ORIGINAL ARTICLE

Spatial Epidemiology of tuberculosis in Ardabil Province: based on Geographical Information System

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ABSTRACT

Background: Tuberculosis is an infectious disease that causes more than three million deaths annually worldwide.
Aim: The present study was designed to distribution and of high-risk regions by using of GIS.
Methods: This descriptive cross-sectional study was determined the distribution of all tuberculosis patients in Ardabil Province 2007 - 2018.All patient's data was collected from Central Diseases Control (CDC) of Ardabil University of Medical Sciences.ArcMap-10.4.1, Moran Index and IDW Interpolation were used to analyse this distribution and its relationship with the contributing factors.
Results: A total of 1619 cases of tuberculosis had been reported that 52% female and 48% male. The mean incidence rate of the disease was 13 per 100000. The incidence rate was higher in the northern regions of the province compared to its southern regions. Assessments based on the Moran index showed a positive spatial autocorrelation between tuberculosis and location and the disease distribution was in cluster form rather than random. The center and north of Ardabil province were identified as the two hot spots of TB incidence.
Conclusions: The main factors potentially contributing to the increased incidence of TB in these regions including the moderate climate with a relative air stagnation in the north of the province, i.e. the areas neighbouring Azerbaijan Republic, with the constant commute of travellers through the border and the relatively poor and dense immigrant population in the suburbs of Ardabil as the provincial capital.
Keywords: Tuberculosis, Spatial Distribution, GIS, Epidemiology, Iran

INTRODUCTION

Mycobacterium tuberculosis is the main cause of tuberculosis that claims more than three million lives worldwide every year. Around a third of the world's population are infected with this bacterium, including 5% to 10% who develop active tuberculosis[1]. Every year, about 9.4 million people develop active tuberculosis and around 1.5 million of them lose their lives to this disease[2,3]. The incidence of treatment-resistant tuberculosis and tuberculosis in HIV patients has become a new cause of concern throughout the world[4].Since affected humans are the main reservoirs for spreading the disease, the most important measure to control tuberculosis is to identify cases of pulmonary tuberculosis (especially those with positive sputum smear) across the society and treat them immediately in order to quickly eradicate the center of bacterial dispersion; consequently, identifying the pattern of disease dispersion may contribute to the development of disease control policies[5]. The Geographical Information System (GIS) is a powerful and efficient tool for revealing the relationship between disease dispersion and its geographical location[6]. The use of this system has been growing in recent years[7] and Ardabil Province has been the focus of some studies conducted using GIS to assess diseases such as visceral leishmaniasis and scorpion and snake bite[8,9,10] .This software can help identify the centers of bacterial concentration and their contributing geographical factors by accurately mapping the disease dispersion regions and help in the management of epidemics of communicable diseases, such as TB, malaria and HIV infection[12-13]. The present study was conducted to investigate how TB is dispersed and determine of hot / cold spots of TB in Ardabil Province of Iran over the last 12 years.

SUBJECTS AND METHODS

Study area: Ardabil province is located at 37°8'48"-39°42'47" northern latitude and 47°22'23"-48°53'41" eastern longitude with over 1° 51' between its northern most and southern most points longitudinally in the northwestern corner of Iran (Figure1). This province shares political borders with Azerbaijan Republic from the north, Guilan Province from the east, East Azarbaijan Province from the west and Zanjan Province from the south. The most prominent geographical feature of Ardabil province is its mountainous form and significant altitude difference from the north to the south, such that the mean altitudes of Parsabad plain and Khalkhal mid-mountain valley reach 100 and over 1800 m, respectively. This feature has moderated the climate violence as geographical latitude increases from the south to the north due to the reduced altitude, such that the north of the province (Parsabad plain) enjoys a more moderate climate.
Data collection: The present descriptive cross-sectional epidemiological study was conducted in Ardabil province after approval by the university's biological research ethics committee. The data of all TB patients between April 2007 and March 2017 were collected from the Tuberculosis Care System in Ardabil province. The data of TB patients from every city, district and village, including their addresses in

the medical records, and also their geographical coordinates were extracted and stored in Arcmap-10.4.1 as a Shape file, and their dispersion map was also drawn.

