Tuberculosis infection and epidemiological characteristics in Haidian District, Beijing, 2005–2018

Fan Wu 1,2†, Caiyun Lai 1†, Yan Wang 1†, Gaoqiang Zhang 1, Yueqi Li 1, Susu Yu 1, Xinyue Peng 1, Jiani Yang 1, Zhisheng Wei 2* and Wenjuan Zhang 1*

Abstract

Background: This study was aimed to investigate the epidemiological characteristic of pulmonary tuberculosis (PTB) in Haidian District, Beijing from 2005 to 2018 and to provide suggestions for controlling tuberculosis (TB) development.

Methods: Epidemiological data about TB were obtained by the Infectious Disease Reporting System at different levels of medical institutions in Haidian District of Beijing from 2005 to 2018. The epidemiological methods combined with χ² test were used to analyze the distribution of TB in population, time, region and TB diagnosis.

Results: In total, 14,449 cases of TB patients were reported in Haidian District from 2005 to 2018 and the average annual morbidity was 31.67/10,000. Of the total cases, housework and unemployed people (20.73%; 2996/14,449) accounted for the highest proportion of occupational distribution, followed by students, accounting for 17.18% (2482/14,449). 2433 patients with the age of 65 years and over accounting for 16.83% (2433/14,449); Laboratory confirmed diagnosis of TB was 26.60% and the diagnostic delays accounted for 54.96%.

Conclusions: From 2005 to 2018, TB incidence was falling gradually in Haidian District. However, particular attention should be paid to the elderly and student groups, and the policy publicity and education should be strengthened to reduce the diagnosis delay of TB.

Keywords: Tuberculosis, Epidemiology, Etiological diagnosis, Beijing

Background

Tuberculosis (TB), an ancient infectious disease caused by the bacillus Mycobacterium tuberculosis, have affected humans for thousands of years. It is the ninth leading cause of death worldwide and the leading cause of death by a single infectious agent, ranking above HIV/AIDS. Millions of people are infected with TB each year according to the World Health Organization (WHO) [1].

TB may spread from ill person to healthy person through the air via coughs, sneezes and spit. It was estimated that 10 million people fell ill with TB in 2017 in the world. China was one of the 30 countries with a heavy burden of TB, accounting for 9% of TB patients, with 63 deaths in every 100,000 people. Mozambique, Philippines and South Africa are the three countries with the highest burden of TB, with more than 500 cases of every 100,000 people. Specific targets for 2030 set in the End TB Strategy would reduce 90% in the absolute number of TB deaths and 80% in TB incidence (new cases per 100,000 people per year), compared with those in 2015 separately [1].
In 1991, the Chinese government introduced Directly Observed Treatment, Short-course (DOTS) strategy, and created the national TB control system, with TB dispensaries and medical institutions at all levels, including rural primary health service networks and urban community health service institutions [2]. Especially, after the Severe Acute Respiratory Syndrome (SARS) was brought under control in 2003, the government increased public-health funding, revised laws of infectious diseases control, implemented the world’s largest internet-based disease reporting system, and started a programme to rebuild local public-health facilities in China [3]. The report of the fifth national sample survey pointed out that the prevalence of TB in eastern China in 2020 had declined compared with that in 2000 [4]. With timely diagnosis and correct drug treatment, most people with TB could be cured, but there are still many people falling ill TB every year, bring the great health and economy burdens.

The average resident population in Beijing is 21,640,000, Haidian District is located in the west and northwest of Beijing city, with an annual resident population of 3,260,000. It has the highest GDP among sixteen districts. There are many colleges and tourists attractions, such as the famous Peking University, Tsinghua University, the Summer Palace and the Zhongguancun Science Park in China. With the prosperous economic and educational environment, it attracted a large number of immigrants and floating people from different regions of China and other countries. About 344,400 foreigners visit the Haidian District every year. As different populations are prone to gather here, the disease spread easily. Therefore, we collected the TB data of Haidian District and analyzed the epidemiological characteristics to provide the theoretical basis and data reference for its prevention and control in Beijing, China.

