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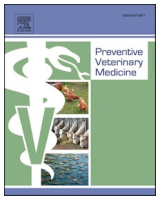

Barriers and opportunities for canine rabies vaccination campaigns in Addis Ababa, Ethiopia

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ABSTRACT

Background: Canine rabies is endemic in Ethiopia and presents a significant burden for both animal and human health. We investigate barriers to dog vaccination in Addis Ababa, Ethiopia. These results can be utilized to improve and target future rabies control efforts.

Methodology/Principle findings: During May of 2017, dog owners were surveyed during a free canine rabies vaccination programs that utilized both door-to-door (DtD) and central point (CP) vaccination methods. Surveys collected information on preferences for rabies vaccine delivery and were administered in Amharic. A total of 1057 surveys were completed. Of those surveyed, 62.4 % indicated that their dogs had been vaccinated against rabies within the last year. Commonly reported barriers to vaccination were a lack of awareness that dogs required rabies vaccines (18.1 %) and lack of knowledge about where to find vaccine (15.0 %). The median price owners were willing to pay for vaccination was 25 birr ($0.91 USD) and the median distance willing to travel was 1.0 km; however, 48.9 % of those surveyed during DtD were unwilling to travel at all. We identified 3 classes of respondents who were grouped due to their responses by latent class analysis: '*the Unaware*', '*the Vaccinators*', and '*the Multiple Barriers*'.

Conclusions/Significance: Although many respondents were willing to pay for rabies vaccine (94.0 %); the preferred cost (median) was less than the actual cost of providing the vaccine. This supports the need for reduced-cost or free vaccine to achieve and sustain the 70 % vaccine coverage target threshold for canine rabies elimination. Additionally, a significant portion (41.5 %) of those surveyed indicated that they were unwilling to travel in order to have their dog vaccinated.

The latent class analysis provides useful guidance on how to reach target vaccination. Owners from 'the Unaware' group made up 18.1 % of respondents and their high rate of allowing their dogs to roam identifies them as a prime target for canine health and behavior education. 'The Multiple Barriers' owners reported lower degrees of dog roaming and were substantially more likely to be found by DtD campaigns, possibly because they have limited ability/interest in handling their dogs. These results demonstrate the importance of incorporating DtD vaccination as well as subsidies to maximize vaccine coverage in Addis Ababa.

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1. Introduction

Rabies is a fatal zoonotic viral disease that results in approximately 59,000 human deaths each year, predominantly localized in the developing world (Hampson et al., 2015). These deaths are disproportionately concentrated in lower socioeconomic populations as well as among children (Sudarshan et al., 2007). Because of systemic under-reporting, the true annual human burden may be well over 100,000 deaths (Fooks, 2007). Bites from domestic dogs are the source of 99 % of human rabies deaths worldwide (Organization WH, 2013) and although rabies vaccination campaigns targeting dogs have been shown to be highly effective at controlling, even eliminating canine rabies (Fooks et al., 2014; Townsend et al., 2013), rabid dogs continue to pose a significant threat globally.

Ethiopia reports one of the highest burdens of human rabies deaths worldwide, with only four other countries having higher estimated fatalities (India, China, Democratic Republic of the Congo, and Myanmar) compared to Ethiopian figures (Hampson et al., 2015; Jemberu et al., 2013). In addition to human deaths, rabies significantly affects the livelihood of pastoralists due to the loss of livestock, amounting to $209 million USD in estimated losses per year in Ethiopian cattle (Jibat et al., 2016). Dogs are responsible for 95 % of human rabies cases in Ethiopia (Yimer et al., 2002) and, in 2011, projections in the capital, Addis Ababa, estimated the dog population to be between 250,000–350,000 (Ethiopian Ministry of Agriculture, 2000). A large proportion of these dogs were unvaccinated (Yimer et al., 2002) and considered to be unowned; though, the ownership status of free-roaming dogs can often be nebulous (Gsell et al., 2012).