Data analysis: The Moran index was used to determine spatial autocorrelation, and interpolation analysis to find the high-risk areas. The climate maps (isothermal lines) were prepared using the data from the synoptic stations of Ardabil province. Data were analyzed in SPSS-25 using descriptive and analytical statistical tests (Chi-square test and T-test). The patients' data remained entirely confidential.

RESULTS

A total of 1619 TB patients underwent treatment in Ardabil province over these 12 years. The incidence rate of TB was between 11 and 15 per 100,000 of the population. In terms of location, Parsabad had the highest rate of TB incidence (20 per 100,000 of the population). A total of 52% of those affected were women and 48% were men and their mean age was 41.38±19.8 and 45.06±19.88 years, respectively, and the youngest of them was two months old and the oldest 91 years. There was a significant age difference between men and women in terms of developing TB (P=0.001). There was also a significant difference between the mean age of the patients in different years of the study (P<0.05), such that the mean age at the time of developing TB increased from 38.5 years in 2007 to 44.5 years in 2018 (Table 1).

The mean weight of the patients was 60.09±15.05 Kg, and there was a significant difference between women (57.96±14.5 Kg) and men (62.46±14.96 Kg) in terms of mean weight (P=0.001). The patients with pulmonary TB (57.01±13.5 Kg) weighed less than the patients with non-pulmonary TB (64.5±17.1 Kg), and the difference between them was significant.

Of the 854 female patients studied, 78.10% were married and 21.90% were single, and of the 765 male patients studied, 79% were married and 21% were single, and no significant relationship was found between the disease and marital status or gender (P=0.67). Comparing the incidence of TB in married and single patients from different cities, however, showed that the incidence of TB was significantly higher in married people compared to singles in all the cities of Ardabil province (P=0.005). A total of 63% of all the patients had pulmonary TB and 37% non-pulmonary TB, and the reported cases of non-pulmonary TB increased significantly over these 12 years, such that the prevalence of pulmonary TB reduced from 67% in 2007 to 47% in 2018 (Figure 4). The incidence of pulmonary TB was significantly lower in women compared to men (P=0.001), such that 67% of men and 59% of women had pulmonary TB. Moreover, 60% of the patients who lived in cities, 67% of those who lived in villages and 72% of those in nomadic tribes had pulmonary TB, and this difference was significant (P=0.001).

Spatial analysis: In the present study, 37% of the patients were from rural areas, 61% from urban areas and 2% from nomadic tribes (Figure 4). The largest population of urban TB patients lived in Ardabil (58%), rural TB patients in Parsabad (33%) and nomad TB patients (54%) in Bilehsavar. The results of the spatial distribution of pulmonary and non-pulmonary TB in Ardabil province showed that the disease dispersion was much higher in the provincial center and the north of the province than its southern regions, particularly in regions bordering Azerbaijan Republic (Figure 2). The rural distribution of TB was also much higher in the northern regions compared to the central and southern regions, and the greatest point-spatial distribution was reported in the north of the province along Azerbaijan borders in Parsabad, Bilehsavar and Germi towns. The results of the spatial autocorrelation of TB in Ardabil province showed a Moran index of 0.495, and since this index is greater than zero, a positive spatial autocorrelation is indicated in cluster form (P=0.002) (Figure 3).

Determining the high-risk and low-risk regions of the disease using interpolation analysis (inverse distance weighting) revealed a high-risk region with over 600 cases over 12 years in the center of the province and also a region with over 300 cases in the north of the province, bordering Azerbaijan Republic, and these two are high-risk regions of the province (Figure 4). The location and temperature analysis of the data showed that the incidence of pulmonary TB is higher than extra-pulmonary TB in the northern regions of the province, and the incidence of extra-pulmonary TB increases as we get closer to the cooler and cold southern and central regions, and this phenomenon is in favor of the more active circulation of the disease agent in the northern regions of the province (Figure 4).

