Understanding the widespread use of veterinary ivermectin for Chagas disease, underlying factors and implications for the COVID-19 pandemic: a convergent mixed-methods study

Boris Apodaca Michel, Miriam Navarro, Michael Pritsch, Jeremy Douglas Du Plessis, Jonathan Shock, Eva-Maria Schwienhorst-Stich, Janina Zirkel, Hanna Schrader, Claudia Saavedra Irala, Gonzalo Rubilar, Carolin Gunesch, Christa Kasang, Thomas Zoller, Ildiko Gagyor, Sandra Parisi

ABSTRACT

Objectives Veterinary ivermectin (vet-IVM) has been used widely in Latin America against COVID-19, despite the lack of scientific evidence and potential risks. Widespread vet-IVM intake was also discovered against Chagas disease during a study in Bolivia prior to the pandemic. All vet-IVM-related data were extracted to understand this phenomenon, its extent and underlying factors and to discuss potential implications for the current pandemic.

Design A convergent mixed-methods study design including a survey, qualitative in-depth interviews (IDI) and focus group discussions (FGD).

Setting A cross-sectional study conducted in 2018 covering the geographic area of Monteagudo, an endemic municipality for Chagas disease.

Participants A total of 669 adult household representatives from 26 communities participated in the survey, supplemented by 14 IDI and 2 FGD among patients, relatives and key informants.

Results 9 IDI and 2 FGD contained narratives on vet-IVM use against Chagas disease. Five main themes emerged: (1) the extent of the vet-IVM phenomenon, (2) the perception of vet-IVM as a treatment for Chagas disease, (3) the vet-IVM market and the controversial role of stakeholders, (4) concerns about potential adverse events and (5) underlying factors of vet-IVM use against Chagas disease.

In quantitative analysis, 28% of participants seropositive for Chagas disease had taken vet-IVM. Factors associated with multivariate analysis were advanced age (OR 17.01, 95 CI 1.24 to 36.55, p=0.027 for age above 60 years), with multivariate analysis were advanced age (OR 17.01, 95 CI 1.24 to 36.55, p=0.027 for age above 60 years), social determinants of health, the experience of someone close as information source (OR 3.13, 95 CI 1.62 to 5.02, p<0.001), seropositivity for Chagas disease (OR 3.89, 95 CI 1.39 to 6.20, p=0.005) and citing the unavailability of benznidazole as perceived healthcare barrier (OR 2.3, 95 CI 1.45 to 5.18, p=0.002). Participants with an academic education were less likely to report vet-IVM intake (OR 0.12, 95 CI 0.01 to 0.78, p=0.029).

Conclusions Social determinants of health, the unavailability of treatment and a wonder drug image might contribute to the phenomenon of vet-IVM.

INTRODUCTION

Ivermectin is a broad-spectrum antiparasitic agent that was discovered in the 1970s and played a fundamental role in control programmes targeting neglected tropical diseases (NTDs) such as onchocerciasis and lymphatic filariasis. Originally approved as a veterinary drug, ivermectin drug donation programmes helped to reduce chronic
moribidity and disability as well as the social consequences of severely stigmatised diseases for vulnerable human populations.\textsuperscript{3} Ivermectin’s discoverers were honoured with the Nobel Prize in 2015.\textsuperscript{2}

Ivermectin belongs to the family of avermectins. It binds to glutamate-gated chloride ion channels, which are present in invertebrate nerve and muscle cells, and causes paralysis and death of the parasite. Its characteristics to treat several helminths, as well as ectoparasites, made it an endo-ecto antiparasitic, which is easily available and effective at treating a broad range of parasites in livestock. It has an excellent safety profile when administered at standard doses. Ivermectin has been used for decades in large-scale drug administration programmes.\textsuperscript{1}

**Ivermectin and COVID-19**

In 2020, Caly et al described potential efficacy of ivermectin against SARS-CoV-2 in vitro, although in much higher doses than approved for human usage.\textsuperscript{4} Since then, several trials of ivermectin efficacy against COVID-19 have been conducted, both for prevention and treatment of the infection, although most of the completed studies are small and few are considered high quality.\textsuperscript{5–7} Current scientific evidence suggests that ivermectin does not have a positive impact on COVID-19-related clinical end points. The unfavourable pharmacokinetics of ivermectin in COVID-19 moreover lead to difficulties in maintaining adequate serum concentration.\textsuperscript{8} A Cochrane systematic review concluded that the reliable evidence available does not support the use of ivermectin either to treat or to prevent COVID-19.\textsuperscript{9}

**Ivermectin and Chagas disease**

Chagas disease (CD) is caused by a parasite called *Trypanosoma cruzi*, which is mainly transmitted by triatomine vectors. After an indeterminate phase that can last for decades, patients with CD may develop chronic cardiac or gastrointestinal complications.\textsuperscript{10} CD is considered an NTD that can lead to mental distress, stigmatisation and participation restriction.\textsuperscript{11} Several authors have moreover highlighted negative COVID-19 implications on NTD-affected population, such as COVID-19’s potential impact on the heart of the over 1 million people with chronic Chagas cardiomyopathy worldwide.\textsuperscript{12 13} Since treatment with benznidazole (BNZ) seems not to be effective in advanced disease,\textsuperscript{14} early diagnosis and treatment is an important strategy to prevent chronic morbidity. BNZ access however continues to be restricted.\textsuperscript{15} Apart from BNZ, a wide range of complementary medicines has been described to be used to halt the progression of CD, including (veterinary) ivermectin (vet-IVM).\textsuperscript{16}

Based on ivermectin’s insecticide properties, a potential use against vectors transmitting infectious diseases, such as mosquitoes, ticks or bugs has been suggested. Dias et al showed that CD-transmitting vectors died if feeding on dogs after their intake of ivermectin.\textsuperscript{17} Although this effect only lasted 2 days after administration of the drug, the authors postulated that there may be potential in using ivermectin in vector control activities. To our knowledge, a connection between ivermectin and *T. cruzi* has never been described in the literature (in neither animal reservoirs nor humans).\textsuperscript{1 17} To the best of our knowledge, there is currently no evidence that would justify CD treatment with ivermectin.