**Methods**

**Data inclusion**

The diagnosis of TB is based on etiology (including bacteriology and molecular biology), combined with clinical manifestations, chest imaging, epidemiological reasons, and other auxiliary examinations for comprehensive analysis. TB cases were based on ≥1 of the following diagnostic criteria, including sputum or body fluid and tissue of smear-positive for acid-fast bacilli (AFB), culture-positive of *Mycobacterium tuberculosis* complex, or both; or clinical appearance, radiographic appearance, or both. A patient > 2 initial sputum smear examinations (direct smear microscopy) AFB-positive; or 1 sputum examination AFB-positive plus radiographic abnormalities, symptoms, or both consistent with active PTB was diagnosed as smear-positive PTB (SPPTB). The diagnosis of smear-negative PTB (SNPTB) case predominantly was relied on clinical symptoms (such as cough for > 2 weeks, fever for > 2 weeks, weight loss, hemoptysis) together with abnormal chest radiograph, the results of bacterial culture, and the response to diagnostic anti-TB treatment.

**Classification methods and definitions**

TB has appeared among all ages including children under 14 years old, so we divide the age into eight stages with the interval of 14. There were 19 occupations in the information system report, among which cadres staffs refer to the employees working in public institutions; Housework are those without a formal job and the unemployed mean people who are unemployed and were reported as such by the respondents; Others refer to people holding occupations other than those listed. Workers were those patients reported to be employed for physical or technical work to earn wages. Migrant workers refer to those individuals who came from rural areas, but engaged in non-agricultural work in cities. Ununknowns meant without the occupation report in detail. The delay in diagnosis was defined as more than 2 weeks from the reported onset of TB symptoms to diagnose at a hospital.

**Data source**

The information of TB patients came from the Chinese Tuberculosis Management Information System. The regional distribution data of Haidian District were derived from the National Bureau of Statistics, and the population data came from Beijing statistical yearbook. Data used in this study were collected from records on condition of anonymity.

**Statistical analysis**

Categorical variables were summarized as proportions including sex and patients type (SPPTB or SNPTB). The continuous variables (age) was summarized with mean and standard deviation (mean ± SD). The Chi-squared test was used to assess the difference in categorical variables. All analyses were performed using SPSS software (version 16.0). The criterion was *P* < 0.05, based on two-sided tests for statistical significance.

**Results**

**The epidemic situation of TB cases**

There were 14,449 TB cases during 2005–2018 in Haidian District, with an average annual incidence rate of 32.67/100,000. The new occurrences were 14,371 (99.46%; 14,371/14,449) and the treated/recurrent cases were 78 (0.54%; 78/14,449) as shown in Table 1. Meanwhile, there were 134 cases of combined pleurisy and 2 carriers of pathogens in 2005. The 5 rifampicin-resistant cases were reported in 2017 and 25 rifampicin-resistant cases in 2018 respectively. The morbidity of TB was the
highest in 2009 with an incidence rate of up to 41.63/100,000 and this has begun to decrease since 2009 until a small increase in 2017. The lowest annual incidence was 26.01/100,000 in 2007.

**Population distribution analysis**

As summarized in Table 2, the number of TB was 1.69 times greater in males than in females from 2005 to 2018 in Haidian District. The number of males was 9083 with the annual average morbidity of 49.09/100,000, while the number for females was 5366 with the annual average morbidity of 31.42/100,000. There was a significant sex difference the incidence ($P < 0.001$). The average age of these patients was 39.69 years. The number of young people, aged from 15 to 24, was highest with a total of 4380 cases (30.31%; 4380/14,449), followed by those who were 25 to 34 years old with a total number of 3626 (25.10%; 3626/14,449). Only 0.41% (59/14,449) of total of TB patients were 14 years old group or less. The oldest patient was 101 year of age and the youngest one was only one day old. The significant difference was observed in each age group ($P < 0.001$). In terms of different occupations, the housework and unemployed individuals comprised 2996 cases, accounting for 20.73% (2996/14,449) and the students up to 2482 cases, occupying for 17.18% (2482/14,449).

**Local distribution**

TB cases occurred in 22 streets and 7 towns in Beijing Haidian District during the investigation period. The total number of cases was 11,359 in The 3843 cases were diagnosed solely as laboratory-confirmed and 2761 in towns, accounting for 78.6% (11,359/14,449) and 19.1% (2761/14,449) respectively. Additionally, there were 329 persons with unknown addresses, occupying 2.3% (329/14,449) of the total number of cases. The incidence rate was the highest in 2009 of urban population, and has been declining gradually since then. However the incidence rate of town population increased gradually from 2005 to 2009, and remained stable thereafter (Fig. 1).

