Geographic distribution and prevalence of human echinococcosis at the township level in the Tibet Autonomous Region

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Abstract

Background

Echinococcosis is a zoonotic parasitic disease caused by larval stages of cestodes belonging to the genus *Echinococcus*. Echinococcosis is prevalent in 10 provinces/autonomous regions in western and northern China. A 2016 epidemiological survey of Tibet Autonomous Region (TAR) showed that the prevalence of human echinococcosis was 1.66% which is much higher than the average prevalence in China (0.24%). Therefore, understanding the prevalence and spatial distribution characteristics of human echinococcosis at the township level in TAR is critical.

Methods

Data from echinococcosis cases were obtained from 692 TAR townships in 2018. Cases were identified using the B-ultrasonography diagnostic method. The epidemic status of echinococcosis was classified in all townships in TAR according to the relevant standards of population prevalence indexes as defined in the national technical plan for echinococcosis control. Spatial scan statistics were used to highlight the geographical townships most at risk of echinococcosis. SPSS 21.0 was used to calculate the prevalence for cystic echinococcosis (CE) and alveolar echinococcosis (AE). For spatial clustering analyses and mapping, data were processed using ArcGIS 10.1. Spatial scan analyses were performed using SaTScan V9.5.

Results

In 2018, 16,009 echinococcosis cases were recorded in 74 endemic counties in TAR. The total prevalence rate was 0.53%. All the 692 townships were classified according to the order of the epidemic degree from high to low. 127 townships had prevalence rates higher than or equal to 1%. The spatial clustering scanning analysis of echinococcosis cases and exposed population showed that CE displayed one primary cluster, two secondary clusters and six minor secondary clusters. The primary cluster and other clusters were defined by Log-likelihood ratio (LLR) statistically significant values. The primary cluster covered 88 townships in 12 epidemic counties. AE displayed one primary cluster and two secondary clusters. The primary cluster covered 38 townships in 6 epidemic counties.

Background

Echinococcosis (commonly known as Hydatidosis) is a zoonotic parasitic disease caused by the larvae of *Echinococcus* parasitizing humans or animals and is widely distributed in pastoral areas of many countries globally [1]. Echinococcosis prevalence in China is actually the highest in the world [2]. There are two major types of echinococcosis: CE caused by larvae of *Echinococcus granulosus* and AE caused by larvae of *Echinococcus multilocularis* [3].

Echinococcosis is a long-course disease, mainly affecting the liver, but also the lung and spleen [4–5]. The infected organs deteriorate with the development of the disease, causing organ dysfunction and eventually death [4]. AE, also known as “parasitic cancer”, is the most lethal parasitic zoonosis with a 10-year mortality rate of more than 90% if untreated [4, 6]. Echinococcosis is a major public health concern and poses a substantial economic burden [3, 7–8]. All of the 692 townships in the 74 counties in 6 prefecture-level cities (Lhasa City Changdu city, Shannan city, Shigatse city, Naqu city, Linzhi city) and 1 prefecture (Ali Prefecture)have been recognized as endemic areas for echinococcosis in TAR.

A national survey on echinococcosis in China, conducted between 2012 and 2016, showed that 31 provinces (autonomous regions and municipalities) had reported cases of echinococcosis. Within these provinces, 370 counties reported local endemic human cases. These cases were mainly detected in the pastoral, semi-agricultural and semi-pastoral areas of TAR, Sichuan, Qinghai, Xinjiang, Gansu, Ningxia, Inner Mongolia, Yunnan and Shaanxi provinces [2]. In addition, echinococcosis has been closely associated with poverty among farmers and herdsmen [9]. In 2016, TAR conducted an epidemiological survey with the assistance of 17 other Chinese provinces [2]. This survey showed that the echinococcosis epidemic is massive in the autonomous region [2]. Human cases of echinococcosis were detected in 74 counties making it the most affected province in the country. The detected prevalence rate of 1.66% makes it the most prevalent region in the world [2]. The average infection rates of cattle and dogs were 13.21% and 7.30%, respectively [2]. Dog infection was closely related to the prevalence of human echinococcosis [10]. Finally, the level of knowledge about the disease and prevention methods was generally low [2, 11].

In the present study, we investigated the prevalence of the two main species of medical interest, AE and CE, causing echinococcosis in all 692 townships in the autonomous region of Tibet.

Materials And Methods

Data source

Demographic data in the each of 692 townships of 74 endemic counties of TAR came from the population survey released by the Bureau of Statistics in 2018. Clinically diagnosed and confirmed cases of human echinococcosis were obtained from the annual report system of echinococcosis of Tibet Center for Disease Control and Prevention. The TAR census of echinococcosis was completed in 692 townships by the end of 2018. Human echinococcosis cases were identified by B-ultrasonography diagnostic examination following the official “Diagnostic criteria for echinococcosis” of China (WS 257–2006) (this standard is in line with that of WHO). Serological tests were provided to suspected patients for further serological enzyme-linked immunosorbent assay (ELISA) tests (Zhuhai Hai Tai Biopharmaceutical Co., Ltd. Zhuhai, China). Data were analyzed at the township level.

Classification of prevalence

According to official “Diagnostic criteria for echinococcosis” of China (WS 257–2006), cases of echinococcosis were classified into CE, AE, and co-infection with CE and AE. The calculation of prevalence for CE included the confirmed cases of CE and the co-infections with CE and AE. Similarly, the calculation of prevalence for AE comprised the confirmed cases of AE and the co-infection with CE and AE. The prevalence of human echinococcosis was classified according to the classification standards for endemic counties as reported in the 2019 edition of technical guidelines for echinococcosis control in China [12]. The characteristics of CE and AE were described and analyzed independently owing to differences in transmission cycle, preventive strategies, control measures, clinical manifestations, and treatment regimens. Each case was classified according to the epidemic status, from the highest to the lowest, to have a qualitative understanding of the epidemic status of echinococcosis in a given townships. Because the current epidemic areas of echinococcosis in China were only considered at the county level and no classification standard for township level was available, we classified the epidemic status of echinococcosis in all townships in TAR following the relevant standards of population prevalence index in the national technical plan for echinococcosis control (2019 Edition). The classification criteria were as follows: Class I epidemic townships: prevalence rate ≥1%; Class II epidemic townships: prevalence rate ≥0.1% and <1%; Class III epidemic townships: prevalence rate ≥0 and <0.1%; Class IV epidemic townships: townships with transmission circulation conditions and a prevalence rate equal to 0. Statistical analysis was performed using the SPSS 21.0 software package (IBM, Armonk, USA). ArcGIS 10.1 program (ESRI, Redlands, USA) was utilized for geographic mapping and prevalence analysis.