**Misuse of ivermectin against COVID-19 and Chagas disease**

Since Caly et al described the effectiveness of ivermectin against COVID-19 in vitro,\textsuperscript{4} there has been a surge in demand in Latin-American countries. Some countries such as Bolivia and Peru included ivermectin in national plans to fight COVID-19, and Bolivia even distributed 350 000 doses in the city of Trinidad.\textsuperscript{18} Apart from this, widespread auto-medication with vet-IVM has been reported.\textsuperscript{19} In Peru, the injection of vet-IVM in 5000 individuals from indigenous communities by Evangelical groups, calling it a ‘salvation’, made news headlines.\textsuperscript{20} Several of these individuals reported adverse side effects, such as tachycardia. The increased demand for ivermectin caused the Food and Drug Administration to put out a warning over its use, and an ongoing scientific debate about the need for rigorousness, clinical trials and the handling of premature scientific information in light of the COVID-19 pandemic.\textsuperscript{21} While the global scientific community underwent an unprecedented efforts race to identify effective drugs to address the pandemic,\textsuperscript{22} the large-scale use of drugs such as ivermectin poses an imminent environmental risk.\textsuperscript{23 24} and is linked to the loss of biodiversity, an important cause of the current pandemic.

The unscientific use of vet-IVM for unapproved diseases seems, however, not to be a new phenomenon. In a representative mixed-methods study on knowledge, perceptions and treatment practices carried out in Monteagudo (Bolivia) in the pre-COVID-19 era in 2018, widespread intake of vet-IVM against CD emerged to an extent that had never been described before.\textsuperscript{25} In light of the current ivermectin hype and use of vet-IVM for COVID-19 in Bolivia and its neighbouring countries, we conducted an in-depth analysis on all vet-IVM-related narratives and survey data. The aim of this analysis was to better understand this phenomenon, its extent and the potential underlying factors.

**METHODS**

**Study setting**

The municipality of Monteagudo lies in the middle of the Bolivian Chaco, a region known for its high CD prevalence. Although CD-related morbidity is not monitored within official health statistics, a high burden caused by chronic CD complications has been described.\textsuperscript{26} The 97 communities of Monteagudo are widely dispersed, with long walking distances between individual households in remote settings. Apart from 17 local health centres, there are 2 hospitals in the town of Monteagudo.

**Study design**

A mixed-methods study was conducted from September to December 2018 in the Municipality of Monteagudo,
Bolivia. The overall aim of the original study was to gain a holistic overview of the CD-related situation in Monteagudo and to explore CD-related knowledge, attitudes, priorities as well as prevention and treatment behaviour in order to plan community-directed interventions. The study used a convergent design including a household survey, as well as qualitative in-depth interviews (IDI) and focus group discussions (FGD). An iterative approach during data collection allowed for further exploration of emerging topics, such as the use of vet-IVM against CD (see also figure 1 and online supplemental file 1). We used methodological, data and investigator triangulation to increase the validity of our results.

Data collection
For the household survey, a multistage stratified random sampling procedure was applied, covering approximately 10% of the municipalities’ households, while maintaining their proportional distribution (see also table 1 and online supplemental file S1). One adult member per household was eligible to participate. Qualitative interviews were conducted with patients with CD, relatives and key informants. Qualitative participants were selected purposefully or by snowball sampling (see also online supplemental file S1).

The widespread use of vet-IVM was a surprising theme that emerged during several initial patient and key informants’ interviews. We therefore included self-reported vet-IVM use within the survey to determine its extent in the context of an iterative approach (see also figure 1). Several participants cited vet-IVM spontaneously as preventive measure against CD. We moreover further explored vet-IVM use during qualitative data collection by purposefully sampling a veterinarian. In other qualitative interviews, we did not specifically address vet-IVM use, but waited to see if participants would talk about it spontaneously to understand its importance in the context of Bolivia’s system of medical pluralism (see also table 1).

Data extraction and analysis on vet-IVM use against CD
A total of 669 household members from 26 communities participated in the survey. No household refused participation. Moreover, 14 IDI and 2 FGD were conducted (table 2 depicts the sociodemographic characteristics of the survey population; the overall results have been reported elsewhere).

Qualitative analysis
We extracted all narratives related to vet-IVM intake against CD using NVivo V.12. The primary focus was to understand the phenomenon of unscientific vet-IVM use, its extent and importance among other treatment options, as well as potential underlying factors. Content analysis with a content-structuring methodology approach aligned to the study by Kuckartz was performed by two independent female researchers (SP/JZ, both medical doctors) using consensual coding. First, narratives on vet-IVM were read several times, focusing on manifest and latent content. Main themes and subcategories were then derived deductively-inductively and case summaries served as an intermediate step for analysis.

Quantitative analysis
For quantitative analysis, we extracted survey data on self-reported vet-IVM use as well as the mentioning of vet-IVM in questions related to preventive behaviour. Self-reported vet-IVM intake against CD was used as a dependent variable after dichotomisation (1=yes, 0=no/do not know) using the survey question: “have you taken (veterinary) ivermectin against CD?” Independent variables of interest were sociodemographic characteristics, information sources on CD, attitudes regarding the

Figure 1 Mixed-methods convergent design using parallel data collection with an iterative approach. vet-IVM, veterinary ivermectin. * To further explore the theme on vet-IVM a veterinarian was purposefully sampled. Vet-IVM was not brought up purposefully in other qualitative interviews in order to assess its relevance compared to other treatments.

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disease and treatment options (aligned to protection motivation theory) as well as potential health system barriers to treatment and other social determinants of health.

The bivariate results were computed using Fisher’s exact test to determine whether a statistically significant difference existed between the preselected reference group (eg, age group 18–25 years, indicated with 1 in the OR column in table 3) and each of the other groups (eg, age groups 26–40 years, 41–60 years, etc) with respect to their use of vet-IVM for each variable of interest. Exposure variables associated with vet-IVM use with a p value=0.1 were included into multivariate analysis. The multivariate results were computed by fitting a logistic regression to the data. In order to account for potential clustering within the data, we calculated robust SEs using the HC3 estimator. Very small groups had to be merged with their neighbouring categories. An association with a p value of <0.05 was considered significant. Finally, we used the Cochran-Armitage test to determine whether any statistically significant trends existed with respect to vet-IVM use for each of the ordinal variables in the data.

All quantitative results were computed in a Jupyter Notebook environment using Python (V.3.8.5). The stats Package from the SciPy library (V.1.21.0) was used to compute Fisher’s exact test, and the statsmodels library (V.0.12.1) was used to fit the logistic regression model and perform associated statistical tests, as well as for the Cochran-Armitage test for trend.

**Patient and public involvement**

The study was part of a baseline assessment aimed at targeting future interventions to the communities’ priorities, knowledge and experiences with former projects. Patients and their relatives participated in all phases of this study, from the planning to the dissemination of results. Because of the high CD prevalence (approximately 46% among adults), there was an overlap between being a patient or relative and being involved as key informant or project staff. In order to assure confidentiality of local participants and key informants, no detailed socio-demographic characteristics will however be presented and not every CD infection will be disclosed.

