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Trends and Determinants of Patient Delay among Pulmonary Tuberculosis Patients in Yantai City, Eastern China: A 16-Year Population-Based Surveillance Study (2010–2025)

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Research Article

Keywords: Pulmonary Tuberculosis, Prolonged Patient Delay, Joinpoint regression, Risk factors

Posted Date: November 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10761713/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Prolonged patient delay (PrPD) increases disease severity and transmission risk, undermining tuberculosis (TB) control efforts. This study aims to describe the patient delay among patients with pulmonary tuberculosis (PTB) and identify the influencing factors.

Methods

A retrospective cohort study was conducted using data extracted from the national Tuberculosis Management Information System (TBMIS) in Yantai City between 2010 and 2025. Joinpoint regression evaluated annual trends in PrPD proportion. Univariable and multivariable logistic regression analyses were used to identify factors associated with PrPD.

Results

The overall PrPD proportion of PTB patients was 65.25% with a median delay of 26 days (IQR: 9–60 days). Despite an overall significant decline over the 16-year period (AAPC = − 1.362%, $P = 0.013$), joinpoint analysis revealed a markedly divergent pattern: a significant increase during 2010–2023 (APC = 1.552%, $P < 0.001$) followed by a sharp reversal and significant decline during 2023–2025 (APC = − 18.368%, $P < 0.001$). Multivariable analysis revealed that older age (25–44 years, aOR = 1.233; 45–64 years, aOR = 1.572; ≥65 years, aOR = 1.432), migrant residential status (aOR = 1.610), passive case finding (aOR = 3.904), bacteriologically positive results (aOR = 1.245), and during the COVID-19 pandemic (aOR = 1.255) were independent risk factors for PrPD. In contrast, non-farmers (aOR = 0.784), and post-COVID-19 pandemic periods (aOR = 0.728) were protective factors associated with lower PrPD odds.

Conclusions

To reduce PrPD and mitigate TB transmission in Yantai City, targeted interventions should prioritize elderly individuals, farmers, and migrant populations, including strengthened active case-finding, improved health education, enhanced healthcare access for migrants, and more equitable allocation of medical resources. Future TB control strategies should adopt context-adapted, integrated approaches to promote early detection and timely treatment, with a focus on vulnerable populations.

Introduction

Tuberculosis (TB) remains a significant global public health threat, with China bearing a high burden of cases. An estimated 10.7 million people developed TB globally in 2024, with 1.23 million deaths attributed to the disease, making TB the leading cause of death from a single infectious disease[1].

China ranks fourth among the 30 high-TB-burden countries, accounting for an estimated 696,000 cases (6.5% of the global total)[1]. The effectiveness of TB control programs hinges on early detection and prompt treatment initiation, which limits transmission, improves individual prognosis, and reduces the risk of drug resistance[2, 3]. Despite decades of advancement in TB control, persistent delays in diagnosis and treatment—averaging weeks to months in high-burden settings—remain a major obstacle to effective disease management, thereby perpetuating community transmission[4, 5]. A critical barrier to achieving this goal is prolonged patient delay (PrPD), defined as the period from the onset of symptoms to the first presentation at a healthcare facility[6]. PrPD is associated with advanced disease severity, increased infectivity, greater treatment complexity, increased cost, and, ultimately, sustained community transmission, thereby undermining global and national TB elimination efforts[7–9].

As one of the 30 global high TB-burden countries, China has achieved a steady decline in national TB notification rates over the past two decades, reflecting substantial progress in TB control[10, 11]. However, significant challenges remain, including a persistently high absolute number of cases and considerable regional heterogeneity in epidemiological trends and disease burden. PrPD persists as a major challenge, influenced by a complex interplay of individual, socio-economic, and health system factors. While numerous studies have identified factors associated with PrPD in cross-sectional analyses[12–14], there is a paucity of longitudinal research examining how these delays and their determinants have evolved over time, particularly in the context of ongoing health system reforms and socio-economic development[15].