Table 1. Cumulative incidence rates for tuberculosis patients in 12 years

County	Mean number of patients over 12 years	Total number of patients over 12 years/Mean population of the related district:	(percentage of the total number of patients)	Accumulative incidence rate per 100,000 of the population over 12 years	Average annual incidence
Pars Abad	31.08	373/173182	0.21%	201.60	16.8
Germi	11.16	134/84267	:0.08	154.68	12.89
Bilehsavar	7.5	93/53768	0.054%	145.06	12.08
Ardebil	59.95	698/564365	:41%	128.91	10.74
Mesh kin Shahr	13.2	158/15156	:0.09	99.75	8.31
Nir	5	41/46682	0.024	87.82	7.31
Sarein	11	91/126009	0.053	72.21	6.01
Namin	48	4/61333	0.0025	65.21	5.43
Khalkhal	4.33	52/92332	0.03%	58.61	4.88
Kousar	1.33	16/26198	0.009%	53.43	4.45

Table 2: The percentage of wind availability and air stagnation in select stations of Ardabil province (2004-2018)

Station	Percentage of gentle breeze	Wind velocity (m/s)	Air flow velocity (m/s)	Percentage of wind availability
Ardabil	43.49	6.95	3.9	56.51
Parsabad	58.38	3.84	1.6	41.62
Meshkinshahr	77.37	7.29	1.6	22.63
Khalkhal	58.58	4.11	1.7	41.42

Fig. 1. Geographical location of Ardabil province in northwestern of Iran

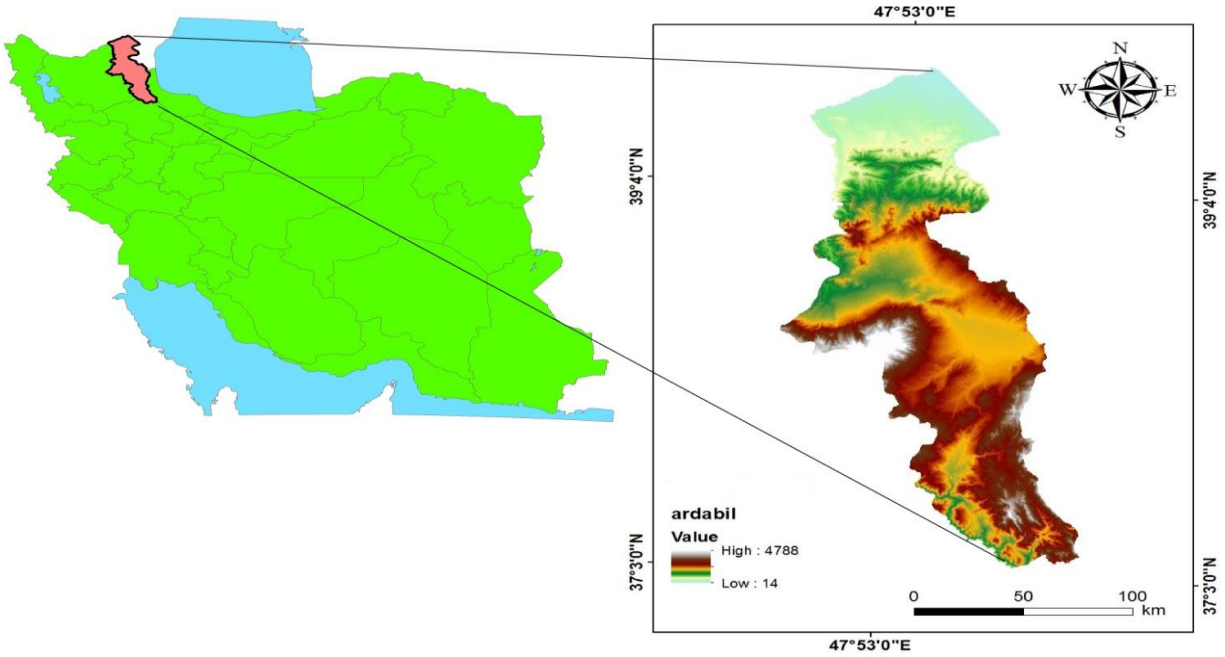


Fig.2: The spatial distribution of TB in Ardabil province based on altitude from the sea level (2007-2018)

