The effects of management of infection source of echinococcosis in Linzhi, Tibet autonomous region of China

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Case Study

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Abstract

**Background** Echinococcosis is highly endemic in western and northern China, Tibet Autonomous Region (TAR) is the most serious prevalent area. Linzhi is located in southeastern part of TAR. Dogs are the main infection source for the transmission of echinococcosis to humans. A control and prevention campaign based on dog management has been conducted in the past three years. This study is to evaluate the effects of dog management on infection rate of dogs.

**Methods** Data of dog population, registration and de-worming of seven counties/district in Linzhi were collected from the annual prevention and control report. Domestic dog fecal samples were collected from each endemic town of seven counties/district in Linzhi in 2019 to determine the infection of domestic dogs using coproantigen ELISA. Data analysis was processed using SPSS statistics to compare dog infection rate between 2016 and 2019 by chi-square test, and maps were mapped using ArcGIS.

**Results** In Linzhi, domestic dog population has decreased from 17407 in 2017, 16512 in 2018, to 12663 in 2019, while the registration rate has increased from 75.9% in 2017, 95.5% in 2018, to 98.6% in 2019. Similarly, stray dog population has decreased from 14336 in 2017, 13067 in 2018, to 11837 in 2019, while sheltered rate has increased from 84.6% in 2017, 92.3% in 2018, to 96.6% in 2019. Dog de-worming frequency has increased from four times per annum in 2017 to 12 times in 2019, indicating that approximately every dog was dewormed monthly. A total number of 2715 dog fecal samples were collected for coproantigen ELISA assay. The dog infection rate was 2.8% (77/2715) in 2019, which was significantly lower than 7.3% (45/618) in 2016 (P<0.05).

**Conclusions** Increased dog registration, decreased dog population, and increased dog de-worming frequency contributed to significantly decreased dog infection rate in Linzhi, TAR. Control and prevention campaign based on dog management can significantly decrease dog infection with *Echinococcus* spp in echinococcosis endemic areas.

**Background**

Echinococcosis is a severe zoonotic disease caused by larval stage of the genus *Echinococcus*. Cystic echinococcosis (CE) caused by metacestode of *Echinococcus granulosus* and alveolar echinococcosis (AE) caused by metacestode of *Echinococcus multiocularis* are two forms of echinococcosis. CE has a global distribution while AE is mainly restricted to the northern hemisphere[1,2]. *Echinococcus* spp. has a complex life cycle that involves two hosts. The main definitive hosts are dogs, which harbor adult worms in their small intestines. Humans and herbivores, particularly sheep, are intermediate hosts of this parasite. The intermediate hosts become infected by ingesting the eggs released in the feces of definitive hosts. Dogs, as the definitive hosts, are pivotal in the transmission of echinococcosis[1].

Echinococcosis was found to be highly endemic in the pasture areas of northwestern China where the prevalence of echinococcosis in human was 0.3% (estimated prevalence was based on case detection rate in sample population), in livestock was 4.7% (10186/217774), and dog infection rate was 4.3%
Echinococcosis, threatening more than 50 million people in China, has been listed as a key parasitic disease. Accordingly, a national control and prevention campaign has been launched by Chinese central government since 2007[5,6]. Control and prevention of echinococcosis relies on dogs de-worming with praziquantel, safe livestock slaughtering conditions, and free patients screening and treatment.

The Tibet Autonomous Region (TAR) of China is located in the Qinghai-Tibet Plateau, which was reported as one of the most serious endemic regions of the world[3,4,7]. The prevalence of echinococcosis remains at a high level despite the fact that there has been control and prevention campaign launched over years. According to epidemiological survey of echinococcosis in TAR in 2016, the prevalence of echinococcosis in humans was 1.7%(estimated prevalence was based on case detection rate in sample population), in livestock was 11.8%(249/2103), and dog infection rate was 7.3%(552/7564)[7]. The government of TAR has strengthened control and prevention campaign of echinococcosis with increased financial support and more technical guidance since 2017. More attention has been paid on dog management due to ubiquity of dogs in TAR. Various measures have been taken to strengthen management of infection sources of echinococcosis, including dog registration, reduction of dog population, and the most importantly, monthly dog de-worming.