Yantai City is a prominent coastal prefecture-level city in northeastern Shandong Province, with a population of approximately 7 million. The city has implemented comprehensive TB control strategies under the National TB Control Programme, yet longitudinal evidence on trends in PrPD and its underlying determinants remains limited. Although the disease burden has been declining, PTB remains a significant public health concern. Notable intra-regional disparities in economic development, healthcare resource distribution, and population mobility—particularly between the urban core and rural coastal areas—may substantially influence health-seeking behavior[16, 17]. However, current knowledge regarding the magnitude and drivers of PrPD among TB patients in Yantai is fragmented, as existing studies have largely been single-center or cross-sectional with limited temporal depth[18]. A comprehensive city-wide longitudinal analysis that systematically quantifies PrPD and disentangles its individual, community, and health-system determinants is still lacking.

Utilizing a robust, long-term dataset from the national surveillance system, this study aims to fill this knowledge gap by analyzing the trends and evolving determinants of PrPD among PTB patients in Yantai City over a 16-year period (2010–2025). The findings will provide critical, time-sensitive evidence to inform and refine targeted public health interventions for reducing PrPD in TB control.

Methods

Study setting

Yantai City is located in eastern Shandong Province, China. It covers a land area of 13,930 square kilometers and has a resident population of approximately 7 million. The city's Gross Domestic Product (GDP) reached 1,135.098 billion RMB in 2025. As a major coastal city with significant internal migration and intra-regional economic disparities, Yantai City presents a relevant setting for examining health-seeking behavior and PrPD among PTB patients.

Data Source and Study Population

This retrospective cohort study utilized data from the nationwide Tuberculosis Management Information System (TBMIS) operated by the China Center for Disease Control and Prevention. TBMIS is a mandatory web-based surveillance platform that registers every diagnosed TB patient in China, providing comprehensive and standardized information on patient demographics, clinical presentation, diagnosis, and treatment outcomes. All PTB cases diagnosed and reported in Yantai City from January 1, 2010, to December 31, 2025, were included in the study, encompassing both bacteriologically confirmed and clinically diagnosed cases. Sociodemographic characteristics included age, gender, ethnicity, occupation, and residence status. Clinical information included date of symptom onset, date of healthcare facility visit, method of case-finding, treatment category, bacteriological diagnostic results, comorbidities (e.g., diabetes mellitus (DM), human immunodeficiency virus (HIV) infection, pneumoconiosis, mental disorder).

Inclusion criteria were as follows: (1) pulmonary tuberculosis was diagnosed according to the Chinese national standard *Diagnosis for Pulmonary Tuberculosis* (WS 288–2008, revised as WS 288–2017); and (2) patients with complete medical records, including key variables such as date of symptom onset, date of first healthcare visit, demographic characteristics, and clinical features. Exclusion criteria were as follows: (1) patients with extrapulmonary TB only (n = 2,111); (2) patients with nontuberculous mycobacterial disease (n = 949); and (3) patients with logically inconsistent dates between symptom onset and medical consultation (n = 828). A total of 29,937 PTB cases were included in the final analysis.

Definitions

Date of symptom onset: The exact calendar date on which the patient first developed any TB-related symptom (e.g., persistent cough, sputum production, chest tightness and pain, low-grade fever, night sweats, weight loss, hemoptysis, fatigue, and other related symptoms).

Date of first healthcare facility visit: The exact calendar date of the patient's first presentation to a medical facility following symptom onset.

Prolonged patient delay (PrPD): Defined as a time interval of exceeding 14 days from the onset of clinical symptoms to the first medical consultation, according to the *Clinical Practice Guideline for Early Detection of Pulmonary Tuberculosis in General Medical Institutions* and the *Technical Specifications for Tuberculosis Prevention and Control in China* (2020 Version).

Active case-finding: Healthcare workers proactively identify individuals with TB symptoms or at high risk, rather than waiting for patients to present voluntarily at clinics. Active screening modalities encompassed two strategies: screening of close contacts and health check-up screening.

Passive case-finding: Patients recognize symptoms, seek care, and present to a healthcare facility on their own initiative. The health system then diagnoses TB among these self-presenting individuals.

Congregate settings: Congregate environments with elevated tuberculosis transmission risk, including schools, correctional facilities, nursing homes, psychiatric hospitals, welfare institutions, and healthcare facilities.