Previously reported dog vaccination coverage rates in Addis Ababa ranged from 1.8 to 26.9 %, far from the sustained coverage of 70 % needed to eliminate canine rabies (Ali et al., 2010; Yimer et al., 2012). Several factors have hampered previous rabies vaccination efforts in Addis Ababa including lack of vaccines, high cost of vaccines (Deressa et al., 2010), poor community participation in pet dog rabies vaccination (Yimer et al., 2012), and an absence of a veterinary workforce trained in canine mass vaccination strategies or safe dog handling techniques (Yimer et al., 2012). To evaluate different vaccination strategies in order to improve the efficiency of vaccine delivery, a survey was conducted during rabies vaccination efforts in Addis Ababa. Evaluation goals included gathering information on dog ownership practices within Addis Ababa, identifying barriers to vaccination, and evaluating the effect of differing methods of service delivery on vaccine accessibility and utilization.

2. Methods

2.1. Survey areas and procedure

Addis Ababa is the capital of Ethiopia and is considered both a city and state with an estimated population of 3.79 million urban-area residents (Adugna, 2017). It is divided into ten named administrative sub-cities and a community survey was conducted in two of these divisions: Lideta (9.2 km^2) and Addis Ketema (~7.4 km^2), in May 2017 (Fig. 1). These sub-cities were selected due to recent rabies cases identified in dogs or people within the communities and the Ethiopian government had targeted the communities for vaccination to prevent further deaths.

Vaccination teams provided free canine vaccine (Novibac®3, Merck Animal Health) to willing dog owners via central point (CP) and door-to-door (DtD) vaccination efforts concurrently in a region of each subcity. A portion of staff stayed at a previously advertised CP location and the remainder would move through the community. As vaccination proceeded, surveyors asked every fifth dog owner if they would participate in the survey (this ratio allowed the survey and vaccination to stay close by). Only individuals over the age of 18 were interviewed, and informed consent was obtained prior to data collection. No reward or payment was provided to the selected participants who were informed that refusal to participate would not affect their animal's vaccination in any