**RESULTS**

**Qualitative results**

Vet-IVM use against CD was discussed in nine IDI and two FGD which were therefore included in the current analysis. These interviews consisted of 21 participants (11

| Table 1 Overview of data collection and extraction for in-depth analysis of vet-IVM use against CD |
|---------------------------------------------------------------|
| **Household survey**                                      | **Qualitative interviews** |
| **Inclusion criteria** | At least 18 years old | At least 18 years old |
| | Resident municipality of Monteagudo | Belonging at least to one of three groups: |
| | One participant/household | 1. Patient with CD |
| | **Exclusion criteria** | **Sampling procedure** |
| | Not present at the moment of study | Multistage-stratified randomised sampling procedure: |
| | No informed consent given | 1. Stratification of all households into 17 health centre strata |
| | **Total sample** | 2. Calculation of households to include/stratum (proportional) |
| | 669 survey participants from 26 communities (9.8% of all households of Monteagudo municipality) | 3. Random selection of communities |
| | **Data extracted on vet-IVM** | 4. Random selection of households |
| | Outcome: self-reported use of vet-IVM against CD | 14 in-depth interviews |
| | Exposure variables of interest† | 2 focus group discussion |
| | vet-IVM mentioned as preventive method against CD | (1 among young adults, 1 among health staff) |
| | Narratives focusing on vet-IVM from: | Purposeful sampling |
| | | 8 in-depth interviews |
| | | 2 focus group discussions |
| | | 1 in-depth interview with a veterinarian focusing on vet-IVM use against CD |

*PIV: community volunteers responsible for vector surveillance.
†Exposure variables of interest: sociodemographic variables and other social determinants of health (eg, rurality, community access to electricity, presence of vectors, reported health access barriers), community and health centre strata, elements aligned to PMT, CD status, self-reported physical and emotional health status, number of symptoms potentially caused by CD.
CD, Chagas disease; PIV, Puesto de informacion vectorial; PMT, Protection Motivation Theory; vet-IVM, veterinary ivermectin.
females) aged 18–70 years. Educational level ranged from no education to academic education. A total of three IDI participants did not have health insurance. CD status ranged from asymptomatic to severe heart failure in need of a pacemaker. Reported professions included subsistence farmers, housekeepers, teachers, students, traditional healer, veterinary doctor, medical doctors, nurses, driver and cleaner.

Five main themes were identified: (1) the extent of the vet-IVM phenomenon, (2) the perception of vet-IVM as a treatment for CD, (3) the vet-IVM market and the controversial role of stakeholders, (4) concerns about potential adverse events and (5) underlying factors of vet-IVM use against CD (the coding framework can be found in online supplemental material S1 and additional verbatims (VS1–VS16) in online supplemental material S2).

**Theme 1: the extent of the vet-IVM phenomenon**

vet-IVM was mentioned as one option for the prevention and cure of CD, extensively used during the last two decades (VS1–VS3, VS8–VS9). Several participants reported own vet-IVM use. It was mainly consumed orally, dispersed in water or milk, adjusted to weight (VS3, VS5) and at times combined with other alternative or biomedical treatments (VS6, VS7).

I have seen injectable Ivermectin being used (against CD). It is not injected, but consumed dissolved in water. Even I took it, because I knew that I had CD[…]

I have seen the majority of people buying it. (FGD, female healthcare (HC) worker)

**Theme 2: the image of vet-IVM as a treatment for Chagas disease**

An image of a ‘wonderdrug’ emerged during narratives. Participants had heard stories about people diagnosed with advanced CD being spontaneously cured. The frequently used term ‘deparasitic’ underlined ivermectin’s image as a potent drug with the ability to clean the (animal) body of all types of parasites (VS1, VS2). There were however also patients that expressed their doubts about its effectiveness, and potential adverse events (VS4, VS5).

Her husband was told that he was about to die, he couldn’t work anymore, or anything. She heard about it (vet-IVM) from other people and told us: ‘I took a syringe of 2 ml and gave ivermectin to my husband. He was completely cured and now he works again’.

I might be because of ivermectin that I killed Chagas. Because it kills every beast. That’s what happens with the cattle too, it kills all the beasts. (Male patient and community leader)

I heard from a man, a friend of a close friend of our family […]. He already suffered from pain in his heart, couldn’t breathe etc. And after treatment with Ivermectin he said ‘I am feeling fine. My doctor said

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**Table 2** Sociodemographic characteristics of the survey population

| Characteristic                        | N=669 (%) |
|---------------------------------------|-----------|
| Gender*                               | 412 (61.8) |
| Female                                |           |
| Male                                  | 255 (38.2) |
| Age group (years)*                    | 95 (14.2)  |
| 18–25                                 |           |
| 26–40                                 | 176 (26.3) |
| 41–60                                 | 248 (37.1) |
| 61–93                                 | 147 (22.0) |
| Highest educational level*            | 420 (62.8) |
| Incomplete schooling                  | 120 (18.0) |
| Complete secondary school             | 62 (9.3)   |
| Tertiary                              | 63 (9.5)   |
| Academic                              |           |
| Profession*                           | 275 (41.4) |
| Household                             |           |
| Farming                               | 151 (22.7) |
| Student                               | 47 (7.1)   |
| Teacher                               | 38 (5.7)   |
| Job within healthcare†                | 22 (3.3)   |
| Other                                 | 131 (19.7) |
| Health insurance*                     | 232 (34.7) |
| Yes                                   |           |
| No                                    | 436 (65.3) |
| Source of information on CD           | 295 (44.1) |
| Healthcare centre                     |           |
| Health campaign                       | 233 (34.8) |
| Experience of someone close           | 215 (32.1) |
| Family                                | 204 (30.5) |
| Hospital                              | 182 (27.2) |
| Radio/TV                              | 155 (23.2) |
| School                                | 87 (13.0)  |
| Social media                          | 21 (3.1)   |
| Have children*                        | 548 (81.9) |
| Yes                                   |           |
| No                                    | 108 (16.1) |
| Tested for CD                         | 511 (76.4) |
| Yes                                   |           |
| No                                    | 153 (22.9) |
| Do not know                           | 5 (0.7)    |
| CD serology result*                   | 236 (46.3) |
| Positive                              | 248 (48.6) |
| Negative                              |           |
| Do not know                           | 26 (5.1)   |

*Non-respondents: gender=2 (0.3%), age=3 (0.5%), education=4 (0.6%), health insurance=1 (0.2%), profession=5 (0.7%), having children=13 (1.9%), CD serology result=1 (0.2%).
†Job within healthcare included health staff and people sought for professional advice on CD (including traditional healers, pharmacists and veterinarians).