Study periods: The study period was stratified into three phases based on China's COVID-19 public health emergency response timeline: the pre-COVID-19 period (2010–2019), the COVID-19 pandemic period (2020–2022), and the post-COVID-19 period (2023–2025). Calendar-year boundaries were used given the annual aggregation of surveillance data, with 2020 and 2023 representing the onset and relaxation of nationwide containment policies, respectively.

Statistical Analysis

Descriptive statistics were used to summarize the characteristics of the study population and the distribution of PrPD. Continuous variables are presented as median and interquartile range (IQR), given their non-normal distribution. Categorical variables are described using frequencies and percentages.

To evaluate temporal trends in the proportion of PrPD cases, we employed Joinpoint regression analysis using the National Cancer Institute's Joinpoint Regression Program (version 5.4.0; Statistical Methodology and Applications Branch, Surveillance Research Program). This method identifies joinpoints—points where significant changes in trend occur— through Monte Carlo permutation tests, with associated *P*-values calculated for each joinpoint. The optimal model was selected based on the Bayesian information criterion (BIC). In this analysis, the annual proportion of PrPD cases served as the dependent variable, and the year of patient notification was the independent variable. A statistically significant trend change within a given segment was defined as an annual percent change (APC) or average annual percent change (AAPC) with $P < 0.05$ and a 95% confidence interval excluding zero.

Potential determinants of PrPD were first explored using univariate logistic regression to obtain crude odds ratios (cORs) with 95% confidence intervals (CIs). Variables showing a statistically significant association ($P < 0.05$) were subsequently entered into a multivariable logistic model to estimate independent effects, expressed as adjusted odds ratios (aORs) with 95% CIs. All statistical analyses were performed using Stata 18.0 (StataCorp, College Station, TX, USA), with a two-sided *P*-value < 0.05 considered statistically significant.

Results

Study Population Characteristics

A total of 29,937 PTB patients were enrolled. The cohort was predominantly male (74.25%), of Han ethnicity (99.14%), and employed as farmers (61.60%). The median delay and proportion of PrPD increased with age, rising from 18 days and 55.81% in patients aged < 25 years to 30 days and 70.09% in those aged 45–64 years. Compared with non-farmers, farmers had longer median delay (29 vs. 20 days) and higher PrPD (68.90% vs. 59.38%). Migrants exhibited a median delay of 33 days and PrPD of 75.08%, compared with 24 days and 64.54% among local residents. A small proportion of patients (1.57%) were identified as residing or working in high-risk congregate settings. Active case finding was associated with substantially shorter median delays (5 days) and lower PrPD (28.11%), compared with 27 days and 66.52% in passively detected patients. Patients diagnosed during the COVID-19 pandemic had the longest median delay (30 days) and highest PrPD (72.25%), compared with those diagnosed in the pre-COVID-19 (26 days, 64.82%) and post-COVID-19 periods (20 days, 60.98%). More detailed information is shown in Table 1.

Table 1
Baseline Characteristics and PrPD among PTB Patients in Yantai City, 2010–2025

Variables	**Total (*N*, %)**	**Days (IQR)**	**PrPD (*n*, %)**	**Non-PrPD (*n*, %)**
Gender				
Male	22,229(74.25)	26(9–60)	14,514(65.29)	7,715(34.71)
Female	7,708(25.75)	25(9–60)	5,019(65.11)	2,689(34.89)
Age (years)				
<25	5,126(17.12)	18(6–42)	2,861(55.81)	2,265(44.19)
25–44	8,047(26.88)	22(8–54)	5,023(62.42)	3,024(37.58)
45–64	9,753(32.58)	30(11–62)	6,836(70.09)	2,917(29.91)
≥65	7,011(23.42)	28(11–61)	4,813(68.65)	2,198(31.35)
Ethnicity				
Han Chinese	29,680(99.14)	26(9–60)	19,384(65.31)	10,296(34.69)
Others	257(0.86)	17(7–52)	149(57.98)	108(42.02)
Occupation				
Farmers	18,442(61.60)	29(11–61)	12,707(68.90)	5,735(31.10)
Non-farmers	11,495(38.40)	20(7–53)	6,826(59.38)	4,669(40.62)
Residential status				
Local	27,939(93.33)	24(9–59)	18,033(64.54)	9,906(35.46)
Migrant	1,998(6.67)	33(15–69)	1,500(75.08)	498(24.92)
DM				
No	28,665(95.75)	25(9–60)	18,661(65.10)	10,004(34.90)
Yes	1,272(4.25)	27(11–61)	872(68.55)	400(31.45)
HIV/AIDS				
No	29,926(99.96)	26(9–60)	19,527(65.25)	10,399(34.75)
Yes	11(0.04)	20(6–46)	6(54.55)	5(45.45)
Congregate settings				
No	29,468(98.43)	26(9–60)	19,255(65.34)	10,213(34.66)
Yes	469(1.57)	20(8–37)	278(59.28)	191(40.72)
Case finding				