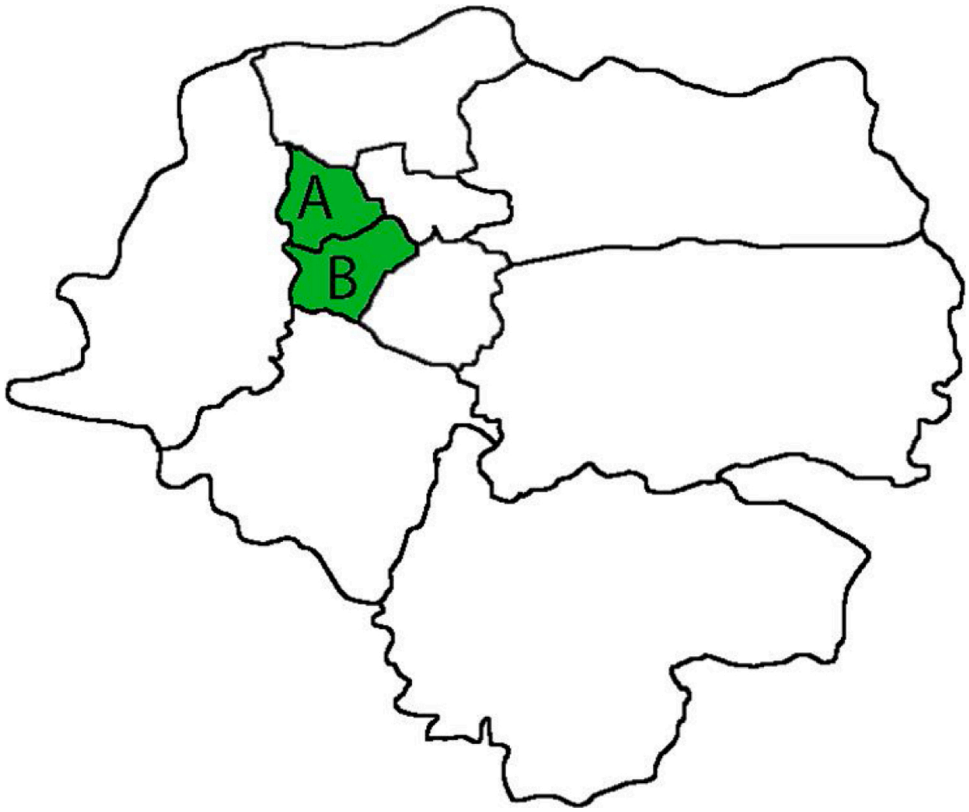

Fig. 1. Sub-cities of Addis Ababa included in the mass vaccination surveys: A (Addis Ketema); B (Lideta); Created by the authors.

way.

2.2. Survey design

The survey was designed to collect baseline data on dog ownership practices, barriers to rabies vaccination, and owner preferences towards rabies vaccination. Topics included: whether the dog had been vaccinated within the past year (or ever), where the vaccination was sourced from, as well as preferences on future vaccination advertising methods, if and when owned dogs are allowed to roam freely on the street, barriers to vaccination (can select multiple options), and interest in future vaccination strategies, such as the distance owners were willing to travel and the price owners were willing to pay for rabies vaccine. The two sub-cities (Lideta and Addis Ketema) were not compared in this study.

The survey was built and administered using the Magpi mobile data service (DataDyne Group, www.magpi.com) on Android tablets. Questions were written in both English and Amharic and are available in the supplemental materials of this paper. The surveyors, Addis Ababa city employees, received training on survey procedures prior to the start of the campaign. All surveyors were bilingual and conducted interviews in Amharic, entering the responses into Magpi in English. The survey protocol and tools were evaluated by the Center for Disease Control and Prevention's National Center for Emerging and Zoonotic Infectious Diseases' Institutional Animal Care and Use Committee and by the Ohio State University Institutional Review Board (#2017E0250).

2.3. Latent class analysis

The binary survey responses that identified factors that might prevent an animal from receiving vaccination (vaccine availability, couldn't afford, lack of trust in the vaccine, couldn't find a vaccinator, no time, unaware a rabies vaccine was needed) as well as their dog's current vaccination status (in the prior year) were used to construct latent class analyses (LCA) in R using the poLCA package (Linzer and Lewis, 2011). A two, three, and four-group analysis were performed and the three-group model was selected by minimizing Akaike's information criterion and Bayesian information criterion while maximizing the entropy values of 3869.38, 3983.53 and 1.00 respectively.

2.4. Statistical analysis

Categorical data was compared across groups using Pearson's Chi-squared test. Pairwise comparisons between LCA groupings (as independent variables) and survey source (DtD vs CP) and levels (none, low, or high) of dog roaming (as dependent variables) were investigated with post-hoc testing using adjusted standardized residuals (Sharpe, 2015). Continuous data (specifically the amounts dog owners were willing to pay and travel for vaccination) were analyzed against survey source (DtD vs CP) using the non-parametric Mann-Whitney *U* test LCA groupings where compared to payment and travel data using an ANOVA. All statistical tests were performed utilizing SPSS v24 (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp).

3. Results

A total of 1057 surveys were completed in the Addis Ketema and Lideta sub-cities (254 CP and 803 DtD). There was a significant difference in owner's willingness to pay ($U = 62{,}642.5$, $p < 0.001$) and the distance they would be willing to travel ($U = 66{,}430.0$, $p = 0.01$.) between those that came to CP clinics versus DtD campaigns (Fig. 2).

The cost they were willing to pay for vaccination was reported on 944 surveys and only 57 (6.0 %) indicated that they were unwilling to pay for a rabies vaccine. Charging 20 birr (0.73 USD) for vaccine would be acceptable to encompass 76.2 % of respondents. Owners surveyed at CP clinics were willing to pay 20 % more (median 30 Birr) than owners surveyed during DtD (median 25 Birr).