In order to evaluate the effects of dog management in the past three years in TAR, we collected data of dog registration, dog population, and dog de-worming from Linzhi, one of the seven prefectures in TAR. Dog feces from Linzhi were collected and coproantigen ELISA method was used to determine dog infection with *Echinococcus* spp. In addition, the differences in dog infection between 2016 and 2019 were analyzed. The results of this work may help to understand the effectiveness of control and prevention campaign in Linzhi and benefit the other echinococcosis endemic areas.

**Methods**

**Study area**

Linzhi is located in the southeastern part of TAR between latitudes 26°52′–30°40′ N, and between longitudes 92°09′098°47′ E. It is in the middle and lower reaches of the YarlungZangbo River with an average altitude of 3100m, a total area of approximately 11.7 km², and an overall population of 231000. Linzhi has one administrative district and six counties, which are Bayi District, Gongbujiangda, Milin, Motou, Bomi, Chayu, and Lang County. Among these seven counties/district, Bayi, Gongbujiangda, Bomi, and Chayuhas were reported as co-endemic areas of both CE and AE while the other three counties were reported as CE endemic areas[4,7].

**Data collection**

Data of dog population, registration and de-worming were collected from the annual prevention and control report of Linzhi Center for Disease Control and Prevention, TAR.
Measures of dogs management

Dog registration

For the convenience of management, a file has been created for each domestic dog, including the owner’s name, gender, age, and the date of each de-worming.

Dog de-worming

Monthly de-worming for domestic dog with praziquantel and each de-worming date were recorded on dog registration files. Dogs weighing less than 5kg were given 50mg each time; dogs weighing 5–15kg were given 200mg each time; and dogs weighing more than 15kg were given 400mg each time. Dog feces were buried in depth or burned after de-worming.

Reduction of dog population

Various measures have been taken to control dog population, including building shelters to contain stray dogs as many as possible, restricting domestic dogs to two individuals per household, leashing domestic dogs, etc. Data on domestic and stray dog population were collected by local veterinarians.

Dog infection assay

One village was randomly selected from each endemic town of seven counties/district of Linzhi, and 20 households with dogs were randomly selected from each selected village according to dog registration files. Only one dog fecal sample was collected from each selected household. The collected fecal samples were frozen at -80°C for at least 72h to inactive any potential Echinococcus eggs. All dog fecal samples were tested for Echinococcus coproantigens by sandwich ELISA (Dog Echinococcus coproantigens ELISA kit, Combined, Shenzhen, China).

Statistical analysis

Data analysis was performed using SPSS Statistics version 21.0 (IBM, New York, USA), geographic information maps were mapped using ArcGIS version 10.1 (ESRI, Redlands, USA). Dog infections were expressed as percentages. Infection rates in 2016 and 2019 were compared using chi-square test, and the level of statistical significance was set at \( P < 0.05 \).

Results

Increased dog registration rate

As in Table 1, registration rate of domestic dog was increased respectively each year from 75.9\% (13216/17407) in 2017, 95.4\% (15766/16512) in 2018, to 98.6\% (12491/12663) in 2019. Almost all the domestic dogs in each county/district have been registered for management. Domestic dog population
has decreased from 17407 in 2017, 16512 in 2018, to 12663 in 2019. The results showed that the dog management is strengthened gradually.

Table 1 Registration of domestic dogs in Linzhi in 2017–2019

<table>
<thead>
<tr>
<th>County/District</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of domestic dog</td>
<td>Number of registered dog</td>
<td>Registration rate(%)</td>
</tr>
<tr>
<td>Bayi</td>
<td>3759</td>
<td>2722</td>
<td>72.4</td>
</tr>
<tr>
<td>Gongbujiangda</td>
<td>3759</td>
<td>3759</td>
<td>100.0</td>
</tr>
<tr>
<td>Milin</td>
<td>3287</td>
<td>1446</td>
<td>44.0</td>
</tr>
<tr>
<td>Motuo</td>
<td>1193</td>
<td>453</td>
<td>38.0</td>
</tr>
<tr>
<td>Bomi</td>
<td>2863</td>
<td>2863</td>
<td>100.0</td>
</tr>
<tr>
<td>Chayu</td>
<td>1912</td>
<td>1339</td>
<td>70.0</td>
</tr>
<tr>
<td>Lang</td>
<td>634</td>
<td>634</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>17407</td>
<td>13216</td>
<td>75.9</td>
</tr>
</tbody>
</table>

Increased dog de-worming frequency

In 2017, annual de-worming frequency was 4 times per annum, and the number increased to 11 in 2018 and 12 in 2019, which indicated that almost all domestic dogs had been de-wormed each month (Table 2).