Variables	Total (*N*, %)	Days (IQR)	PrPD (*n*, %)	Non-PrPD (*n*, %)
Active	996(3.33)	5(1–18)	280(28.11)	716(71.89)
Passive	28,941(96.67)	27(10–61)	19,253(66.52)	9,688(33.48)
Treatment category				
New	27,890(93.16)	25(9–60)	18,137(65.03)	9,753(34.97)
Previously treated	2,047(6.84)	29(11–61)	1,396(68.20)	651(31.80)
Bacteriological results				
Negative	15,808(52.80)	22(8–49)	9,836(62.22)	5,972(37.78)
Positive	14,129(47.20)	30(11–62)	9,697(68.63)	4,432(31.37)
Year				
Pre-COVID-19	21,323(71.23)	26(9–61)	13,821(64.82)	7,502(35.18)
During COVID-19	4,075(13.61)	30(13–62)	2,944(72.25)	1,131(27.75)
Post-COVID-19	4,539(15.16)	20(9–41)	2,768(60.98)	1,771(39.02)

PrPD, Prolonged Patient Delay; IQR, Interquartile Range; PTB, Pulmonary Tuberculosis; DM, Diabetes Mellitus.

Temporal trends of prolonged patient delay

Across the 16-year study period, the overall proportion of patients with PrPD was 65.25%, with a median delay of 26 days (IQR: 9–60 days). Male patients consistently outnumbered females at a ratio of approximately 3:1 throughout the study period, with both sexes showing a downward trend from 2010 to 2025. PrPD proportions followed similar trajectories for both sexes, fluctuating between approximately 60% and 75% from 2010 to 2020 before peaking at approximately 75% in 2022. Subsequently, PrPD proportions declined sharply for both sexes, reaching approximately 50% in males and 46% in females by 2025 (Fig. 1). For patients aged ≥ 65 years, the proportion of PrPD remained consistently high (approximately 65%–75%) throughout most of the study period, with only minor fluctuations, before declining sharply from 2023 onward. Similarly, the 45–64 age group maintained the second-highest PrPD proportion, peaking at approximately 78% in 2016 and 2022, followed by a marked decrease in the final three years. In contrast, the 25–44 age group exhibited moderate PrPD proportions with a gradual downward trend beginning in 2023. The youngest group (patients aged < 25 years) consistently showed the lowest PrPD proportions and also experienced the steepest decline after 2023. Notably, all four age groups demonstrated a synchronized reduction in PrPD proportions from 2023 to 2025 (Fig. 2).

Joinpoint regression analysis revealed a dichotomous temporal pattern: the PrPD proportion increased significantly from 2010 to 2023 (APC = 1.552%, $P < 0.001$), followed by a sharp decline during 2023–

2025 (APC=-18.368%, $P < 0.001$). Despite the prolonged upward phase, the average annual percent change (AAPC) across the entire 16-year period was − 1.362% ($P = 0.013$), driven by the steep drop in the final two years, indicating an overall net decreasing trend. Both sexes exhibited significant increasing trends during 2010–2023 and decreasing trends thereafter, with a slightly greater magnitude of change observed among females. For all subgroups, the negative AAPC values reflected the dominant influence of the steep post-2023 decline, which offset the preceding upward trends. Among age groups, the < 25 years age group exhibited the most pronounced changes: a non-significant initial decline during 2010–2013, followed by a significant increase during 2013–2023 and then the steepest decline after 2023 (APC= -35.749%, $P < 0.001$). The ≥ 65 years age group was the only one that exhibited no significant change during 2010–2023 but showed a significant decline thereafter. All age groups demonstrated a significant negative AAPC, confirming an overall downward trend in PrPD proportions over the study period. These results are summarized in Table 2.