Of those owners who indicated they were willing to travel to get their dog vaccinated, the median distance was 1 km (range 0.05–10 km). However, of the 972 owners who responded, 403 (41.5 %) reported that they would not travel at all to obtain a vaccine for their dog.

Additional barriers to vaccination were also investigated. Of the 1057 who responded: 198 (18.7 %) reported being unaware that dogs required rabies vaccines; 177 (16.7 %) reported not knowing where to find vaccine; 75 (7.1 %) were too busy or unable to leave work; 18 (1.7 %) were not able to afford vaccine; and 14 (1.3 %) reported not trusting the vaccine or vaccinators (Fig. 3). Looking further into awareness of local rabies vaccination efforts, 1055 respondents were asked how they would prefer to learn about upcoming vaccination campaigns. The use of a loudspeaker by someone walking through the community was the preferred means of advertising a Mass Vaccination Campaign (MVC) (78.1 %) followed by radio (33.5 %) and posters (25.9 %).

Of the 1057 owners interviewed about their dog's vaccination status, 62.4 % reported they were current on their rabies vaccine (1 year or less since vaccination). Owners interviewed during DtD reported higher rates of vaccination in their dogs compared to owners interviewed at CP

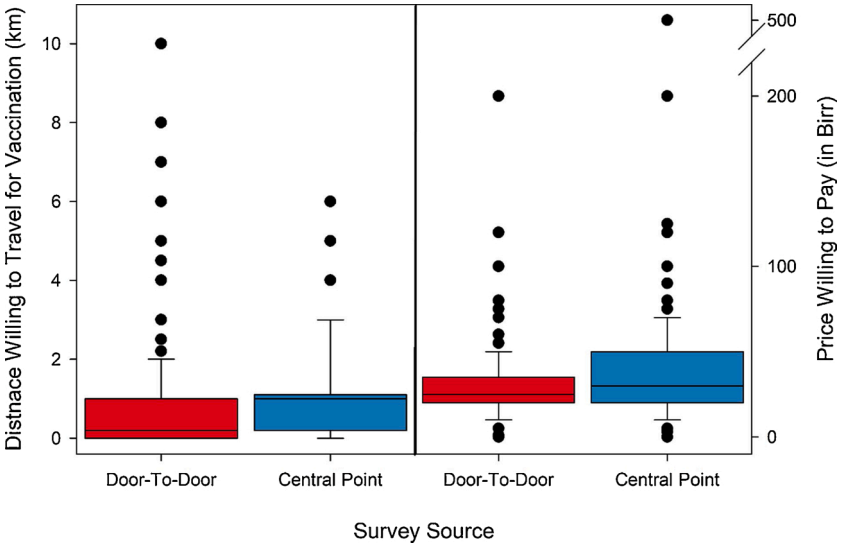

Fig. 2. Distance willing to travel and pricing willing to pay by CP and DtD survey respondents.

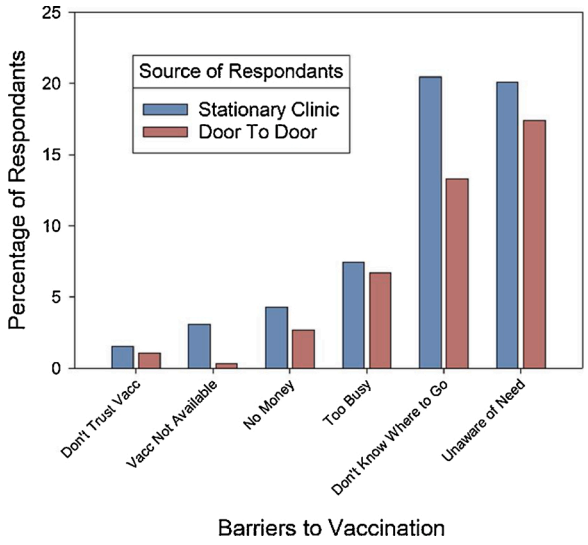

Fig. 3. Barriers to vaccination reported by dog owners in Addis Ababa, Ethiopia, 2017.