CD, Chagas disease; MC, multiple choice.
### Table 3  Side-by-side display of quantitative and qualitative results of factors related to the use of vet-IVM against CD

| Categories                  | Unadjusted (bivariate) | Adjusted (final model) | Verbatims                                                                                                                                                                                                 |
|-----------------------------|------------------------|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                             | N (%)                  | OR 95% CI P value      | aOR 95% CI P value |                                                                                                                                                    |
| **Gender**                  |                        |                        |                   |                                                                                                                                                      |
| Male                        | 255 (38.2)             | 1                      | 1                 | “It's more common among older people. Most of their children have already graduated from school, gone to university where they learn that there are medications for human use, free of charge. But those with the old beliefs: it is all about what helped his comrade. He will take what helped his fellow”. (Veterinarian) |
| Female                      | 412 (61.8)             | 0.82 0.55 to 1.23 0.35 | 0.85 0.21 to 1.43 |                                                                                                                                                      |
| **Age group (years)**       |                        |                        |                   |                                                                                                                                                      |
| 18–25                       | 95 (14.2)              | 1                      | 1                 |                                                                                                                                                      |
| 26–40                       | 176 (26.3)             | 4.15 1.21 to 14.31 0.01 | 6.25 0.58 to 17.36 | 0.01                                                                                                                                                      |
| 41–60                       | 248 (37.1)             | 8.54 2.6 to 28.02 <0.001 | 12.17 0.94 to 26.95 | 0.059                                                                                                                                                     |
| 61–93                       | 147 (22.0)             | 11.46 3.43 to 38.29 <0.001 | 17.01 1.24 to 36.55 | 0.027                                                                                                                                                     |
| **Education**               |                        |                        |                   |                                                                                                                                                      |
| Incomplete schooling        | 420 (62.8)             | 1                      | 1                 |                                                                                                                                                      |
| Complete schooling          | 120 (18.0)             | 0.5 0.28 to 0.9 0.02  | 0.49 0.29 to 1.56  | 0.356                                                                                                                                                     |
| Tertiary                    | 62 (9.3)               | 0.52 0.24 to 1.13 0.13 | 0.54 0.15 to 2.45  | 0.475                                                                                                                                                     |
| Academic                    | 63 (9.5)               | 0.12 0.03 to 0.48 <0.001 | 0.12 0.01 to 0.78  | 0.029                                                                                                                                                     |
| **Information sources**     |                        |                        |                   |                                                                                                                                                      |
| Experience of someone close | 215 (32.1)             | 2.77 1.85 to 4.14 <0.001 | 3.13 1.62 to 5.02  | <0.001 “In Santa Cruz a man told me: ‘you are not going to get cured. You’ll be at the hospital in vain[…] Leave and take Ivermectin![…] Back home happened the same thing, again and again, until I took it’. (Older women, advanced CD) |

Elements aligned to protection motivation theory

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Continued
| Categories                                      | Unadjusted (bivariate) | Adjusted (final model) | Verbatims                                                                 |
|------------------------------------------------|------------------------|------------------------|---------------------------------------------------------------------------|
|                                                | OR         95% CI      P value | aOR      95% CI      P value |                                                                           |
| **Perceived effectivity of health system to care for CD** |                        |                        |                                                                           |
| Strongly disagree                              | 1.00 1.00 | 1.00 1.00 | 1.00 1.00 | “CD (serology) doesn’t become negative right away. This is why a lot of people have already taken ivermectin. Because of the long time it takes for the test (serology) to get negative. They don’t believe much in the effectiveness of benznidazole”. (Rural physician) |
| Disagree                                       | 1.44 0.36 to 5.77 | 1.35 0.06 to 4.83 | 0.572                     |                                                                           |
| Uncertain                                      | 1.07 0.27 to 4.17 | 1.07 0.06 to 5.21 | 0.621                     |                                                                           |
| Agree                                          | 1.01 0.28 to 3.62 | 0.95 0.09 to 6.11 | 0.773                     |                                                                           |
| Strongly agree                                 | 0.38 0.09 to 1.62 | 0.38 0.02 to 1.88 | 0.15                      |                                                                           |
| **Self-rated health and disease status**        |                        |                        |                                                                           |
| Health status                                  |                        |                        |                                                                           |
| Very good                                      | 1.00 1.00 | 1.00 1.00 | 1.00 1.00 | “It’s both: people that are sick and have been diagnosed by laboratory and people that don’t want to get sick, because there might be people affected (by CD) within the family. So, everyone takes it (ivermectin) to prevent”. (Veterinarian) |
| Good                                           | 1.3 0.29 to 5.81 | 1.26 0.01 to 4.28 | 0.324                     |                                                                           |
| Fair                                           | 2.96 0.68 to 12.96 | 2.81 0.01 to 5.01 | 0.374                     |                                                                           |
| Bad                                            | 6.92 1.29 to 37.29 | 0.034 0.06 to 16.61 | 0.769                     |                                                                           |
| Very bad                                       | 1.00 1.00 | 1.00 1.00 | 1.00 1.00 | “I went to all the doctors, then to a company who make medicines, they sell herbs, powders, solutions […]. After that I took Ivermectin”. (Older woman, advanced CD) |
| Emotional health status                        |                        |                        |                                                                           |
| Very good                                      | 1.00 1.00 | 1.00 1.00 | 1.00 1.00 |                                                                           |
| Good                                           | 0.88 0.25 to 3.1 | 0.85 0.06 to 16.61 | 0.99                      |                                                                           |
| Fair                                           | 2.37 0.69 to 8.14 | 2.81 0.09 to 25.16 | 0.782                     |                                                                           |
| Bad                                            | 2.16 0.45 to 10.32 | 7.5 0.02 to 9.10 | 0.574                     |                                                                           |
| Very bad                                       | 1.00 1.00 | 1.00 1.00 | 1.00 1.00 |                                                                           |
| Categories                          | N (%) | Unadjusted (bivariate) | Adjusted (final model) | Verbatims                                                                 |
|------------------------------------|-------|------------------------|------------------------|---------------------------------------------------------------------------|
|                                    |       | OR                     | 95% CI                 | P value  | aOR                     | 95% CI | P value |       |
| Self-reported number of chronic symptoms |       |                        |                        |          |                         |        |         |       |
| 0                                  | 384 (57.4) | 1                      |                        | 1        | 1                      |        |         |       |
| 1                                  | 108 (16.1) | 1.77                   | 1.02 to 3.05           | **0.047** | 1.77                   | 0.60 to 2.65 | 0.543 |
| 2                                  | 81 (12.1)  | 1.36                   | 0.71 to 2.61           | 0.378    | 1.16                   | 0.20 to 1.64 | 0.295 |
| 3                                  | 41 (6.1)   | 3.39                   | 1.67 to 6.88           | **0.002** | 3.49                   | 0.50 to 3.39 | 0.595 |
| 4                                  | 30 (4.5)    | 2.8                    | 1.21 to 6.45           | **0.026** | 2.36                   | 0.23 to 2.42 | 0.617 |
| 5                                  | 19 (2.8)    | 3.81                   | 1.43 to 10.12          | **0.011** | 3.93                   | 0.34 to 5.31 | 0.672 |
| 6                                  | 6 (0.8)     | 6.53                   | 0.9 to 47.39           | 0.092    | 6.73                   | 0.06 to 64.36 | 0.684 |
| Test result of CD serology         |       |                        |                        |          |                         |        |         |       |
| Negative                           | 236 (46.3) | 1                      |                        | 1        | 1                      |        |         |       |
| Positive                           | 248 (48.6) | 4.07                   | 2.42 to 6.86           | <0.001   | 3.89                   | 1.39 to 6.20 | **0.005** |
| Do not know                        | 26 (5.1)    | 1.92                   | 1.04 to 3.53           | **0.039** | 1.68                   | 0.23 to 9.16 | 0.683 |
| Never tested                       | 158      | 3.08                   | 1.12 to 8.48           | **0.035** | 1.8                    |        |         |       |
| Perceived HC barriers in CD treatment |      |                        |                        |          |                         |        |         |       |
| Unavailability of biomedical treatment | 140 (20.9) | 2.14                   | 1.38 to 3.31           | **0.001** | 2.3                    | 1.45 to 5.18 | **0.002** |
| Badly treated in health centre     | 96 (14.3)  | 1.77                   | 1.07 to 2.94           | **0.031** | 1.8                    | 0.65 to 2.79 | 0.425 |
| HC barriers encountered            |       |                        |                        |          |                         |        |         |       |
| Yes                                | 99 (14.8)  | 1                      |                        | 1        | 1                      |        |         |       |
| No                                 | 514 (76.8) | 0.67                   | 0.4 to 1.14            | 0.147    | 0.66                   | 0.63 to 3.00 | 0.431 |
| Did not try to access HC           | 56 (8.4)   | 1.28                   | 0.6 to 2.73            | 0.559    | 1.23                   | 0.87 to 8.46 | 0.086 |