Spatial scan clustering

The spatial scan statistic is a method for analyzing data based on moving a scanning window across the geographical region of interest. This analysis can directly show the distribution of diseases and model the trend of diseases expansion [13-15]. In our study, a retrospective spatial scan analysis was performed using SaTScan V9.5 (Management Information Services, Maryland, USA). The spatial clustering scanning analysis was based on echinococcosis cases and exposed population in the 692 townships at the end of 2018. The discrete Poisson probability model was applied using a circular window for high-rate clusters. Areas of high incidence were scanned using a moving circular window dynamically varying in size. The maximum size of the spatial and temporal windows was defined as 25% of the total population of the entire area. Likelihood ratio tests and Monte Carlo randomization tests were used to evaluate the significance of the spatiotemporal clusters. Finally, the window with the maximum Log-likelihood ratio (LLR) value was defined as the primary cluster and other clusters with statistically significant LLRs were defined as secondary clusters. The relative risk (RR) and P-value of each cluster were obtained by Monte Carlo randomization tests. W randomization data sets were generated by Monte Carlo randomization tests. The maximum LLR were calculated in the same way as the observed data and were sorted from large to small. If the maximum LLR of the real data set is ranked R, then $P=R/(W+1)$. The higher the ranking, the smaller the P-value, indicating that the probability of random aggregation is smaller. The scan results were visualized using Arcgis10.1 software (ESRI, Redlands, USA).

Results

Prevalence of human echinococcosis

A total of 3,002,828 people were examined and 16,009 echinococcosis-positive patients were identified yielding a 0.53% prevalence rate. Among them, 14,398 (89.94%) CE cases, 942 (5.88%) AE cases and 137 (0.86%) with co infection of CE and AE were identified. A total of 532 cases (3.32%) were unclassified due to a lack of detailed classification records and failure to classify them as cystic or alveolar echinococcosis (Table 1).

The prevalence rate of global human echinococcosis at the township level ranged from 0% to 7.78% in TAR. The three townships with the highest prevalence were Axiu township (7.78%) in the Baqeen County of the Naqu Prefecture-level city with 216/2775 cases, Buta township (3.99%) in Deengqeen County with 130/3260 cases, and Meiyu township (3.90%) in the Zogang county of the Changdu Prefecture-level city with 201/5152 cases. All cases were distributed over 655 townships. However, 37 townships did not show any case of echinococcosis (Fig. 1, Table 2).

The prevalence of CE and AE in each township was further calculated. The overall prevalence rate of CE was 0.48%. All cases were distributed over 655 townships of 74 counties. The three townships with the highest prevalence for CE were Axiu township (6.16%) in Baqeen County of Naqu Prefecture-level city with 171/2775 cases, Meiyu township (3.90%) in Zogang county of Changdu Prefecture-level city with 201/5152 cases, and Baixiong township (3.33%) in Nierong County of Naqu Prefecture-level city with 144/4325 cases (Fig. 2, Table 3). The overall prevalence rate of AE was 0.04%, and the 1079 recorded cases were distributed over 143 townships from 32 counties. The three townships with the highest prevalence for

AE were Axiu township with 46/2775 cases (1.66%), Baqeen township with 35/2300 cases (1.52%), both in the Baqeen County of the Naqu Prefecture-level city, and Buta township in Deengqeen County with 34/3260 cases (1.04%) (Fig. 3, Table 4).

Table 1 Epidemic status of human echinococcosis in TAR, 2018.

Prefecture / Prefecture-level city (municipal level)	Number of endemic counties	Population of endemic areas	All cases					Prevalence rate (1/10000)	Prevalence rate of CE (1/10000)	Prevalence rate of AE (1/10000)
			Total cases	CE	AE	Co infection of CE and AE cases	Unclassified cases			
Lhasa	8	477,334	958	932	3	1	22	20.07	19.55	0.08
Changdu	11	723,005	2,856	2,266	312	54	224	39.50	32.09	5.06
Shannan	12	306,813	1,295	1,259	1	7	28	42.21	41.26	0.26
Shigatse	18	772,334	3,147	3,025	10	12	90	40.75	39.32	0.28
Naqu	11	478,172	6,019	5,273	603	44	99	125.88	111.19	13.53
Ali	7	103,155	1,075	986	3	17	69	104.21	97.23	1.94
Linzhi	7	141,995	659	647	10	2	0	46.41	45.71	0.85
Total	74	3,002,828	16,009	14,398	942	137	532	53.31	48.40	3.59

Classification of the prevalence of human echinococcosis in China

The epidemic level of 692 townships in TAR ranged as follows: 127 (18.35%) were Class I epidemic townships; 446 (64.45%) were Class II epidemic townships; 82 (11.85%) were Class III epidemic townships; and 37 (5.35%) were Class IV epidemic townships (Figure 1, Table 2). The classification of CE and AE was further analyzed according to similar classification criteria. Among the 692 townships in TAR, 655 (94.55%) displayed CE cases with 116 (16.76%) Class I epidemic townships, 445 (64.31%) Class II epidemic townships, 94 (13.58%) Class III epidemic townships and 37 (5.35%) Class IV epidemic townships (Fig. 2, Table 3). With respect to AE, 143 out of 692 townships (20.7%) townships displayed AE cases with 3 (0.43%) Class I epidemic townships, 53 (7.66%) Class II epidemic townships, 87 (12.57%) Class III epidemic townships and 549 (79.34%) Class IV epidemic townships (Fig. 3, Table 4).