Table 2 De-worming frequency of domestic dogs in Linzhi in 2017–2019

<table>
<thead>
<tr>
<th>County/District</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of domestic dog</td>
<td>Deworming doses (times)</td>
<td>Annual deworming frequency</td>
</tr>
<tr>
<td>Bayi</td>
<td>3759</td>
<td>14460</td>
<td>4</td>
</tr>
<tr>
<td>Gongbujiangda</td>
<td>3759</td>
<td>13514</td>
<td>4</td>
</tr>
<tr>
<td>Milin</td>
<td>3287</td>
<td>14372</td>
<td>4</td>
</tr>
<tr>
<td>Motuo</td>
<td>1193</td>
<td>4162</td>
<td>3</td>
</tr>
<tr>
<td>Bomi</td>
<td>2863</td>
<td>11452</td>
<td>4</td>
</tr>
<tr>
<td>Chayu</td>
<td>1912</td>
<td>7633</td>
<td>4</td>
</tr>
<tr>
<td>Lang</td>
<td>634</td>
<td>1759</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>17407</td>
<td>67352</td>
<td>4</td>
</tr>
</tbody>
</table>

Decreased stray dog population

So far, three shelters have been established for stray dogs in Linzhi, TAR, and stray dog population has gradually decreased from 14336 in 2017, 13067 in 2018, to 11837 in 2019, while sheltered rate of stray
dog was increased from 84.6% in 2017, 92.3% in 2018, to 96.6% in 2019. The results indicated that the vast majority of stray dogs have been sheltered by 2019 (Table 3).

<table>
<thead>
<tr>
<th>County/District</th>
<th>Number of stray dogs 2017</th>
<th>Number of sheltered dogs 2017</th>
<th>Sheltered rate (%) 2017</th>
<th>Number of stray dogs 2018</th>
<th>Number of sheltered dogs 2018</th>
<th>Sheltered rate (%) 2018</th>
<th>Number of stray dogs 2019</th>
<th>Number of sheltered dogs 2019</th>
<th>Sheltered rate (%) 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayi</td>
<td>3016</td>
<td>2684</td>
<td>89.0</td>
<td>2684</td>
<td>2518</td>
<td>93.8</td>
<td>2280</td>
<td>2166</td>
<td>95.0</td>
</tr>
<tr>
<td>GongbuJiangda</td>
<td>2914</td>
<td>2475</td>
<td>84.9</td>
<td>2486</td>
<td>2368</td>
<td>95.3</td>
<td>1751</td>
<td>1663</td>
<td>95.0</td>
</tr>
<tr>
<td>Milin</td>
<td>2064</td>
<td>1785</td>
<td>86.5</td>
<td>1954</td>
<td>1759</td>
<td>90.0</td>
<td>1780</td>
<td>1719</td>
<td>96.6</td>
</tr>
<tr>
<td>Motuo</td>
<td>1795</td>
<td>1468</td>
<td>81.8</td>
<td>1616</td>
<td>1437</td>
<td>88.9</td>
<td>1567</td>
<td>1536</td>
<td>98.0</td>
</tr>
<tr>
<td>Bomi</td>
<td>2715</td>
<td>2468</td>
<td>90.9</td>
<td>2684</td>
<td>2538</td>
<td>94.6</td>
<td>2986</td>
<td>2926</td>
<td>98.0</td>
</tr>
<tr>
<td>Chayu</td>
<td>986</td>
<td>684</td>
<td>69.4</td>
<td>917</td>
<td>846</td>
<td>92.3</td>
<td>855</td>
<td>825</td>
<td>96.5</td>
</tr>
<tr>
<td>Lang</td>
<td>846</td>
<td>568</td>
<td>67.1</td>
<td>726</td>
<td>597</td>
<td>82.2</td>
<td>618</td>
<td>603</td>
<td>97.6</td>
</tr>
<tr>
<td>Total</td>
<td>14336</td>
<td>12132</td>
<td>84.6</td>
<td>13067</td>
<td>12063</td>
<td>92.3</td>
<td>11837</td>
<td>11438</td>
<td>96.6</td>
</tr>
</tbody>
</table>

Table 3 Stray dog population in Linzhi in 2017–2019

**Dog infection status**

A total of 2715 fecal samples were collected from domestic dogs in all seven counties/district in Linzhi, TAR. The infection rate with *Echinococcus* spp. among dogs was determined by the coproantigen ELISA. The dog infection rate in Linzhi was 2.8% (77/2715) in 2019, significantly lower than that in 2016, which was 7.3% (45/618) ($P<0.05$). At the county level, the highest dog infection rate was 3.8% (40/1058) in Bayi district, followed by 3.4% (26/774) in Lang county, and the lowest dog infection rate was 0% (0/200) in Chayu county in 2019. There was a significant difference in dog infection between 2016 and 2019 in two county/district (Bayi district and Motuo county) ($P<0.05$), and the other five counties showed no significant difference ($P>0.05$) (Table 4).