Values in bold: \( P < 0.05 \) (statistically significant).
aOR, adjusted OR; CD, Chagas disease; HC, healthcare; Inf, Infinite; vet-IVM, veterinary ivermectin.

“Patients come here and ask for Ivermectin[…] If there is no benznidazole, they have to try other things. What they really want is to get treated”. (Female nurse)
that I don’t have any disease anymore’. (Female patient and HC worker)

Local HC workers partially believed in the effectiveness of vet-IVM against CD (VS5, VS10–VS11). Even though they were often aware about the lack of scientific evidence, their narratives at times indicated a belief that vet-IVM might have a (yet unproven) effect.

It seems that someone took Ivermectin and told that prior to treatment he was Chagas (sero) positive and then […] a while after treatment, the test turned out negative. That is what this person says, but in reality, scientifically we can’t know. […] What we would need is to take a CD positive patient as reference, treat him with ivermectin and after a while re-do the serological test. To see what results we get. To be scientifically sure if the medication had an effect or not’. (Female patient and HC worker)

Theme 3: the vet-IVM market and the controversial role of stakeholders

In addition to self-medication, vet-IVM is administered by a wide array of professionals, such as veterinarians, traditional healers, private practitioners and physicians working in public facilities (VS6, VS10, VS11, VS16). Although many HC workers sought to offer a treatment option to their patients, concerns about unethical commercial interests were also raised. The lack of formal information for veterinarians on this subject as well as on human CD was raised as a concern, because of the important role they play in treatment decisions, especially in remote areas.

There is always a controversy between colleagues (veterinarians). Some think that it is good and others don’t. […] We have never handled this topic at a congress or within a meeting.

I consider it more a business that they have constructed, playing with people’s feelings: Playing with CD, because we know that a lot of people in this zone suffer from it. (Veterinarian)

Theme 4: concerns about potential adverse events

Key informants expressed concerns regarding potential adverse events, related to the lack of data, dosage and the use of veterinary formula. Some participants reported adverse outcomes, although direct association with vet-IVM and dosage remained unclear (VS13–VS15), in particular due to the lack of follow-up.

We don’t know the pharmacological functioning of this medication within the human body, because it was obviously designed for other species […] There are associated risks that lead to problems that we will see in the long run. (Urban physician)

There is no follow up. Who would take the responsibility, knowing that it was an animal product administered to humans? (Veterinarian)

Theme 5: underlying factors of vet-IVM use against Chagas disease

Social determinants associated with vet-IVM intake in qualitative analysis were poverty, distance from infrastructure, lack of education, old age and barriers to health information, prevention and care and were also connected to being an easy target for unethical practices. The experiences of other community members were often decisive for making treatment decisions. The lack of availability of BNZ (prior to the introduction of decentralised treatment, and due to BNZ frequently being out of stock), its perceived strong adverse effects, the need for long-term administration and a lack of a perceived effectiveness were linked to the use of vet-IVM. Vet-IVM was taken at different disease stages as well as for prevention. Patients with advanced CD had often tried several treatments. Being a parent and fearing having to leave one’s children as orphans was also linked to the trial of several different treatments (narratives on underlying factors are summarised side by side with quantitative results in table 3).

Survey results

Participants’ ages ranged from 18 to 93 (mean 46.1). There were 61.8% female and 38.2% male participants. Most participants had been tested for CD (76.4%) and the self-reported prevalence was 46.2%. For detailed descriptions of the included participants and communities, please refer to Parisi et al.25

Among survey participants, 17.9% (120/669) of all household representatives and 28.4% (67/236) of those who were seropositive for CD reported having used vet-IVM as prevention or treatment against CD (additionally, three people did not know if they had taken vet-IVM). In comparison, only 17.8% (42/236) had completed first-line treatment with BNZ. Moreover, vet-IVM was mentioned as a preventive method by 16.3% (109/669) of survey participants.

Bivariate analysis

Factors associated with vet-IVM intake in the bivariate analysis are summarised in table 3 and online supplemental file S3. Education, age, decreased emotional and physical health status and the perception that biomedical treatment with BNZ had strong side effects showed an effect on vet-IVM intake. In total, 289 patients (42.5%) reported one or more chronic symptoms compatible with CD and an increased number of symptoms was related to vet-IVM intake. On the other hand, the perceived effectiveness of local health facilities to provide adequate care for CD showed a decrease with vet-IVM intake (figure 2). There was no association between the use of vet-IVM and BNZ.