Table 2 Classification of the prevalence of human echinococcosis at township level in TAR,2018

District/ Prefecture-level city (municipal level)	Total number of towns	$P \geq 100/10000$		$10/10000 \leq P < 100/10000$		$0 < P < 10/10000$		$P = 0$	
		Number of towns	constituent ratio (%)	Number of towns	Constituent ratio (%)	Number of towns	Constituent ratio (%)	Number of towns	Constituent ratio (%)
Lhasa	65	1	1.54	39	60.00	22	33.85	3	4.62
Changdu	138	11	7.97	95	68.84	24	17.39	8	5.80
Shannan	82	8	9.76	46	56.10	14	17.07	14	17.07
Shigatse	203	24	11.82	157	77.34	19	9.36	3	1.48
Naqu	114	66	57.89	46	40.35	2	1.75	0	0.00
Ali	37	15	40.54	22	59.46	0	0.00	0	0.00
Linzhi	53	2	3.77	41	77.36	1	1.89	9	16.98
Total	692	127	18.35	446	64.45	82	11.85	37	5.35

P: Prevalence rate

Table3. Classification of the prevalence of human CE at township level in TAR,2018

District/ Prefecture-level city (municipal level)	Total number of towns	*P*≥ 100/10000		10/10000 ≤*P*< 100/10000		0 <*P*< 10/10000		*P* = 0	
		Number of counties	constituent ratio (%)	Number of counties	Constituent ratio (%)	Number of counties	Constituent ratio (%)	Number of counties	Constituent ratio (%)
Lhasa	65	1	1.54	37	56.92	24	36.92	3	4.62
Changdu	138	9	6.52	90	65.22	31	22.46	8	5.80
Shannan	82	7	8.54	46	56.10	15	18.29	14	17.07
Shigatse	203	24	11.82	158	77.83	18	8.87	3	1.48
Naqu	114	61	53.51	49	42.98	4	3.51	0	0.00
Ali	37	12	32.43	25	67.57	0	0.00	0	0.00
Linzhi	53	2	3.77	40	75.47	2	3.77	9	16.98
Total	692	116	16.76	445	64.31	94	13.58	37	5.35

P: Prevalence rate

Table4. Classification of the prevalence of human AE at township level in TAR, 2018

District/ Prefecture-level city (municipal level)	Total number of towns	*P*≥ 100/10000		10/10000 ≤*P*< 100/10000		0 <*P*< 10/10000		*P* = 0	
		Number of counties	constituent ratio (%)	Number of counties	Constituent ratio (%)	Number of counties	Constituent ratio (%)	Number of counties	Constituent ratio (%)
Lhasa	65	0	0.00	0	0.00	2	3.08	63	96.92
Changdu	138	1	0.72	12	8.70	26	18.84	99	71.74
Shannan	82	0	0.00	0	0.00	6	7.32	76	92.68
Shigatse	203	0	0.00	4	1.97	10	4.93	189	93.10
Naqu	114	2	1.75	33	28.95	33	28.95	46	40.35
Ali	37	0	0.00	3	8.11	3	8.11	31	83.78
Linzhi	53	0	0.00	1	1.89	7	13.21	45	84.91
Total	692	3	0.43	53	7.66	87	12.57	549	79.34

P: Prevalence rate

Spatial distribution and identification of clusters of human echinococcosis

Spatial clustering of human echinococcosis

Based on the echinococcosis cases and exposed population in the 692 townships at the end of 2018, spatial clustering scanning analysis was performed to explore key epidemic clusters of echinococcosis in TAR.

CE displayed one primary cluster and seven secondary clusters. The primary cluster was centered at 36°10’ North and 89°39’ East with a radius of 632.91 km, covering 88 townships in 12 counties. It was dominated by Naqu Prefecture-level city, with 82 townships in all the 10 epidemic counties (Nagqum, BIrum, Nyainrong, Amdo, Xainza, Sog, Bangoin, Baqeen, Nyima, Shuanghu), followed by Damxung in Lhasa city and Geerzee in the Ali Prefecture. This cluster involved 356,976 exposed persons, with a risk of infection 3.35 times higher than in other areas (P<0.01). It is the key area for the prevention and control of CE in TAR. Extent and risk status of the secondary clusters are shown in Figure 4 and Table 5. A relatively important secondary cluster area was centered at 30°11’ North and 92°86’ East with a radius of 103.61km, covering 27 towns from 7 counties, including Maizhokunggar in Lhasa city, Sangri and Gyaca of Shannan Prefecture-level city, Nagqu and Jiali in Naqu Prefecture-level city, and Nyingchi and Gongbo’gyamda in Linzhi Prefecture-level city. The RR value of this cluster was 1.77 (P<0.01). Another important secondary cluster area was centered at 28°75’ North and 84°83’ East with a radius of 151.51 km, covering 25 towns from 6 counties. The RR value of this cluster was 1.71 (P<0.01). The remaining secondary clusters were relatively small, involving only a few townships. These gathering areas exist sporadically. We suggest that the relevant departments of the epidemic counties to which these towns belong pay more attention to the epidemic towns in the gathering areas, and strengthen the monitoring of echinococcosis and patient screening in these towns. If the epidemic area involves the junction area of multiple epidemic counties, relevant epidemic counties need to cooperate to carry out prevention and control work together.

The spatial clustering scan of AE showed the presence of one primary cluster and two secondary clusters (Figure 5 and Table 6). The primary cluster was centered at 32°49’ North and 94°54’ East, with Gongri township in Baqeen county as the center and a radius of 157.23 km, covering 38 townships in 6 counties, including Deengqeen and Banbar in Changdu Prefecture-level city and Biru, Nyainrong, Sog, and Baqeen in Naqu Prefecture-level city. The RR value of this cluster area was as high as 21.04 times that of the surrounding area (P<0.01).