($\chi^2 = 19.03$, $p < 0.001$, 66.0 % and 50.8 %, respectively). Of the 688 owners who reported their dog had been previously vaccinated, 58.0 % reported the source of their dog's vaccine was for-profit individual vaccinators who came to their home, 39.2 % traveled to a veterinary clinic themselves, and 2.5 % reported receiving vaccination through a free or subsidized government program. One household (0.1 %) cited a non-governmental organization as the source of vaccine.

To assist with determining the best time to conduct vaccination efforts, we investigated if and when owned dogs were permitted to roam freely (n = 1055). Overall, 34.4 % of dog owners said their animals were never allowed to roam, with 65.9 % roaming part or all of the day. The daytime/early morning hours were reported to be the time with the lowest degree of roaming, averaging just 16.2 % of owned dogs on the street. From 9 pm to 3 am, approximately 44.5 % of owned dogs were reported as freely moving on the street (Fig. 4). The eight 3 -h time periods collected by the survey were collapsed into 3 roaming categories: no roaming, low roaming (3−12 h of roaming during the day), and high roaming (12 or more hours). There were significant differences between survey sources (DtD vs CP) when compared to these roaming categories ($\chi^2 = 8.545$, $p = 0.014$) mostly driven by DtD survey being more likely to allow no roaming ($p = 0.022$) and DtD being more likely to allow a low amount of roaming ($p = 0.006$).

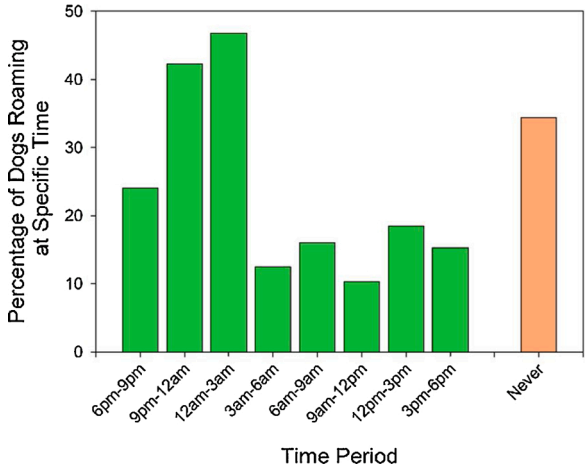

Fig. 4. Percentage of dogs allowed to roam freely, by hour, as reported by dog owners, Addis Ababa, Ethiopia, 2017.

3.1. Latent classes

Three groupings were found by latent class analysis looking for patterns in responses to the six questions about barriers to vaccination and whether or not the dog had been vaccinated in the previous year. The three groupings were 'the Unaware' (18.1 %), 'the Vaccinators' (61.2 %), and 'the Multiple Barriers' (20.7 %) (Fig. 5).

These latent groups had no significant relationship to the distance owners were willing to go, nor the amount they would be willing to pay. However, they did demonstrate significant relationships with two important metrics: whether they were interviewed during a DtD or CP portion of the vaccination campaign and dog roaming.

The significant differences ($\chi^2 = 22.96$, $p < 0.001$) were found among latent classes of owners on whether they were found on DtD or CP. Post-hoc adjusted residuals showed that 'the Vaccinators' (nearly all of whom had vaccinated their dog in the past year) were much more likely to be found during DtD ($p < 0.001$) while 'the Multiple Barriers' individuals, those were normally have difficulties getting their dogs vaccinated saw this as a rare opportunity and were significantly more likely ($p < 0.001$) to be found at a CP clinic.

Dog roaming behavior also differed significantly between owner's latent classes ($\chi^2 = 38.69$, $p < 0.001$). 'The Unaware' allowed their dogs to roam significantly more and were found in the high roaming category ($p < 0.001$), 'the Vaccinators' were found significantly more in the low roaming category ($p < 0.001$), and 'the Multiple Barriers' were found significantly more in the no roaming category ($p < 0.001$).