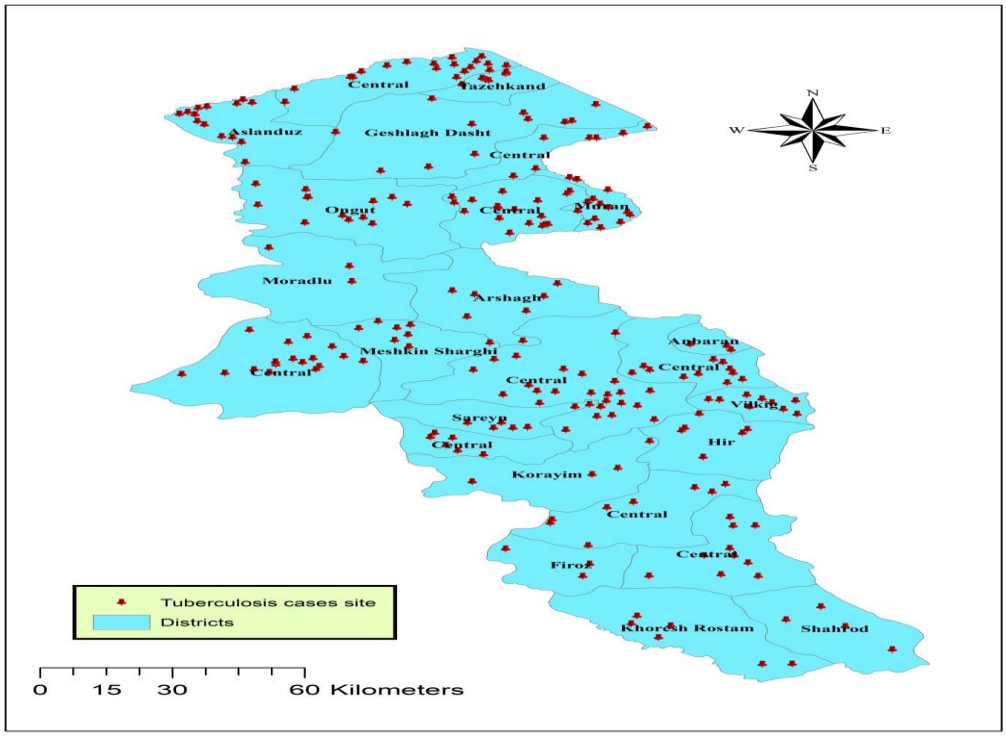


Fig. 3: The results of analyzing the Moran index for determining the spatial autocorrelation of TB in Ardabil province.