**Etiological diagnosis**

The 3843 cases were diagnosed solely as laboratory-confirmed cases, and 10,606 cases were determined by radiographic appearance and laboratory diagnosis as the clinical cases, accounting for 26.6% (3843/14,449) and 73.4% (10,606/14,449) of the total cases respectively, of which 134 had pleurisy. The clinical diagnosis exhibited a downward trend, while the laboratory confirmation showed an upward trend from 2005 to 2018 from Fig. 2. The highest positive rate occurred in 2018 and the number of smear positives highest in 2011. There was a total of 3849 bacteria positive cases including smear-positive, positive bacterial culture and Rifampin resistance. The bacteria negative reached 7344 cases and the average rate of sputum was 77.47% (11,193/14,449) (Table 3).

**Diagnosis time**

As illustrated in Fig. 3, the average diagnosis time was 56.41 days with the median of 18 days. The average diagnosis time was 55.72 days for smear positive. Among them, 6 cases were diagnosed in advance and the earliest

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**Table 1 The morbidity and case type of TB patients in Haidian District, 2005–2018**

| Year | no. patients | Morbidity (/100,000) | Case type | TB pleurisy |
|------|--------------|----------------------|-----------|-------------|
|      |              |                      | New cases | treated cases or recurrence | |
| 2005 | 986          | 38.13                | 983       | 3           | 27          |
| 2006 | 767          | 28.54                | 754       | 13          | 19          |
| 2007 | 732          | 26.01                | 723       | 9           | 7           |
| 2008 | 912          | 31.13                | 891       | 21          | 9           |
| 2009 | 1283         | 41.63                | 1279      | 4           | 2           |
| 2010 | 1204         | 36.70                | 1200      | 4           | 6           |
| 2011 | 1251         | 36.77                | 1242      | 9           | 9           |
| 2012 | 1228         | 35.25                | 1224      | 4           | 3           |
| 2013 | 1118         | 31.26                | 1116      | 2           | 6           |
| 2014 | 1057         | 28.74                | 1055      | 2           | 6           |
| 2015 | 1036         | 28.05                | 1032      | 4           | 6           |
| 2016 | 965          | 26.86                | 965       | 0           | 5           |
| 2017 | 1011         | 29.05                | 1010      | 1           | 13          |
| 2018 | 899          | 26.77                | 897       | 2           | 16          |
| Total| 14,449       | 32.67*               | 14,371    | 78          | 134         |

*Table footnotes: The average annual morbidity
was 1 year. The 7941 people showed a diagnosis delay between 2005 and 2018, accounting for 54.96% of the total case. Among the delayed diagnosis cases, 1591 cases were smear-positive and 5115 cases were smear-negative, with the delay rates of 20.04% (1591/7941) and 64.41% (5115/7941) respectively. The smear-positive diagnosis delay rate was less than the smear-negative with the statistically significant difference ($P < 0.001$).

### Discussion

In this study, the TB morbidity was decreased by 29.8% (from 38.13 to 26.77 per 100,000 population) in Haidian District of Beijing from 2005 to 2018 with an average annual morbidity of 32.67/100,000, closely to the total incidence of TB reported in Beijing in 2017 (32.70 per 100,000 population) [5], but far lower than that in China in 2017 (63 per 100,000 population) [1], which was closely related with the national policies to control the incidence of TB. Since 1949, China has paid much attention to the prevention and control of TB. The Chinese government incorporated this issue into the economic and social development plan, continuously increased the investment of prevention and control funds, strengthened the construction of institutions, and constantly improved the prevention and control service system. There was an important period of improvement and innovation in TB control from 2001 to 2010. By the end of 2005, China’s DOTS coverage had reached 100% [6].

From the perspective of age distribution, most patients were young adults aged from 15 to 44. However, the increasing attention should be placed on the old population over 75 years old. Many relapsed patients were found in the elderly population [7]. The immunity of the elderly population has generally weakened, and hence prone to infection or relapse. Additionally, some investigations showed that the BCG vaccine was more useful for younger people and less effective for the middle or senior-age people, with an average efficacy of only about 50% for those groups [8]. Considering the rapid aging of the Chinese population and high morbidity rate of TB in seniors, we should pay more attention to the potential high-risk elderly sub-populations who may contribute to the increased proportion of the actively infected people [9]. In this context, an effective vaccine control strategy should be implemented for them to reduce their TB morbidity.

The results showed that the most cases were distributed in urban areas, where a number of colleges and universities were located. As a consequence, students were found to be a high-risk group of TB. TB was easy to spread among crowded population, leading to the prevalence in campus areas. Schools are considered common places for the community-based of outbreak of TB in China, so the exposure risk in the dorm room and tuberculin test results should be taken into consideration in prevention and control [10, 11]. Moreover, although students were screened, no surveillance, follow-up or control activities were carried out, which may result in delays in the diagnosis of TB and thus caused its wide spread [12]. Therefore, the delayed diagnosis, lacked of preventive treatment and no follow-ups were the typical contributing factors in the outbreak of school TB.