Multivariate analysis

In the multivariate analysis, being above 60 years old, being diagnosed with CD and the unavailability
Figure 2  Bivariate analysis on factors associated with veterinary ivermectin intake, test for trend. Variable categories: education 0=no/incomplete schooling, 1=complete schooling (secondary), 2=tertiary education, 3=academic. Health status and emotional health status 1=very good, 2=good, 3=fair, 4=bad, 5=very bad. Perceived effectiveness of health system: responses to the question “If I go to the health center, I will get all the help I need to get cured”. Belief in adverse events of benznidazole (BNZ): responses to the question: ‘The treatment has strong negative effects’, both assessed on a 5-point Likert scale 1=strongly disagree, 2=disagree, 3=uncertain, 4=agree, 5=strongly agree. ns, p>0.05; *0.01<p<0.05; **0.001<p<0.01; ***0.0001<p<0.001; ****p<0.0001.
and the experience of someone close were underlying factors associated with vet-IVM intake, but only academic education reached statistical significance. The experience of other community members as information sources played a significant role in the decision to be treated with vet-IVM. Table 3 displays a summary of the main factors associated with vet-IVM intake in quantitative and qualitative interviews (the complete table can be found in online supplemental material S3).

**DISCUSSION**

This is the first study exploring underlying factors of unscientific vet-IVM use against CD. The results serve to derive similarities in light of vet-IVM hype during the COVID-19 pandemic.

Our study highlights that vet-IVM has played a major role in the prevention and treatment of CD for several years. Although its use against CD had been documented before, the extent of the phenomenon was a surprising finding. vet-IVM use was reported by 18% of total and 28% of survey participants seropositive for CD and exceeded BNZ intake. There was no association between vet-IVM and BNZ intake, indicating that both were rather complementary than competing treatments. vet-IVM often formed part of a ‘pragmatic multiple strategy’ previously described in Bolivia, which included self-medication alongside traditional and biomedical treatment options. Increasing age, lack of education, unavailability of BNZ and the experience of someone close were underlying factors for vet-IVM intake.

In line with findings from other countries, ivermectin had an excellent reputation among communities. vet-IVM’s broad spectrum against endoparasites and ectoparasites led to a perceived ability to ‘clean’ animal and potentially human bodies of all kinds of germs. An image of a ‘wonderdrug’ emerged in several narratives, a term also used by some scientific authors when referring to ivermectin and its potential efficacy against yet undiscovered diseases. The hope that (veterinary) ivermectin might be effective against CD was also reflected in narratives among HC workers, despite their awareness on the lack of scientific evidence.

vet-IVM had been distributed against CD by a wide range of influential stakeholders for almost two decades, indicating that the belief in its effectiveness might be strongly anchored in the region. Some key informants however raised concerns about unethical, economically motivated vet-IVM administration and adverse events potentially related to overdosage and veterinary formulations, which are not designed for humans and have never been assessed in trials. A recent systematic review concluded that serious adverse events cannot be ruled out when ivermectin is administered at higher doses.

Underlying factors resulting from the triangulation of qualitative and quantitative results were lack of education and advanced age. Although vet-IVM was also taken to prevent CD, a CD diagnosis and a decreasing health status were related to trial and error of different treatments, including vet-IVM. Barriers to health access also played a role and were connected to misinformation and vulnerability to unethical practices in qualitative analysis. Narratives of community members often centred around stories of spontaneous healing and played a fundamental role in treatment decisions. In line with findings from the USA, especially older patients relied on their friends’ advice for health decisions.

Several factors connected to vulnerability in our study have also been linked to COVID-19-related morbidity, such as old age, lack of education and access barriers to HC and information. Indigenous populations are often vulnerable to CD and considered at special risk for COVID-19 complications. Although CD is not systemically assessed as a comorbid condition and therefore invisible in death statistics, it could also directly contribute to COVID-19-related mortality among Latin-Americans, with an estimated 1 million people suffering from CD-related cardiac manifestations.

**Implications for the COVID-19 pandemic**

The extent of the phenomenon, the existing vet-IVM market and ivermectin’s widespread image as ‘wonderdrug’ against CD, a disease often associated with despair, might have contributed to its premature proclamation as a cure against COVID-19, when initial in vitro experiments suggested a potential effect. In the absence of accessible options, health professionals and vulnerable communities can easily project their hopes into ivermectin’s ‘yet’ unproven efficacy against CD and COVID-19. According to current evidence, ivermectin is however not recommended against SARS-CoV-2. Indiscriminate use of ivermectin is problematic due to environmental concerns and because it hinders high-quality trials on its effectiveness. Other concerns are the lack of follow-up on complications, especially when using vet-IVM and off-label treatment of severely ill patients with COVID-19. A hyperinflammatory state might lead to severe neurotoxicity caused by ivermectin, which is usually prevented from passing to the central nervous system by an intact blood-brain barrier. Moreover, individuals with specific gene mutations may have adverse reactions.

In light of the COVID-19-related infodemic, our study highlights that special emphasis should be on vulnerable communities to make this updated information available and to foster resilience against circulating misinformation. NTDs are considered indicators for health (in) equity and could help to identify communities most in need of interventions.
Promoting health literacy and adequate dissemination tools, such as audio-based interventions for illiterate community members, could reduce their chances of becoming an easy target for unethical practices.\textsuperscript{60–62} Effective education messages should be in easy-to-understand language, built on local knowledge and include circulating health information. Their design and dissemination should be participatory,\textsuperscript{60–62} including communities and all relevant stakeholders such as HC worker, traditional healers, pharmacists and also veterinarians, who can play an important role distributing vet-IVM.\textsuperscript{63,64}

Finally, as shown in our study, the misuse of inadequate treatment is caused by the unavailability of real options. In case of CD, there is an urgent need for better and faster working treatments and to assure accessibility of existing treatments. In the case of COVID-19, global solidarity is needed to assure equity of access to potential future treatments and vaccinations to prevent COVID-19 from becoming the ‘newest serious NTD in the region’.\textsuperscript{65}

This is the first study exploring the phenomenon of unscientific vet-IVM use against CD and underlying factors. There were however also some limitations: (1) the study was conducted in one Bolivian municipality at the end of 2018, in the pre-COVID-19 era. Although we tried to discuss some potential similarities, the current COVID-19 situation might be very different and our results cannot be generalised to other regions; (2) there was an over-representation of females during the survey, which were more often encountered at home during daytime; (3) vet-IVM was a theme that emerged during qualitative data collection and was integrated in the survey, in line with an iterative approach. Apart from the purposeful interview with a veterinarian, we did not bring up vet-IVM, but waited if the topic was spontaneously addressed to understand its importance in the context of different treatment options. Participants not talking about vet-IVM might therefore have a different opinion or attribute less importance to the topic and it was difficult to assess data saturation. We however tried to mitigate this effect by analysing contrasting viewpoints during qualitative analysis. We moreover believe that the triangulation of several data sources (qualitative: participants spontaneously talking about vet-IVM, own vet-IVM intake; narratives of patients and key informants about the vet-IVM extent; quantitative: self-reported vet-IVM, citing vet-IVM as preventive measure) allowed an overall understanding of the extent and importance of the vet-IVM phenomenon.