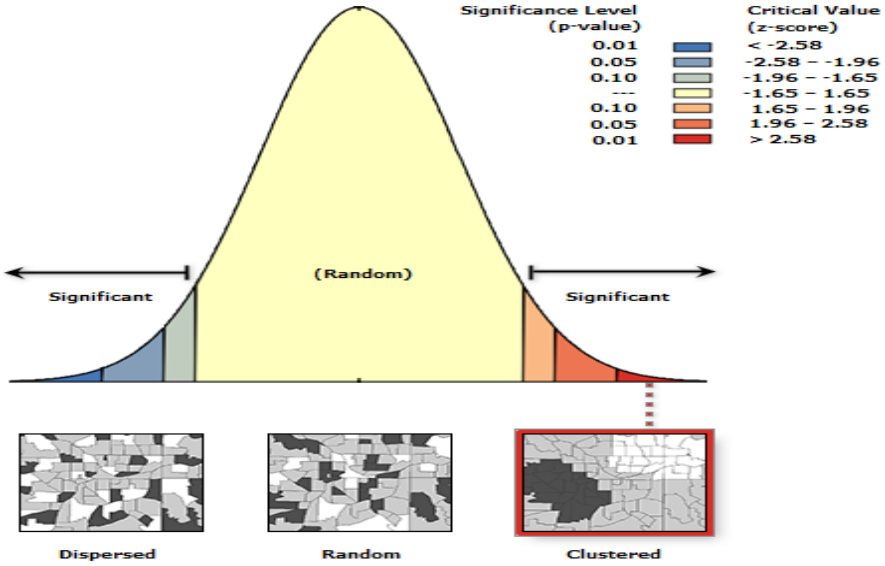
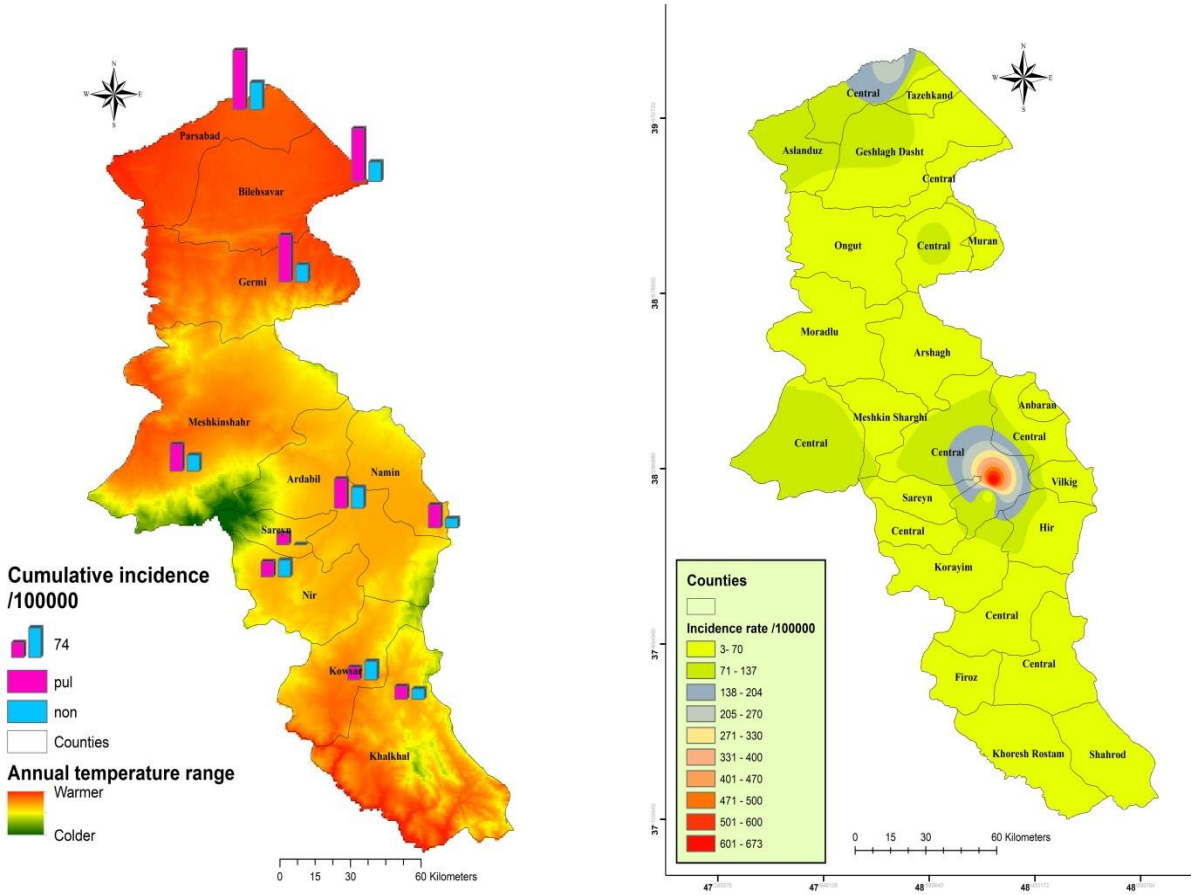


Fig. 4. The results of the IDW interpolation analysis of TB (on the right) and the incidence rates of pulmonary and extra-pulmonary TB based on the range of temperature (on the left) in Ardabil province from 2007 to 2018.