4. Discussion

Mass vaccination campaigns have been shown to be an invaluable tool in eliminating canine rabies and preventing human deaths (Organization WH, 2013; Fooks et al., 2014; Wallace et al., 2017). Vaccination strategies and efforts are most effective when they are tailored to meet the specific needs of each community. With this in mind, we designed this survey to collect information that could assist in targeting vaccination and awareness efforts as well as increase vaccination coverage. They were administered in conjunction with rabies vaccination efforts occurring in two Addis Ababa sub-cities (Fig. 1).

A majority (62.4 %) of surveyed owners reported having their dog(s) vaccinated within the last year. This is a much higher vaccination rate than expected based on other studies in Addis Ababa which reported rates between 1.8 and 26.9 % (Ali et al., 2010; Yimer et al., 2012). It is also notably higher than the 5 % region-wide vaccination coverage estimated by the East Africa Rabies Network (covering Kenya, Ethiopia, Tanzania, Rwanda, and Uganda) (Pieracci et al., 2017) and the reported vaccination coverage in N'Djamena, Chad (19 %) a similar urban African center (Durr et al., 2009). Whether or not 62.4 % is reflective of the true vaccination rate, it suggests an awareness that canine rabies vaccination is desirable as well as an openness to vaccination if it is available and affordable. The LCA groupings show that 'the Unaware', who do not know that rabies vaccination is required, only make up 18.1 % of the survey population. The other two groups included those who had already made efforts to vaccinate their animal, 'the Vaccinators' and those with some problem that might be solved by better public awareness campaigns and more convenient vaccination methods, 'the Multiple Barriers.'

Interestingly, several for-profit vaccinators were encountered during both this and prior vaccination campaigns by the vaccination teams. This non-governmental source of vaccines may, at least partially, explain the higher than expected owner-reported vaccination rate. Anecdotally, concerns were raised by our community partners regarding the efficacy and safety of vaccines administered by for-profit vaccinators. Exploration into the sources and handling of these vaccines may be warranted, as is consideration of coordinating vaccination efforts with and outreach to train this potential source of vaccinators in Addis Ababa.

A large percentage (41.5 %) of owners surveyed indicated that they

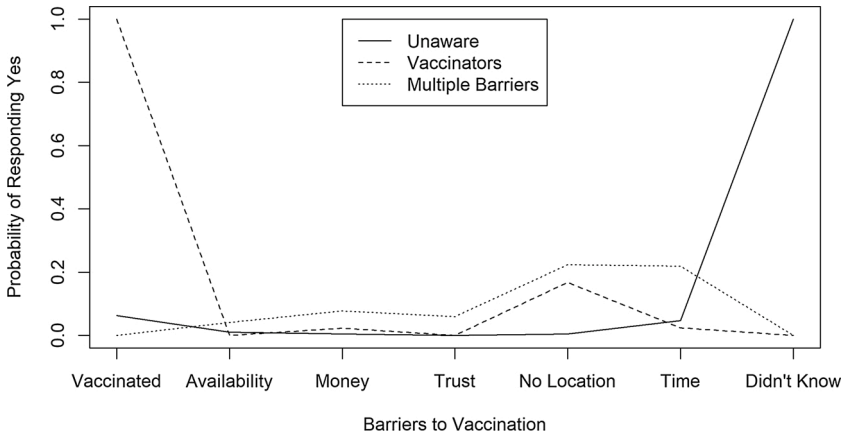

Fig. 5. The three latent groups identified and their characteristic responses.