Our study found that the incidence of TB in males was higher than that in females, and the occupational distribution

### Table 2: The patient demographics of TB in Haidian District, Beijing, 2005–2018

| Characteristics                  | f   | (%)   | p-value |
|----------------------------------|-----|-------|---------|
| Age (years)                      |     |       |         |
| 0–14                             | 59  | 0.41  |         |
| 15–24                            | 4380| 30.31 |         |
| 25–34                            | 3626| 25.10 |         |
| 35–44                            | 1481| 10.25 | < 0.001|
| 45–54                            | 1306| 9.04  |         |
| 55–64                            | 1164| 8.06  |         |
| 65–74                            | 976 | 6.75  |         |
| ≥75                              | 1457| 10.08 |         |
| Sex                              |     |       |         |
| Female                           | 5366| 37.14 |         |
| Male                             | 9083| 62.86 | < 0.001|
| Career                           |     |       |         |
| Housework and unemployed         | 2996| 20.73 |         |
| Students                         | 2482| 17.18 |         |
| Retired staffs                   | 2189| 15.15 |         |
| Cadre staffs                     | 1960| 13.56 |         |
| Others                           | 1028| 7.11  |         |
| Business servicers               | 921 | 6.37  |         |
| Workers                          | 835 | 5.78  |         |
| Farmers                          | 513 | 3.55  |         |
| Unknown                          | 422 | 2.92  |         |
| Food and beverage industry workers| 273 | 1.89  |         |
| Migrant workers                  | 239 | 1.65  |         |
| Teachers                         | 215 | 1.49  |         |
| Medical staffs                   | 167 | 1.16  |         |
| Public place attendants          | 163 | 1.13  |         |
| Scattered children               | 18  | 0.12  |         |
| Seafarers and long distance drivers| 18  | 0.12  |         |
| Nurses and babysitters           | 5   | 0.03  |         |
| Kindergarten children            | 3   | 0.02  |         |
| Herders                          | 2   | 0.01  |         |
| Total                            | 14,449| –     |         |
of TB was mainly due to housework and unemployment and students. These were well explained by cluster aggregation. Men may have a higher morbidity of latent TB infection and greater exposure to conditions that favor the development of the disease, such as alcoholism, smoking and precarious working conditions [13, 14]. In the decade after the outbreak of SARS in China, TB incidence showed an increasing trend by age, especially noticeable among men [15].

From 2005 to 2018 in Haidian District, the positive rate of laboratory detection was lower than the 50% positive rate of pathogen diagnosis proposed in the 13th Five-Year National Tuberculosis Control Plan. Meanwhile, the smear-positive diagnosis delay rate was significantly less than that of the smear-negative diagnosis. Therefore, the laboratory testing level should be strengthened, and conventional smear culture should be combined with genetic testing to improve the detection rate of pathogens in Haidian District in the future. In particular, medical staffs should improve the vigilance of smear-negative patients with suspicious symptoms to avoid the diagnosis delay.

Although DOTS have been fully covered, there are still delays in TB diagnosis which may be caused due to the long distance from home to the health center and the
physical problem of many elderly people who have difficulty in walking. Housework and the unemployed, many of whom lived in rural areas and were older, also had this problem. Additionally, with the amount of housework and farm work, TB patients in rural villages felt it almost impossible to visit the long distant health centers. Even though TB diagnosis and treatment are free, they may not be able to afford the costs associated with other things in the diagnosis process such as accommodation, dinning. Although most of the patients knew TB disease, they were lacking in knowledge about the symptoms and few people were aware of its severity. Discrimination from others may also discourage them to have access to the healthcare services. All these factors contribute to the delays in diagnosis, so resulting in the high prevalence of TB among the elderly, housework and unemployed [16].