<table>
<thead>
<tr>
<th>County/District</th>
<th>Total number of dogs 2016</th>
<th>Number of dog fecal samples 2016</th>
<th>Number of positive samples 2016</th>
<th>Infection rate (%) 2016</th>
<th>Total number of dogs 2019</th>
<th>Number of dog fecal samples 2019</th>
<th>Number of positive samples 2019</th>
<th>Infection rate (%) 2019</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayi</td>
<td>6775</td>
<td>117</td>
<td>27</td>
<td>23.1</td>
<td>2783</td>
<td>1058</td>
<td>40</td>
<td>3.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>GongbuJiangda</td>
<td>6673</td>
<td>81</td>
<td>4</td>
<td>4.9</td>
<td>2393</td>
<td>166</td>
<td>2</td>
<td>1.2</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Milin</td>
<td>5351</td>
<td>80</td>
<td>1</td>
<td>1.3</td>
<td>2229</td>
<td>192</td>
<td>5</td>
<td>2.6</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Motuo</td>
<td>2988</td>
<td>80</td>
<td>6</td>
<td>7.5</td>
<td>432</td>
<td>120</td>
<td>2</td>
<td>1.7</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Bomi</td>
<td>5578</td>
<td>80</td>
<td>1</td>
<td>1.3</td>
<td>2721</td>
<td>205</td>
<td>2</td>
<td>1.0</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Chayu</td>
<td>2898</td>
<td>100</td>
<td>3</td>
<td>3.0</td>
<td>2078</td>
<td>200</td>
<td>0</td>
<td>0.0</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Lang</td>
<td>1480</td>
<td>80</td>
<td>3</td>
<td>3.8</td>
<td>426</td>
<td>774</td>
<td>26</td>
<td>3.4</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total</td>
<td>31743</td>
<td>618</td>
<td>45</td>
<td>7.3</td>
<td>13062</td>
<td>2715</td>
<td>77</td>
<td>2.8</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
According to National plan for echinococcosis and other key parasitic diseases prevention (2016–2020) [6], all echinococcosis endemic counties were categorized as three classes according to their prevalence in humans and dog infection rate. Class I (prevalence in humans $\geq 1\%$ or dog infection rate $\geq 5\%$) is the most serious level. The epidemiological survey of echinococcosis in TAR in 2016 reported that the prevalence in humans in Linzhi was 1.6%, and the infection rate of dogs was 7.3% (45/618) [7]. As shown in Fig. 1, among seven counties/district of Linzhi, there were two counties were categorized as class I (Red in Fig. 1A) and the other 5 counties were categorized as class II (0.1% $\leq$ prevalence in humans $< 1\%$ or $1\% \leq$ dog infection rate $< 5\%$) (Orange in Fig. 1A) in 2016. After three years with effort on control and prevention, 2 counties in Linzhi were down-categorized as class II, a total of five counties were categorized as class II (Orange in Fig. 1B), and the other 2 counties were down-categorized as class III (0 $<$ prevalence in humans $< 0.1\%$ or $0 <$ dog infection rate $< 1\%$) (Yellow in Fig. 1B) in 2019. The dog infection level of Linzhi in 2019 was significantly lower than that in 2016. This change illustrated that dog management can significantly decrease dog infection with Echinococcus spp.

**Discussion**

The echinococcosis has been listed in 17 neglected tropical diseases by the World Health Organization (WHO) [8]. China, specifically the Qinghai-Tibet Plateau region, has the highest endemicity of echinococcosis in the world [3,4,7]. The public health burden is heavy because the diseases are difficult to treat, requiring complex surgical procedures and long-term high dose anti-helminthic treatment [9]. In addition, the unique social-cultural background and lifestyle in Tibetan communities adds further difficulties to diseases control and prevention. Echinococcosis has been considered as a serious public health issue in China, especially in TAR.