were unwilling or unable to travel to CP clinics. This is a notable finding as successful campaigns in many other countries rely heavily on CP vaccine delivery methods as an efficient means of reaching owned dogs (Kaare et al., 2009; Muthiani et al., 2015; Cleaveland et al., 2003; Léchenne et al., 2016). Further evaluation into the reasons owners are unwilling or unable to take their dogs to a CP clinic may reveal additional barriers to this vaccination strategy and allow for targeted interventions that could increase participation in CP clinics. During the survey period, it was observed that many owners had challenges safely handling their dogs or were too afraid to attempt to do so. This is a well-documented barrier to implementation of successful vaccination campaigns and achieving high coverage (Kaare et al., 2009; Muthiani et al., 2015; Lapiz et al., 2012), and likely contributes to the high proportion of respondents who indicated they were unwilling to travel with their dogs to receive vaccination. For those willing to travel to a CP clinic, survey responses indicated that CP locations should expect to service owners within a 1 km radius, however, 500 m would capture over 70 % of those willing to take their dogs for rabies vaccination. However, a significant portion of owners may not be reached by CP no matter how close to their home if they are unwilling or unable to travel with their dog. This data supports the necessity for DtD strategies to be included as a major component of vaccination efforts in Addis Ababa as elsewhere in sub-Saharan Africa (Kaare et al., 2009; Muthiani et al., 2015).

In Ethiopia, as in most developing countries, dogs are primarily kept for protection (Kitala et al., 2001; Butler and Bingham, 2000; McCrindle et al., 1999) and as such, aggressive behavior towards strangers is a desired trait. Unneutered male dogs are perceived to exhibit more aggressive behaviors than females or neutered males, and are preferred, in part, for this reason (Flint et al., 2017; Polo et al., 2015). Prior work by the authors here observed a 4:1 skew towards males in owned dogs (Yoak et al., 2016). Unfortunately, the desired aggression is not limited to strangers; owners and their household members are also at risk. An evaluation in South Africa documented that 88 % of those bitten in a survey in KwaZulu-Natal were bitten by either their own dog or a neighbor dog, with only 12 % bitten by a stray dog (46). Socialization of dogs could be encouraged with the expectation of fewer behavioral issues and a reduction in handler-directed aggression (Wormald et al., 2016). If dogs were safer to handle they could be vaccinated more easily and their owners might be more likely to take them to CP clinics (Muthiani et al., 2015; Mazeri et al., 2018). Information on canine health and behavior (Polo et al., 2015; World Animal Protection, 2015) could be delivered alongside rabies awareness messaging which would substantially benefit the two groups with low vaccination rates, ‘the Unaware’ and ‘the Multiple Barriers’, which make up 38.8 % of the respondent population.

Most owners (94.0 %) surveyed indicated that they were willing to pay a fee to have their dog vaccinated. The median price owners were willing to pay in this study ($0.91 USD) was similar to another willingness to pay survey conducted in Africa (Dürr et al., 2008). A sufficient majority of dog owners (76.2 %) interviewed during this survey indicated a willingness to pay up to 20 birr ($0.73 USD). The average cost per dog of providing a rabies vaccine through a mass vaccination campaign (MVC) in developing countries is $2.45 USD (adjusted for inflation to 2016 dollars using BLS.gov) (Durr et al., 2009). While it is encouraging to see this willingness to pay, the majority of respondents indicated an amount that was approximately 1/3 of the estimated cost of vaccination per dog. Several studies in African countries have reported that offering free vaccines for dogs increases the vaccination coverage during MVCs (Durr et al., 2009; Sambo et al., 2014; Jibat et al., 2015; Mauti et al., 2015), which is essential to maintaining a target rate of 70 %. Free vaccine would also remove the incentive for for-profit vaccinators and veterinary clinics who benefit from the sale of vaccines (which may be mock or expired); though, it would also alienate these vaccinators, who are potential partners in rabies control efforts. Responses from owners on willingness to pay provide strong support for the need for subsidized vaccination costs.

When respondents at both CP and DtD were asked about barriers to vaccination (Fig. 3), the two most commonly selected responses were that they weren’t aware of the need for vaccination and that they didn’t know where to get the vaccine. Most who were unsure where to get the vaccine were in ‘the Multiple Barriers’ group but even ‘the Vaccinators’ had a minority of members who were unsure where to get additional vaccine as many opportunistically utilized the DtD for-profit vaccinators. These barriers may be addressed through community sensitization, underscoring the importance of awareness to future vaccination campaigns. Dedicated time and resources are essential to ensure that the community is well informed about the location of MVC events, as well as the benefits of vaccination to the dog, the owner and the community. The majority of respondents (78.1 %) preferred loudspeakers as a means of advertisement. We also recommend that awareness campaigns involve all members of the healthcare community, along with schools and religious organizations, as deemed appropriate, and engage respected members of the community (Cleaveland et al., 2003).