One secondary cluster was centered on 31°56’ North and 89°52’ East, with Mendang township inBangoin county at the center and a radius of 158.35 km, covering 22 townships in 4 counties in Naqu Prefecture-level city, including 10 townships in Bangoin county，7 townships in Xainza county，1 township in Suanghu county and 1 in Amdo county. The RR value of this cluster area was 8.02. The risk of AE transmission in this aggregation area is significantly higher than that in the surrounding area.

The other secondary cluster was centered on 30°34’ North and 93°04’ East, with Niangpu township in Gongbo' gyamda as the center and a radius of 93.93 km, covering 20 townships in 4 counties, including 8 townships in Gongbo' gyamda, 10 townships in Jiali county，1 township in MaizhoKunggar county and 1 in Banbar county. The RR value of this cluster area was 2.58 (P<0.01).

The spatial distribution of AE is more limited, with only three aggregation areas, but the epidemic risk is relatively high, especially in the primary cluster area, suggesting that these aggregation areas require a strengthening of prevention and control.

Table 5 Spatial clustering analysis of human CE in TAR,2018

Cluster	The center point		Scope		Radius （km）	Exposed population	Number of cases	Expected cases	RR	LLR	P-value
	latitude	longitude	center town	Number of towns							
Primary cluster	36.099499 N	89.386002 E	Sewu town of Amdo county	88	632.91	356,976	4,494	1,716	3.35	1,876.79	＜0.01
Secondary cluster1	30.110399 N	92.856300 E	Jinda town of Gongbo' gyamda	27	103.61	98,424	815	473	1.77	105.65	＜0.01
Secondary cluster2	28.750000 N	84.828003 E	Gongdang town of Gyirong county	25	151.51	53,153	431	255	1.71	51.00	＜0.01
Minor secondary cluster1	28.343500 N	89.611000 E	Samada town of Kangmar county	9	48.71	18,832	219	91	2.44	65.61	＜0.01
Minor secondary cluster2	30.401300 N	98.491096 E	Latuo town of Konjo county	7	37.23	22,215	233	107	2.20	56.17	＜0.01
Minor secondary cluster3	28.755199 N	91.116699 E	Gongbuxue town of Nagarzee county	3	30.80	16,538	371	79	4.76	283.07	＜0.01
Minor secondary cluster4	29.071199 N	90.505997 E	Kalong town of Nagarzee county	4	20.62	8,920	98	43	2.29	26.01	＜0.01
Minor secondary cluster5	28.648899 N	97.541801 E	Zhuwagen town of Zayuu county	2	47.02	6,316	73	30	2.41	21.48	＜0.01
Minor secondary cluster6	31.132999 N	98.431099 E	Niangxi town of Jomda county	2	21.23	10,820	104	58	1.80	14.96	＜0.05

Table 6 Spatial clustering analysis of human AE in TAR,2018

Cluster	The center point		Scope		Radius (km)	Exposed population	Number of cases	Expected cases	RR	LLR	P-value
	latitude	longitude	center town	Number of towns							
Primary cluster	32.494598 N	94.544701 E	Gongri town of Baqeen county	38	157.23	194,212	557	61	21.04	916.09	<0.01
Secondary cluster1	31.559900 N	89.523499 E	Mendang town of Bangoin county	22	158.35	70,604	152	22	8.02	173.05	<0.01
Secondary cluster2	30.342400 N	93.036400 E	Niangpu town of Gongbo' gyamda	20	93.93	69,309	54	22	2.58	17.56	<0.01

Discussion

TAR is the province with highest prevalence of echinococcosis in China and even worldwide [2]. In 2016, a sampling survey was conducted and all the 74 counties under TAR jurisdiction were identified as epidemic counties. Considering the severe epidemic situation and the serious harm caused by echinococcosis, a general survey of human echinococcosis was carried out in 2017 with the assistance of other provinces to achieve early detection and diagnosis. All patients with echinococcosis were identified, and with their informed consent, were treated with albendazole. Some patients were recommended for surgical treatment, and part of the surgical expenses was subsidized. Therefore, data on patients with echinococcosis collected in this study were representative of the burden and spatial distribution and epidemic characteristics of echinococcosis in TAR. In 2018, comprehensive prevention and control measures of echinococcosis were carried out in the 74 epidemic counties. However, this was largely offset by the complex natural environment, harsh climate conditions, inadequate infrastructure, poor agricultural practices and animal husbandry, and lagging social and economic development, coupled with delayed prevention and disease control, difficult living and working conditions, outdated medical and health facilities and equipment, lack of vehicules suitable for the complex road conditions, sparsely populated areas, large service radius, and lack of professional and technical personnel [10, 16–19]. Therefore, determining priority areas in TAR is of primary significance for a successful prevention and control of echinococcosis and rational allocation of health resources.

Since the launch of the National Echinococcosis Prevention and Control Project in 2008, the county has always been considered the relevant level to define the epidemic risk and allocate health resources [20]. However, the epidemic level between epidemic townships varies significantly within the same county, with different epidemic characteristics. Therefore, scaling down the epidemic region from the county level to that of the township level was both urgent and required to appropriately allocate health resources and significantly improve the efficiency of prevention and control measures. This is a first important conclusion from this work: relevant administrative departments should focus on townships with high prevalence and primary cluster areas when allocating health resources.

The risk of transmission of echinococcosis was assessed globally for human echinococcosis as it corresponds to the data considered by health authorities. However, the breakdown of data between AE and CE provides a major and very useful insight in the dynamic of the disease and in its relative distribution depending on the pathogen. CE and AE have different transmission cycles and epidemic characteristics, and require different prevention and control measures and strategies. Therefore, a careful analysis of the relative distribution of CE and AE is necessary to design relevant control measures, adapt them to local conditions, classify guidance, and improve efficiency. In China, whether it is *E. granulosus* or *E. multilocularis*, the primary definitive host is the dog [21–22]. Therefore, monitoring the number of dogs and regularly deworming infected dogs remain the most important prevention and control approach [23]. To prevent and control CE in TAR, effective monitoring of dogs was recommended. Each dog must be dewormed monthly in class I and class II epidemic townships. In addition, health education and people awareness should be intensified. In townships with insufficient health workers, rural cadres and volunteers should be actively recruited and trained to promote the implementation of this measure. In class III townships, the frequency of deworming can be reduced to once every three months. The deworming of dogs during the slaughtering season of intermediate hosts such as yaks and sheep and the strengthening of health education, people awareness and slaughter management procedures must be implemented. Moreover, the intensification of health education and awareness of residents, as well as echinococcosis monitoring are suggested in class IV epidemic townships.