CONCLUSION

This is the first in-depth study on the extent and underlying factors of vet-IVM against CD. Although the results cannot be generalised to other settings, they serve to discuss potential similarities in light of the widespread use of vet-IVM during COVID-19. Our results highlight the pre-existing importance of unscientific vet-IVM intake. Social determinants of health, the unavailability of effective treatment options and circulating rumours may be underlying factors of the phenomenon. In times of increased vulnerability, local and international stakeholders should put specific attention on communities with high NTD burdens, such as CD. Continuing the work to engage and empower neglected communities can help to protect them from fake news and unethical practices, such as the indiscriminate use of vet-IVM.

Author affiliations

1Department of Medical and Social Projects, DAHW, Würzburg, Germany
2Medical Department, Centro Integral Dermatológico, Monteagudo, Plurinational State of Bolivia
3Department of Public Health, Science History and Gynecology, Universidad Miguel Hernández, Alicante, Spain
4Division of Infectious Diseases and Tropical Medicine, University Hospital LMU Munich, Munich, Germany
5Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, South Africa
6Department of General Practice, University Hospital Würzburg, Würzburg, Germany
7Medical Faculty, University of Würzburg, Würzburg, Germany
8Department of Infectious Diseases and Respiratory Medicine, Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Berlin, Germany

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Contributors

SP, BAM, MN and MP were responsible for the conception of study and development of methodology. SP, BAM, CSI and CK conducted funding acquisition and project administration. SP, BAM, CSI and GR collected qualitative interviews and supervised quantitative data collection. SP, JDDD and JS conducted quantitative analysis and visualisation of data. SP and JZ conducted qualitative analysis. BAM, MN, JDDD, JS and SP prepared the original draft. IG, E-MS-S, HS, JZ, GR, CK, TZ, CSI and CG contributed significantly to the improvement of the manuscript. SP is the overall guarantor of the study.

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Competing interests

None declared.

Patient and public involvement

Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the ‘Methods’ section for further details.

Patient consent for publication

Not applicable.

Ethics approval

This study was approved by Institutional Review Board at the Ludwig-Maximilians-University in Munich, Germany (opinion dated 25 September 2018, number 18–686) and Institutional Review Board at the University Mayor, Real y Pontificia de San Francisco Xavier de Chuquisaca in Sucre, Bolivia (opinion dated 23 August 2018). Participants gave informed consent to participate in the study before taking part.

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Data availability statement

Data are available on reasonable request. Additional data are available on reasonable request emailing Paris_Silukv.de.

Supplemental material

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REFERENCES

1. Crump A. Ivermectin: enigmatic multifaceted ‘wonder’ drug continues to surprise and exceed expectations. J Antibiot 2017;70:495–505.

2. Heidary F, Gharebaghi R. Ivermectin: a systematic review from antiviral effects to COVID-19 complementary regimen. J Antibiot 2020;73:593–602.

3. Okeibunor JC, Amuyunzu-Nyamongo M, Onyeneho NG, et al. Where would I be without ivermectin? capturing the benefits of community-directed treatment with ivermectin in Africa. Trop Med Int Health 2011;16:608–21.

4. Cally L, Druce JD, Catton MG, et al. The FDA-approved drug ivermectin inhibits the replication of SARS-CoV-2 in vitro. Antiviral Res 2020;182:104787.

5. López-Medina E, López P, Hurtado IC, et al. Effect of ivermectin on time to resolution of symptoms among adults with mild COVID-19: a randomized clinical trial. JAMA 2021;325:1426.

6. Roman YM, Burela PA, Pasapuletli V. Ivermectin for the treatment of COVID-19: a systematic review and meta-analysis of randomized controlled trials. Clin Infect Dis 2021;ciaa591.

7. Pharmacologic treatments for COVID-19 patients. Available: https://covid-nma.com/living_data/index.php?comparison=36 [Accessed 11 Aug 2021].

8. Mittal N, Mittal R. Inhaled route and anti-inflammatory action of ivermectin: do they hold promise in fighting against COVID-19? Med Anthropol 2021;146:110364.

9. Popp M, Stegemann M, Metzdorf M-I. Ivermectin for preventing and treating COVID-19. Cochrane Database Syst Rev 2021;2021.

10. Pérez-Molina JA, Molina I. Chagas disease. The Lancet 2018;391:82–94.

11. Gómez LJ, van Wijk R, van Selm L, et al. Stigma, participation restriction and mental distress in patients affected by leprosy, cutaneous leishmaniasis and Chagas disease: a pilot study in two co-endemic regions of eastern Colombia. Trans R Soc Trop Med Hyg 2020;114:476–80.

12. Zaied EL, Forsyth CJ, Novick G, et al. COVID-19: implications for people with Chagas disease. Glob Heart 2020;15:69.

13. Tilli M, Olliaro P, Gobbii F, et al. Neglected tropical diseases in non-endemic countries in the era of COVID-19 pandemic: the great forgotten. J Travel Med 2021;28:taaa179.

14. Morillo CA, Marin-Neto JA, Avezum A, et al. Randomized trial of benznidazole for chronic Chagas’ cardiomyopathy. N Engl J Med 2015;373:1295–306.

15. Forsyth CJ. ‘I Cannot Be Worried’: Living with Chagas Disease in Tropical Bolivia. PLoS Negl Trop Dis 2017;11:e0005251.

16. Forsyth C. From lemongrass to ivermectin: Ethnomedical management of Chagas disease in tropical Bolivia. Med Anthropol 2018;37:236–52.

17. Dias JCP, Schofield CJ, Machado EM, et al. Ticks, ivermectin, and experimental Chagas disease. Mem Inst Oswaldo Cruz 2005;100:828–32.