DISCUSSION

The incidence rate of TB in Ardabil province is 13 per 100,000 of the population on average. This rate varies in other parts of the world from five per 100,000 in Norway to 198 in Tajikistan[14]. Previous studies conducted in Iran have shown that the incidence of TB has reduced from 142 cases per 100,000 of the population in 1963 to 13.5 cases per 100,000 in 2008, but this trend has been unstable and fluctuating[15] Like in other provinces of Iran, the incidence of pulmonary TB has been greater than extra-pulmonary TB in Ardabil province, but the rate of pulmonary TB in Ardabil province has reduced in recent years and the rate of extra-pulmonary TB has instead grown, especially in the south of the province. Studies conducted by Khazei in Zabol and Tabatabaee in Guilan also obtained similar results[16-17]. The increase in the rate of extra-pulmonary TB may be attributed to the greater diagnostic power for this type of TB due to the increase in the number of specialists and medical equipment available for it or in the number of people with immunodeficiency, such as kidney or liver transplant patients and those with various rheumatic disorders treated with immunosuppressive medications. The patients' mean age was 43.11±19.2 years. This age group is regarded as the active working age and its illness has adverse economic implications. In agreement with the present findings, a study conducted in the neighboring province of Guilan also found the mean age of TB patients as 46-48 years[17].

The incidence rate of TB in proportion to the population showed the highest incidence in Parsabad (201 per 100,000 of the population). This rate is 128 per 100,000 of the population in Ardabil province and has a descending trend from the north to the south, with the exception of Ardabil city, which has a high ranking in this respect, probably due to its poverty-stricken suburbia. A significant relationship was found between the incidence rate of TB and climatic variables, including temperature, and TB had a greater distribution in areas with a higher mean temperature, including the northern towns of Parsabad and Bilehsavar, such that the highest incidence rate was in Aslanduz district of Parsabad with a recorded prevalence of 307 per 100,000 of the population, and in contrast, this rate reached its lowest in the south of the province. In terms of the wind status, regions with higher air calm are expected to have a higher incidence of TB. The data presented in Table two show that the mean wind velocity is higher in Ardabil and Meshkinshahr stations and almost equal in Parsabad (in the north) and Khalkhal (in the south) stations, and the percentage of gentle breeze is also equal in these two stations, although the incidence of TB reaches its highest rate in Parsabad and its lowest in Khalkhal. Consequently, wind and its related factors cannot be regarded as the only factors associated with TB. Nevertheless, the number of days with dust and haze in the north of the province in relation to its south due to Moghan plain's mean altitude being less than 200 m compared to Khalkhal's altitude of more than 1800 m may be able to create local-indigenous dust and haze and displace atmospheric bacteria as a main cause of TB. Moghan plain in Iran and Azerbaijan is considered part of the Kura subsidence, and the circulation of haze may have a key role in facilitating the transmission of Koch bacillus. A similar phenomenon is confirmed with a significant relationship between extra-local atmospheric haze (displaced by planetary winds) and the number of patients with pulmonary TB in Minqin town in the northwest of China[18]. An active customs life in the north of the province with a daily commute of 3000-5000 people for different reasons, including medical treatment, through the border with Azerbaijan Republic can also act as an important factor contributing to the spread of TB bacillus, since the incidence of TB is five to six times higher in this country than Iran, and according to a 2017 report, this rate was 67 per 100,000 of the population, with 80% being pulmonary[19].

The interpolation analysis showed that the northern towns with moderate and warm climate were among the high-risk places for the incidence of TB in Ardabil province. The incidence rate of TB, especially in the rural regions of this province (comprising 37% of the total number of TB patients), with 20-35 cases per 100,000 of the population, is higher than the provincial and national averages and approaches the Azerbaijan Republic statistics[19].

CONCLUSION

The Moran index showed a positive spatial autocorrelation between the incidence of TB and location. The dispersion of this disease was in cluster form rather than random. The center and north of Ardabil province were identified as the two active points of TB incidence. The main factors potentially contributing to the increased incidence of TB in these regions including the moderate climate with a relative air stagnation in the north of the province, i.e. the areas neighboring Azerbaijan Republic, with the constant commute of travelers through the border; and the relatively poor and dense immigrant population in the suburbs of Ardabil as the provincial capital. Interventions based on the TB care system in high-risk regions can contribute to reducing the incidence of this disease within the next few years. Providing annual statistics by the existing monitoring system, using an active patient screening system, the early treatment of the affected and public training are preventive measures recommended in these two active centers to control the spread of the disease through early diagnosis and treatment.

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Conflict of Interests: The Authors declare that they have no conflict of interests.

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