Our findings demonstrate that the prevalence of AE in TAR was relatively lower than that of CE, and its distribution was relatively limited. However, given the heavy disease burden on AE patients, the 56 epidemic townships of class I and class II of AE and the three AE cluster areas should be considered a priority. In addition to strengthening the control of infection sources and health education measures, it is necessary to increase the surveillance of small rodents and lagomorphs (alternative intermediate hosts of *E. multilocularis*), strictly control the number of stray dogs, and strengthen the screening of AE patients in these townships [24].

In conclusion, the prevention and control of echinococcosis in TAR are currently far from successful. Our findings may provide a scientific reference for the relevant administrative departments in TAR to appropriately adjust prevention and control strategies according to the different epidemic characteristics and epidemic degrees. The population should be actively mobilized to participate in the prevention and control of echinococcosis. Implementing prevention and control approaches well adapted to the local reality and with high economic effects should be a priority in order to significantly reduce the disease burden and efficiently control echinococcosis epidemics. There were 532 unclassified cases in 93 townships, and in some townships it was true for all cases. This might seriously affect the management and prevention of echinococcosis and this issue should be addressed as a priority.

This study has some limitations. Firstly, as a chronic infectious parasitic disease, echinococcosis is characterized by occult onset and long incubation period. Therefore, although the spatial distribution of prevalence can reflect the disease burden and historical risk of echinococcosis in different areas, it cannot sensitively reflect the current infection risks. The prevalence of human echinococcosis can be affected by several factors. With the implementation of therapy, the number of cases will change and they might no longer be representative of the risk of transmission. Therefore, the dog infection rate should be monitored at the township level on a routine basis to better reflect environmental infection, locate epidemic key areas and assess risks. Secondly, populations were screened for hydatid lesions using portable B-mode ultrasonography. Only abdominal lesions of CE and AE could thus be detected, whereas lesions in the lungs, brain, and other organs outside the abdomen could not be investigated. Furthermore, most patients were identified by screening or clinical examination, but a part of the infected population was not identified. The prevalence determined in the survey may thus be underestimated. Finally, for 532 (3.3%) confirmed patients, there were no clear classification (CE or AE) and no clear B-mode ultrasound images, which may lead to failure in identification and treatment. This may not only affect the analysis but also the follow-up and treatment of patients. B-mode ultrasound technicians should be trained at the township level. Quality control and supervision of the integrity of patient records and materials should also be improved.

Conclusions

This study explored the prevalence of echinococcosis and identified spatial distribution characteristics in the human population at the township level in TAR. Human echinococcosis prevalence in TAR remains high and worrisome with a wide geographic distribution of the disease. About 95% of the villages and towns displayed echinococcosis cases. The prevalence of human echinococcosis was clustered in space and the specific clustering areas were identified. Therefore, future studies should formulate more advanced prevention and control strategies to efficiently prevent and control echinococcosis in TAR at a more accurate level.

Abbreviations

AE: Alveolar echinococcosis; CE: Cystic echinococcosis; TAR: Tibet Autonomous Region; LLR: Log-likelihood ratio; RR: Relative risk

Declarations

Data Availability Statement

All data analyzed in the present study are included in the article material. Any inquiries can be directed to the corresponding author.

Ethics Statement and consent to participate

This survey was approved by the Ethics Review Committee of the National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention (No. 20160810). These activities are all within the scope of the national project for echinococcosis control. All participants were informed of the content and purpose of the investigation and examination, potential complications, consequences and benefits before examination. Those who agreed to participate signed a written informed consent form. All the participants were given feedback. All patients with the diagnosis of echinococcosis gave written agreement to participate and were provided with free drug treatment or a subsidized cost of surgery.

Consent for publication

Not applicable.

Authors' contributions

LW designed the study, contributed to data collection and screening, verification and analysis, charting and writing. GQ and HP contributed to data collection, MQ and ZL participated in data analysis and charting. RF and LG participated in spatial analysis, review and supervised the study. RF and LG revised the manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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Tables

Table 7 is available as download in the Supplemental Files section.

