19.2% (Bayer et al., 2009).

Despite the higher prevalence of triatomine vectors in *pueblos jóvenes*, this study concluded that most of the migrants to these towns did not originally come from *T. cruzi*-

endemic areas, and are thus unlikely to have brought the vector or parasite to periurban Arequipa. Nevertheless, residents of these *pueblos jóvenes* did make many short- to medium-term moves to Chagas-endemic areas in search of agricultural work. It is possible that they were infected during such moves or transported the vector back to their *pueblo joven* in their belongings. Another hypothesis that would explain vector presence in the *pueblos jóvenes*—and one that is not mutually exclusive—is that *Triatomina infestans* had always been present in the agricultural areas surrounding the city, but the insect population did not explode until the periurban settlements reached a certain “critical mass” of human and animal populations. Please refer to the original article by Bayer et al. (2009) for further details. In its exploration of human migration and settlement of periurban Arequipa, this study generated several hypotheses to explain how Chagas disease was introduced to periurban Arequipa, and how the settlement patterns of the *pueblos jóvenes* may create especially favorable conditions for the proliferation of triatomine bugs.

### ***Spatial Patterns and Discordant Diagnostic Test Results***

Despite the presence of risk factors like those described in the preceding studies, diagnosing chronic Chagas disease is often difficult due to the lack of a “gold standard” test. In order to confirm Chagas, a patient must test positive on two or more serological tests, which are based on different antigens. Discordance between the two tests occurs in a certain percentage of results. This discordance is sometimes attributed to the presence of *Leishmania spp.* or *Trypanosoma rangeli*, two other parasites that may cross-react with Chagas diagnostic tests. Individuals who test positive during the initial screening but negative during confirmatory testing do not typically receive treatment because their results are deemed to be false positives due to the inadequacy of the screening test’s specificity (Levy et al., 2009).

In the article, “Spatial Patterns in Discordant Diagnostic Test Results for Chagas Disease: Links to Transmission Hotspots,” Levy et al. (2009) examined the relationship between discordant test results and spatially clustered *T. cruzi* transmission hotspots. The authors contended that the spatial information generated from clustered cases of *T. cruzi* could be used as a substitute indicator for parasite exposure and thus provide a lens to evaluate discordant results. The authors hypothesized that if discordant results represented true Chagas infection and were due to the low sensitivity of confirmatory tests, they would be more likely to occur among individuals living in areas with high incidences of confirmed human *T. cruzi* infection, or so-called “hotspots.” However, if the discordant results were in fact true negatives, and not a result of low screening test specificity, they should be randomly distributed relative to the confirmed cases of Chagas-infected individuals in the community (Levy et al., 2009).

The subsequent study was also conducted in Guadalupe, a *pueblo joven* on the southwestern margins of Arequipa. Between August and October 2005, a peripheral blood sample was collected from study participants and screened for antibodies to *T. cruzi*. All specimens that were positive at the initial screening were analyzed using two confirmatory tests. A spatial analysis was then conducted on all discordant confirmatory test results, and the average distance between the residence of individuals with discordant results and of those with confirmed Chagas disease was calculated (Levy et al., 2009).

Of the 1,053 participants in the study, 60 (5.7%) had positive results during the screening phase. Of these 60 individuals, 47 (78.3%) tested positive on both Chagas confirmatory tests while 13 (21.7%) had discordant confirmatory test results. These 13 participants lived an average of 21.4 meters away from a household with a confirmed case of Chagas, which is similar to those with consistent results (21.1 meters away). The results thus revealed that individuals with discordant results were spatially clustered in *T. cruzi* “hot spots,” confirming the importance of spatial analysis in Chagas diagnosis, as well as the further evaluation of discordant test results. Please refer to the original article by Levy et al. (2009) for further details.

### **Risk factors associated with Chagas disease in Periurban Arequipa**

In their respective investigations into Chagas disease in periurban Arequipa, the four studies described here identify several distinct risk factors. In general, these factors can be categorized into two major themes: population dynamics and the urbanization of poverty.

#### ***Population Dynamics***

Population dynamics—specifically migration and settlement patterns, population density, and age—represent a significant risk factor for Chagas transmission.

Population density, both on the community and household level, represents one risk factor. Bowman et al. (2008) and Levy et al. (2006) confirm that the likelihood of *T. cruzi* infection is higher in Arequipa’s highly dense *pueblos jóvenes* as compared to less dense communities. Bowman et al. (2008) also note that this phenomenon is especially true in communities with a greater proportion of vector-infested households. Thus, campaigns and programs to control triatomine insects are particularly important in high-density urban areas that continue to attract rural migrants. Based on the evidence in Bayer et al. (2009), it is particularly crucial to promote vector surveillance of mobile populations that make frequent moves between communities.

Age, another measure of population dynamics, is also associated with disease transmission. Bowman et al. (2008) demonstrate that the risk of Chagas infection increases 12% for every year of age, and thus, older, school-age children and adults



should regularly be screened for the *T. cruzi* parasite. This information will not only improve prognosis for infected individuals, but it will also allow officials to track transmission over time and increase their understanding of the disease in periurban areas.

### ***Urbanization of Poverty***

Residents in periurban communities in Arequipa are generally poorer than those in the city center and are, therefore, only able to afford inexpensive building materials that are particularly attractive to triatomine infestation (Levy et al., 2006). Furthermore, to supplement already meager incomes, many residents' raise small animals. Such animal husbandry practices are associated with triatomine vector infestation (Levy et al., 2006; Bayer et al., 2009). Thus, appearance of Chagas in marginalized periurban Arequipa underscores the fact that the disease is associated with poverty in general, not just poverty in rural areas.

### **Conclusions**

As metropolitan Arequipa—and other urban areas in Latin America—continues to grow, it will be important for public health and medical professionals to use a range of research methods to investigate the major risk factors associated with Chagas transmission and monitor how they evolve. Understanding the disease within an urban context will allow for public health prevention efforts; however, it is important for all of these initiatives to be undertaken collaboratively by community members and by research and policy teams and leaders at the district, province, regional, national, and international levels. The results of the four studies described here underscore several individual interventions that could be combined to form a multi-pronged prevention approach: (1) coordinated insecticide application and surveillance of vector reinfestation, particularly in areas with highly-mobile populations; (2) improvement of building materials used in houses and peridomestic small animal enclosures; (3) health education for migrant workers to Chagas-endemic areas; and (4) collection of spatial data on Chagas as a complement to diagnostic tests.

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