| Year | Bacteria positive Swear-positive TB (cases) | Positive bacterial culture (cases) | Total (cases) | Bacteria negative (cases) | Without sputum examination (cases) | Total | Positive rate (%) | Rate of sputum (%) |
|------|--------------------------------------------|-----------------------------------|---------------|---------------------------|-----------------------------------|-------|------------------|-------------------|
| 2005 | 179                                        | 6                                 | 185           | 440                       | 361                               | 18.76 | 63.39            |                   |
| 2006 | 165                                        | 27                                | 192           | 391                       | 184                               | 25.03 | 76.01            |                   |
| 2007 | 169                                        | 1                                 | 170           | 379                       | 183                               | 23.22 | 75.00            |                   |
| 2008 | 196                                        | 18                                | 214           | 504                       | 194                               | 23.46 | 78.73            |                   |
| 2009 | 272                                        | 10                                | 282           | 716                       | 285                               | 21.98 | 77.79            |                   |
| 2010 | 260                                        | 22                                | 282           | 675                       | 247                               | 23.42 | 79.49            |                   |
| 2011 | 314                                        | 29                                | 343           | 612                       | 296                               | 27.42 | 76.34            |                   |
| 2012 | 281                                        | 25                                | 306           | 624                       | 298                               | 24.92 | 75.73            |                   |
| 2013 | 299                                        | 34                                | 333           | 548                       | 237                               | 29.79 | 78.80            |                   |
| 2014 | 288                                        | 35                                | 323           | 533                       | 201                               | 30.56 | 80.98            |                   |
| 2015 | 283                                        | 27                                | 310           | 501                       | 225                               | 29.92 | 78.28            |                   |
| 2016 | 250                                        | 19                                | 269           | 487                       | 209                               | 27.88 | 78.34            |                   |
| 2017 | 280                                        | 37                                | 317           | 514                       | 180                               | 31.36 | 82.20            |                   |
| 2018 | 251                                        | 72                                | 323           | 420                       | 156                               | 35.93 | 82.65            |                   |
| Total| 3487                                       | 362                               | 3849          | 7344                      | 3256                               | 26.64 | 77.47            |                   |

Fig. 3 The diagnosis time (in weeks) of TB. Differences in the constituent ratio between timely diagnosis and delayed diagnosis in SNPTB and SPPTB of reported TB cases in Haidian District, Beijing, 2005–2018.
In addition to causing the parenchyma of the lung, mycobacterium TB affects other areas other than the lung, leading to extrapulmonary tuberculosis (EPTB), most commonly pleurisy. EPTB is usually not an infectious disease. However, it can cause death if undiagnosed or untreated, especially in immunosuppressed individuals. EPTB patients were largely at 65 years or older, who had retired and was living in urban areas [17]. In our study, TB pleurisy has been reported every year. Notably, patients with HIV and diabetes were more likely to contract TB, but less likely to contract EPTB [18].

Strengths and limitations
In this study, we have carried out a detailed descriptive epidemiological study to provide data references for the TB control. However, there are still some limitations to our study. In the future, the qualitative methods should be applied to explore the reasons for delay in diagnosis, including studies on individual behaviour and characteristics embedded in social, cultural and health service. In addition, a large scale study to cover the whole of Beijing might be beneficial.

Conclusions
In conclusion, the overall incidence of TB in Beijing Haidian District dropped from 2005 to 2018, but there were still many new cases every year. National plans for TB control need to target populated regions, with special attention to elderly males without occupation who are at higher risk, and should strengthen publicity and education activities, especially in schools.

Acknowledgements
Not applicable.

Authors’ contributions
FW, CL and YW interpreted the data and wrote the manuscript. GZ and YL collected and collated data. SY, XP and JY revised the work. The study on which this paper was conceived and designed by ZW and WZ. All authors have commented on drafts of the paper and approved this submitted version.

Funding
This work was funded by National Natural Science Foundation of China (81473014); Top Young Talents of Guangdong Hundreds of Millions of Projects (B73160M); Jinan University High-level University Construction Public Health and Preventive Medicine Fund (UNHFPHM016003); Outstanding Young Talent of Double Hundred Talents Plan in Jinan University; Open Fund of State Key Laboratory of Respiratory Diseases (SKLRD-OP-201810). The funding body had no role in the design of the study and collection or in the analysis and interpretation of the data or in writing the manuscript.

Availability of data and materials
Data of the study was not publicly available, the datasets used and analyzed during the current study are available from the corresponding author upon reasonable request. Restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with the permission of Four Seasons Hospital.

Ethics approval and consent to participate
According to National Health Commission of the People’s Republic of China [19], data involved in this study did not include any data of patients’ personal information, including name, identity information, exact address, telephone number, etc. This study mainly focused on aggregating the available data, so consent to participate and ethics approval are unnecessary.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 8 January 2020 Accepted: 24 April 2020
Published online: 01 June 2020

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