Figures

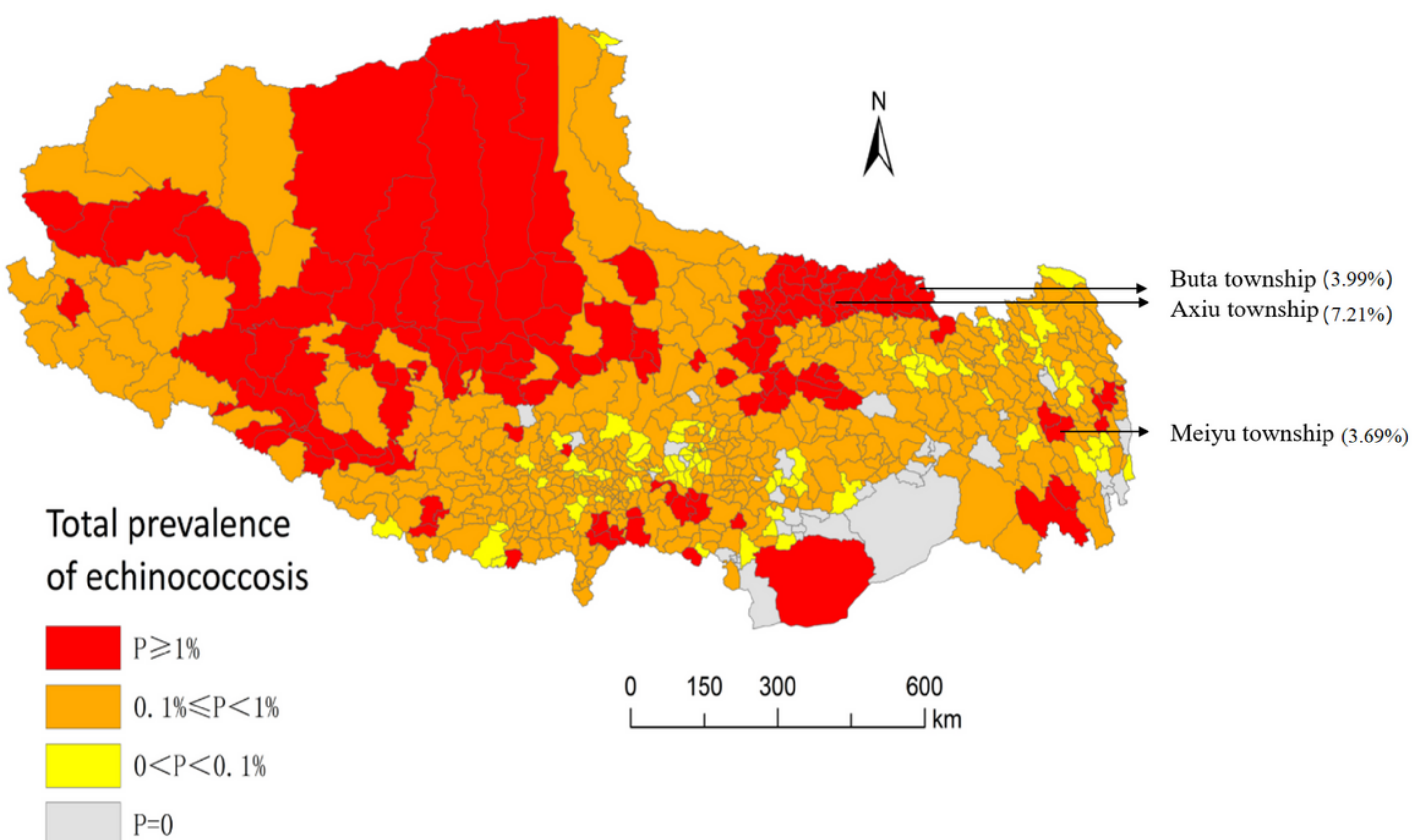

Figure 1

Spatial distribution of human echinococcosis

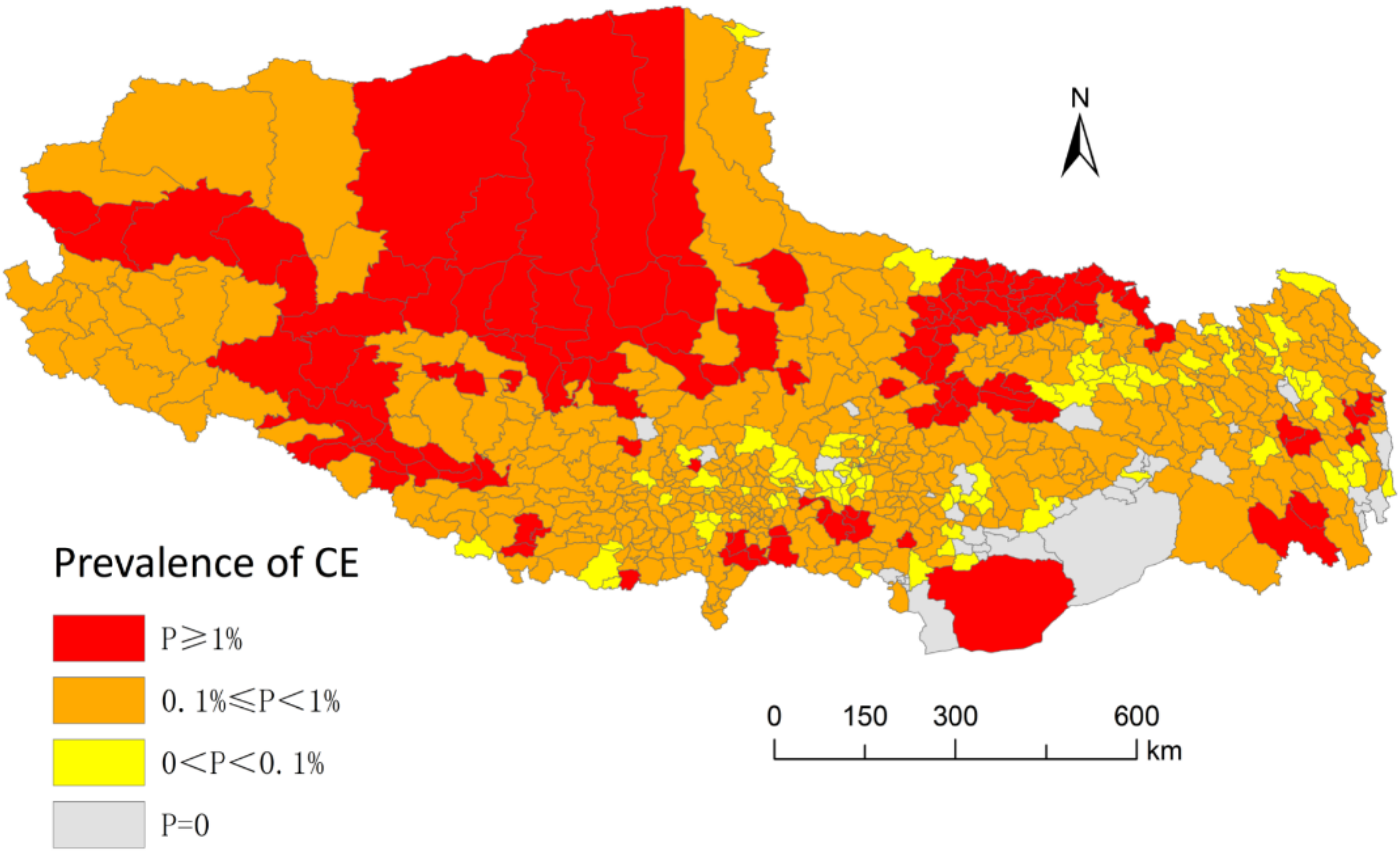

Figure 2

Spatial distribution of human CE