18. Ivermectin and COVID-19: how a flawed database shaped the pandemic response of several Latin-American countries. Available: https://www.isglobal.org/en/healthisglobal/-/custom-blog-portlet/ivermectin-and-covid-19-a-flawed-database-shaped-the-COVID-19-response-of-several-latin-american-countries/2877257/0 [Accessed 11 Aug 2021].

19. Chaccour C, Hammann F, Ramón-García S, et al. Ivermectin and COVID-19: keeping rigor in times of urgency. Am J Trop Med Hyg 2020;102:1156–7.

20. Un Grupo evangélico peruano inyecta un medicamento veterinario a miles de personas para La covid-19. Available: https://elpais.com/covid-19-response-of-several-latin-american-countries/2877257/0 [Accessed 11 Aug 2021].

21. Bray M, Rayner C, Noël F, et al. Ivermectin and COVID-19: a report on antiviral research, widespread interest, an FDA warning, two letters to the editor and the authors’ responses. Antiviral Res 2020;178:104805.

22. Saxena A. Drug targets for COVID-19 therapeutics: ongoing global efforts. J Biosci 2020;45:87.

23. Nippes RP, Macruz PD, da Silva GN, et al. A critical review on environmental presence of pharmaceutical drugs tested for the covid-19 treatment. Process Saf Environ Prot 2021;152:568–82.

24. Zeaheer T, Pal K, Abbas RZ, et al. COVID-19 and ivermectin: potential threats associated with human use. J Mol Struct 2021;1243:130908.

25. Parisi S, Navarro M, Du Plessis JD, et al. “We have already heard that the treatment doesn’t do anything, so why should we take it?” A mixed method perspective on Chagas disease knowledge, attitudes, prevention, and treatment behaviour in the Bolivian Chaco. PLoS Negl Trop Dis 2020;14:e0008752.

26. Fernandez AB, Nunes MCM, Clark EH, et al. Electrocardiographic and echocardiographic abnormalities in Chagas disease: findings in residents of rural Bolivian communities hyperendemic for Chagas disease. Glob Heart 2015;10:159–66.

27. Fettert MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs-principles and practices. Health Serv Res 2013:48:2134–56.

28. Noble H, Heale R. Triangulation in research, with examples. Evid Based Nurs 2019;22:52–6.

29. Kuckartz U. Qualitative Text Analysis: A Guide to Methods, Practice & Using Software. 1. Oliver’s Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd, 2014.

30. Understanding robust standard errors. Available: https://data.library.virginia.edu/understanding-robust-standard-errors/ [Accessed 07 Jun 2022].

31. Mathez-Stiefel S-L, Vandenbroeck I, Rist S. Can Andean medicine coexist with biomedical healthcare? A comparison of two rural communities in Peru and Bolivia. J Ethnobiol Ethnomed 2012;8:26.

32. Ómura S, Crump A. Ivermectin: panacea for resource-poor communities? Trends Parasitol 2014;30:445–55.

33. Crump A, Ivermectin OS. ‘Wonder drug’ from Japan: the human use continues to surprise and exceed expectations. J Antibiot 2012;65:219–26.

34. Auffrey V, Olulana O, Avula V, et al. Racial, economic, and health inequity and COVID-19 infection in the United States. J Racial Ethn Health Disparities 2021:8:732–42.

35. Aldridge RW, Lever D, Katikireddi SV, et al. Black, Asian and minority ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. Wellcome Open Res 2020;5:88.

36. Andrade LA, Gomes DS, Lima SVM, et al. COVID-19 mortality in an area of northeast Brazil: epidemiological characteristics and prospective spatiotemporal modelling. Epidemiol Infect 2020;148:e288.

37. Concepción-Zavaleta MJ, Coronado-Arroyo JC, Zavaleta-Gutiérrez FE, et al. Does level of education influence mortality of SARS-CoV-2 in a developing country? Int J Epidemiol 2021;49:2081–3.

38. Kaplan HS, Steinberg BC, Steiglitz J, et al. Voluntary collective isolation as a best response to COVID-19 for Indigenous populations? A case study and protocol from the Bolivian Amazon. The Lancet 2020;395:1727–34.

39. Meneses-Navarro S, Freirumth-Mencia MG, Pelcastre-Villafuerte BE, et al. The challenges facing Indigenous communities in Latin America as they confront the COVID-19 pandemic. Int J Equity Health 2021;20:196.

40. Weltgesundheitsorganisation editor. Integrating neglected tropical diseases into global health and development. Geneva: World Health Organization, 2017.

41. Alberca RW, Yendo TM, Leuzzi Ramos Yasmin Alefe, et al. Case report: COVID-19 and Chagas disease in two coincident patients. Am J Trop Med Hyg 2020;103:2353–5.

42. Chagas disease in Latin America: an epidemiological update based on 2010 estimates. Wkly Epidemiol Rec 2015;90:33–43.

43. Perez-Garcia LA, Mejias-Carpio IE, Delgado-Noguera LA, et al. Ivermectin: repurposing a multipurpose drug for Venezuela’s humanitarian crisis. Int J Antimicrob Agents 2020;56:106037.

44. Carmona D, Almeee M, Martinez-Solar H, et al. Lack of efficacy of standard doses of ivermectin in severe COVID-19 patients. PLoS One 2020;15:e0242184.
Verdú JR, Cortez V, Ortiz AJ, et al. Biomagnification and body distribution of ivermectin in dung beetles. Sci Rep 2020;10:9073.

Verdú JR, Lobo JM, Sánchez-Piñero F, et al. Ivermectin residues disrupt dung beetle diversity, soil properties and ecosystem functioning; an interdisciplinary field study. Sci Total Environ 2018;618:219–28.

Mega ER. Latin America’s embrace of an unproven COVID treatment is hindering drug trials. Nature 2020;586:481–2.

Baudou E, Lespine A, Durrieu G, et al. Serious Ivermectin Toxicity and Human ABCB1 Nonsense Mutations. N Engl J Med 2020;383:787–9.

Islam MS, Sarkar T, Khan SH, et al. COVID-19-Related Infodemic and its impact on public health: a global social media analysis. Am J Trop Med Hyg 2020;103:1621–9.

Barua Z, Barua S, Akhtar S, et al. Effects of misinformation on COVID-19 individual responses and recommendations for resilience of disastrous consequences of misinformation. Prog Disaster Sci 2020;8:100119.

Fitzpatrick C, Engels D. Leaving no one behind: a neglected tropical disease indicator and tracers for the sustainable development goals. Int Health 2016;8 Suppl 1;15–18.

Molyneux DH. Neglected tropical diseases: now more than just ‘other diseases’--the post-2015 agenda. Int Health 2014;6:172–80.

Engels D. Neglected tropical diseases in the sustainable development goals. The Lancet 2016;387:223–4.