Dog is the main definitive host for *E. granulosus* and a major host for *E. multilocularis* if infected by ingesting small mammalian with metacestodes infection[9-12]. Dogs are considered as the main risk to humans echinococcosis due to their close relationship with human[13-15]. Human become infected by ingesting the Echinococcus eggs released in the feces of dogs. Dog is an important part of most Tibetan pastoral families and communities, which resulted in large numbers of dogs around, including domestic and stray dogs. Therefore, how to reduce the dog population in the community and decrease dog infection are essential for echinococcosis control and prevention.

Domestic dogs in the Qinghai-Tibet Plateau, especially those of herdsmen, have a wide range of activities and can roaming on the grassland freely. The feces of infected domestic dogs are scattered around the herdsmen’s living areas, which can easily infect dog owners. Thus management measures for domestic dogs include leashing domestic dogs to limit their roaming range and reduce their chance of infection, restricting domestic dogs to 2 individuals per household to control dog population and reducing the risk of transmission. Among those measures, de-worming dogs monthly is the most important one. All domestic dogs should be registered, and wear tags to distinguishing them. Moreover, each date of de-worming should be recorded on the file, so as to ensure the monthly de-worming. Dog feces are buried in depth or burned after de-worming to cut off the transmission route. By 2019, the registration rate of
domestic dogs in Linzhi was 98.6% (Table 1), the number of domestic dogs had gradually decreased (Table 1), and the annual deworming frequency had reached to 12 times (Table 2). The infection rate of dogs in Linzhi in 2019 was significantly lower than that in 2016. Showing that these management measures were effective,

Dogs that are not leashed, not wear tags and not registered are considered as stray dogs. Stray dogs usually have a larger range of activities than domestic dogs and are more likely to be infected by ingesting internal organs of infected livestock and small mammalian. In addition, the feces of infected stray dogs are scattered in the surrounding areas, which made stray dogs more important for the transmission. The most important management measure for stray dogs is to contain them as much as possible, and de-worming of sheltered stray dogs is essential too. Sheltered dog feces are buried in depth or burned after de-worming to reduce environmental contaminant. Table 3 showed that by 2019, the vast majority (96.6%) of stray dogs had been contained in shelters and dewormed, there are only a few stray dogs in surrounding areas. Decreased number of stray dogs greatly reduced the risk of echicococcosis transmission. Therefore, the infection rate of stray dogs was not detected in this study.

Meanwhile, we noticed that although dog infection rate in Linzhi was significantly decreased, it still remained at a relatively high level. In some counties, dog registration, reduction of dog population and dog de-worming have been carried out better (from the data), and the vast majority of dogs had been registered and de-wormed monthly by 2019. However, the dog infection still remained high, which seems to be a contradiction to the results. The coproantigen ELISA method has been used to determine dog infection and may have cross reaction with other cestode infection. False positive caused by this [2,16] may be one of the reasons why infection rate remained relatively high. In addition, there may be some problems during implementation of dog de-worming because it is difficult to ensure that dogs take praziquantel successfully during the process, which may lead to ineffective de-worming.

**Conclusions**

This work described the changes of dog registration, dog population and dog de-worming frequency in Linzhi, TAR from 2017 to 2019, and compared dog infection between 2016 and 2019. The results illustrate that increased dog registration rate, decreased dog population and increased dog de-worming frequency contributed to significantly decreased dog infection rate in Linzhi, TAR. Control and prevention campaign based on dog management can significantly decrease dog infection with *Echinococcus* spp in echinococcosis endemic areas.

**Abbreviations**

AE: Alveolar echinococcosis; CE: Cystic echinococcosis; ELISA: Enzyme-linked immunosorbent assay; TAR: Tibet Autonomous Region; WHO: World Health Organization.

**Declarations**
Acknowledgement

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Authors’ contributions

YW, LYW, GQ designed the study; BCM, GQ, HSP collected data and samples; YW, BCM, HSP performed ELISA assays; LYW, GQ analyzed data; YW, LYW drafted the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

All relevant data can be found within this paper.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Consent to publish was secured from the study participants.

Competing interests

The authors declared no competing interests.

References


Figures

A  Dog infection distribution by county in Linzhi, TAR in 2016

B  Dog infection distribution by county in Linzhi, TAR in 2019

Figure 1

Dog infection distribution by county in Linzhi, TAR
Figure 1

Dog infection distribution by county in Linzhi, TAR