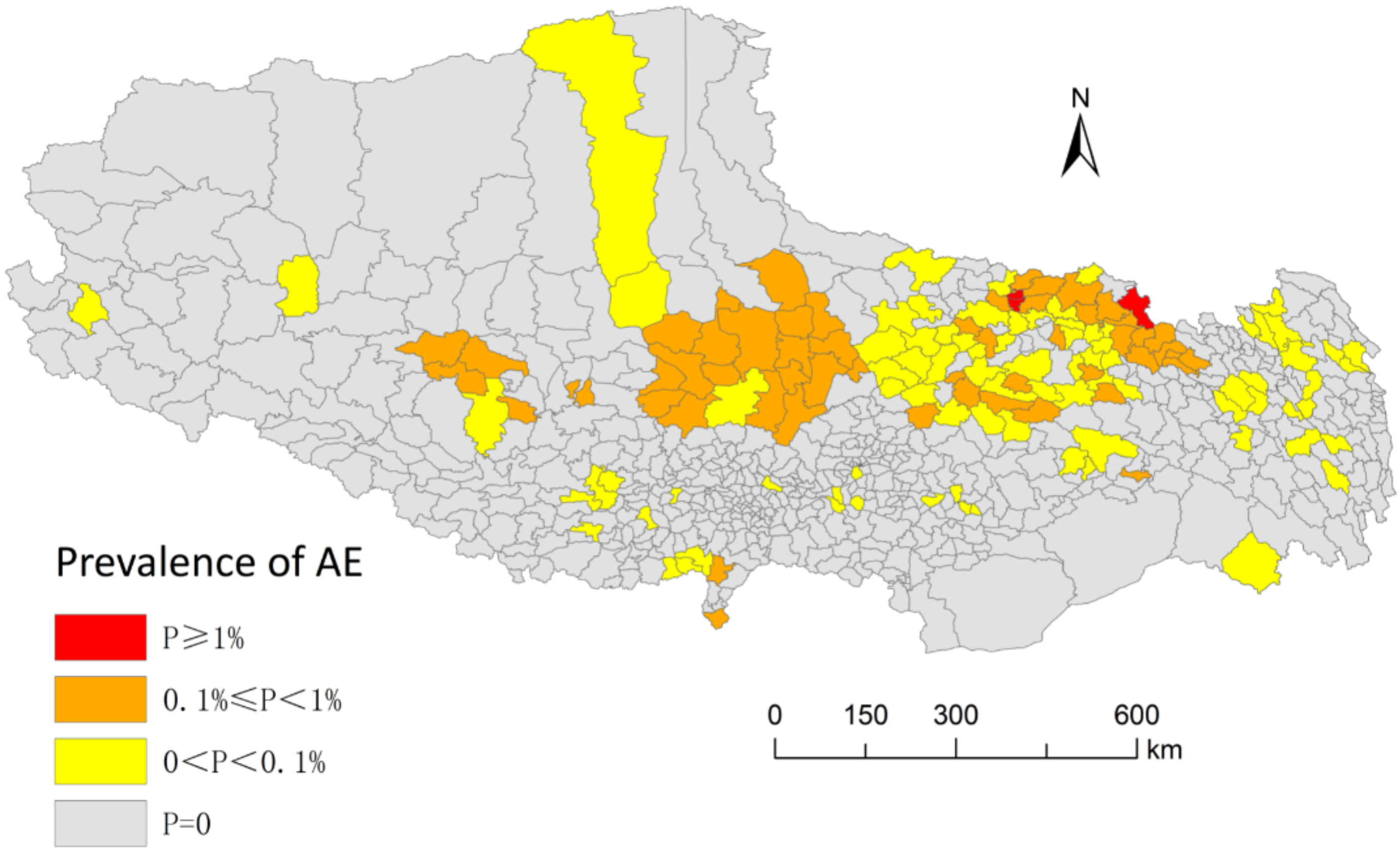

Figure 3

Spatial distribution of human AE

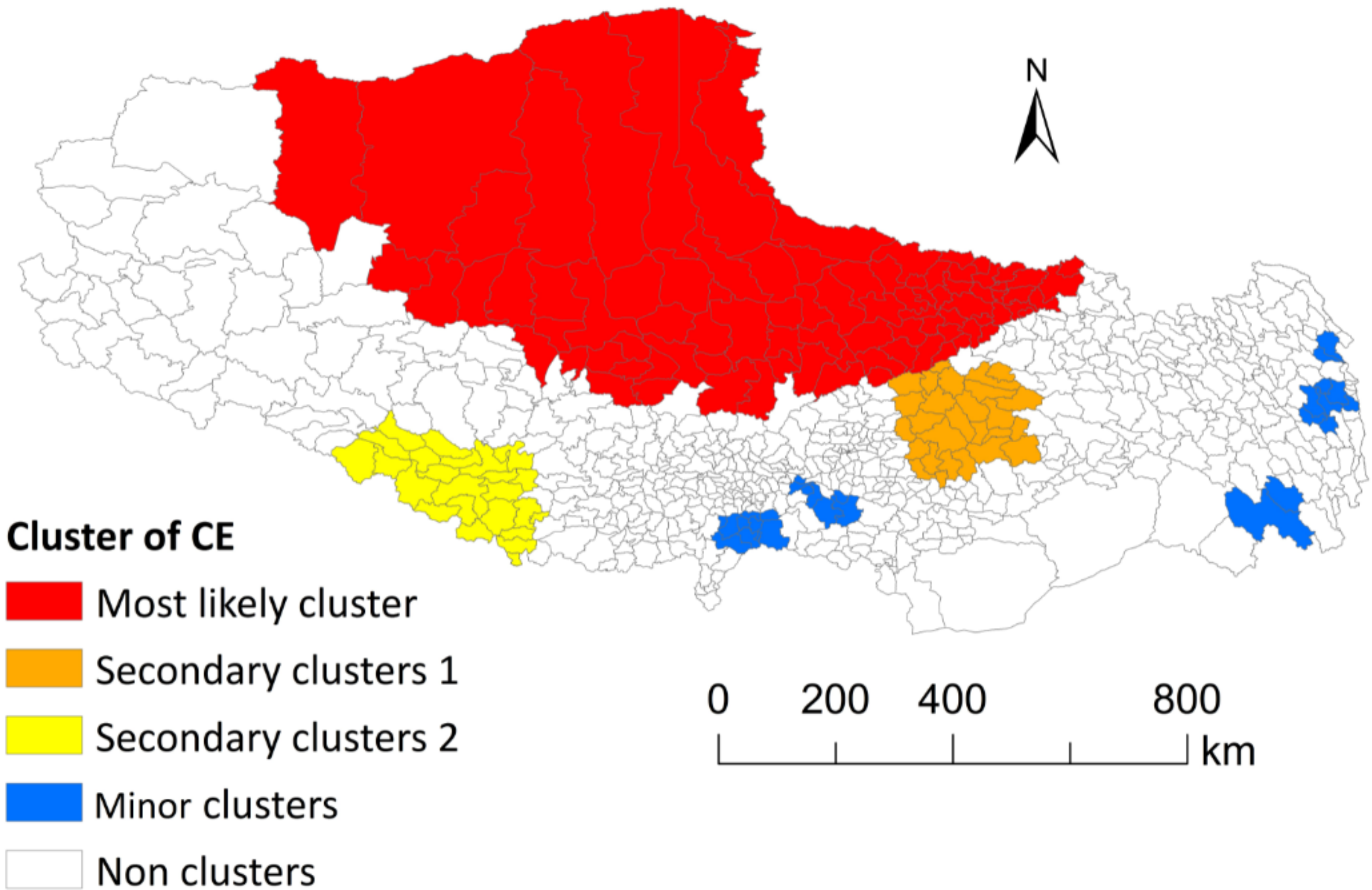

Figure 4

SaTScan spatial clustering analysis of human CE