Dogs in Addis Ababa were observed by the authors to be frequently confined in cages or tethered. However, 65.9 % of owned dogs are allowed to roam part or all of the day and these roaming patterns match closely with latent class groupings, lending them additional weight as truly different types of owners. ‘The Vaccinators’ allow their animals to roam limited times but ‘the Unaware’ are likely those with the least knowledge about dogs/rabies and also utilize the least direct management and allow high degrees of roaming. Their animals are likely closer to true ‘street dogs’ than the other groups’ dogs. The ‘Multiple Barrier’ group owners are generally aware of the need to vaccinate their dogs but

have not done so yet, possibly causing them to more closely restrain their rabies-susceptible animal. The two unvaccinated groupings, "the Unaware" and "the Multiple Barrier", present targets for vaccination but differ in the particular needs of the group, awareness versus access, respectively. The dog and dog-owner populations of Addis Ababa are heterogenous so better understanding the differences among groups, both in their behavior and knowledge of rabies management, provides useful insight for targeting rabies control efforts.

Our study has several limitations. The respondents in Addis Ababa are from an urban center and their attitudes may not be reflective of rural or pastoral communities elsewhere in Ethiopia. Using owners as a source of information means we are unable to assess unowned dogs' vaccination histories like that a blood antibody test would provide. Respondents may not have felt comfortable discussing monetary questions with strangers which may have biased our willingness to pay results; nevertheless, our willingness to pay findings are similar to other willingness to pay surveys conducted in multiple African countries. Finally, respondents reported an unusually high vaccination response rate that we attributed to DtD for-profit vaccinators; however, there may have been misinterpretation or hesitancy to admit lack of prior vaccination to a vaccination team, so owner-reported vaccination rates may be inflated.

The results of this survey provide information valuable to the planning and targeting of future mass vaccination efforts in Addis Ababa and other similar African urban centers. It provides a benchmark for the cost of vaccine that dog owners in Addis Ababa are willing to pay as well as the distance they are willing to travel to a vaccination site. Our study highlighted some of the barriers to CP in Addis Ababa and owner vaccination preferences, indicating that a DtD vaccination strategy may be better suited as the primary method for vaccinating owned dogs, either alone or in conjunction with other vaccination strategies. Providing education on canine health and behavior could be integrated into an overall strategic plan for rabies elimination and may, in time, improve the ability to handle dogs, thereby increasing willingness to vaccinate, especially with respect to travelling to CP clinics. Lastly, providing government subsidized or free vaccine will likely help to increase coverage rates as will planning to address for-profit vaccinators, regardless of the strategies employed.

Author summary

Rabies is a fatal zoonotic disease that results in approximately 59,000 human deaths globally each year. In order to better direct rabies prevention efforts, we explored the knowledge, attitudes, and practices of dog owners in Addis Ababa, Ethiopia. Ethiopia reports one of the highest burdens of human rabies deaths worldwide and Addis Ababa is a growing urban center. Vaccinating 70 % of the canine population has proven an effective method of protecting both human and animal lives. Reaching an appropriate level of vaccination is a deceptively complex task that is abetted by understanding the barriers that exist in the community. This study finds that a multi-strategy approach which specifically includes mobile vaccination teams and subsidies for vaccines would be the most efficacious. The results of this work will aid future mass vaccination campaigns in Addis Ababa, Ethiopia and as well as decision makers in other East African urban centers.

Disclosure

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention, the Global Alliance for Rabies Control, Otterbein University, or The Ohio State University. This work was funded by a cooperative agreement (U2) with the CDC Center for Global Health and The Ohio State University (grant number - U2GGH001752).

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.prevetmed.2020.105256.

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