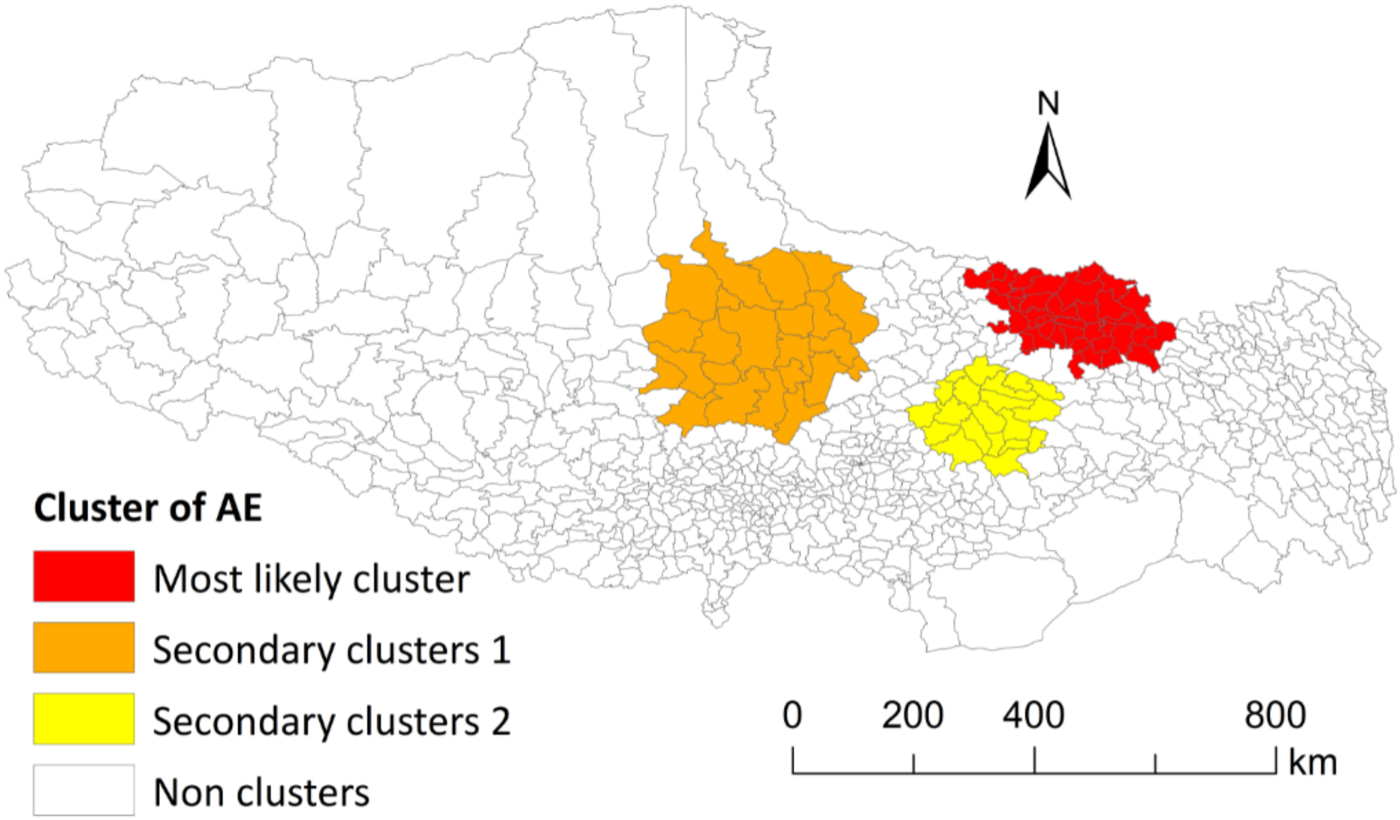

Figure 5

SaTScan spatial clustering analysis of human AE

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