Table 2
Joinpoint analysis of trends in the proportion of PrPD among PTB patients in Yantai City, 2010–2025

Total	Year	APC (95% CI)	*P* value	AAPC (95% CI)	*P* value
	2010–2023	**1.552(1.094, 2.011) ***	**< 0.001**	**-1.362(-2.423, -0.291) ***	**0.013**
	2023–2025	-18.368(-25.107, -11.023) *	< 0.001		
Male	2010–2023	1.521(1.063, 1.982) *	< 0.001	-1.240(-2.303, -0.164) *	0.024
	2023–2025	-17.442(-24.271, -9.998) *	< 0.001		
Female	2010–2023	1.640(1.101, 2.296) *	< 0.001	-1.731(-2.544, -1.205) *	< 0.001
	2023–2025	-21.073(-26.282, -13.018) *	< 0.001		
< 25	2010–2013	-3.705(-11.192, 2.469)	0.311	-3.820(-5.104, -2.721) *	< 0.001
	2013–2023	4.225(3.046, 8.889) *	0.003		
	2023–2025	-35.749(-42.326, -24.002) *	< 0.001		
25–44	2010–2023	1.889(1.170, 2.788) *	< 0.001	-1.873(-2.823, -1.153) *	< 0.001
	2023–2025	-23.160(-29.078, -13.967) *	< 0.001		
45–64	2010–2023	0.924(0.387, 1.585) *	0.002	-1.776(-2.563, -1.237) *	< 0.001
	2023–2025	-17.648(-22.917, -10.798) *	< 0.001		
≥ 65	2010–2023	0.313(-0.201, 0.937)	0.189	-1.619(-2.195, -1.091) *	< 0.001
	2023–2025	-13.303(-17.420, -6.911) *	< 0.001		

*: *P* < 0.05, APC=Annual Percent Change; AAPC=Average Annual Percent Change; CI= Confidence Interval

Factors associated with PrPD

In univariate analysis, age, ethnicity, occupation, residential status, case finding approach, treatment classification, bacteriological results, DM, congregate settings, and study period were significantly associated with PrPD (all $P < 0.05$). After adjusting for confounders, multivariable analysis identified age, occupation, residential status, case finding approach, bacteriological results, and study period as independent predictors of PrPD. All older age groups exhibited significantly higher odds of delay compared with the reference group of patients aged < 25 years. Specifically, the 45–64 years group had the highest adjusted odds ratio (aOR = 1.572, 95% CI: 1.457–1.696, $P < 0.001$), followed by the ≥ 65 years group (aOR = 1.432, 95% CI: 1.318–1.555, $P < 0.001$) and the 25–44 years group (aOR = 1.233, 95% CI: 1.145–1.327, $P < 0.001$). In addition, non-farmers had significantly lower odds of delay than farmers (aOR = 0.784, 95% CI: 0.743–0.827, $P < 0.001$). Compared with local residents, migrants had higher adjusted odds of delay (aOR = 1.610, 95% CI: 1.447–1.791, $P < 0.001$). Passive case finding was associated with approximately 4-fold higher odds of delay than active case finding (aOR = 3.904, 95% CI: 3.382–4.507, $P < 0.001$). Patients with bacteriologically positive results were more likely to experience delay than those with bacteriologically negative results (aOR = 1.245, 95% CI: 1.181–1.313, $P < 0.001$). Furthermore, relative to the pre-COVID-19 period, the COVID-19 pandemic period was associated with a 25.5% increase in the odds of delay (aOR = 1.255, 95% CI: 1.162–1.356, $P < 0.001$), whereas the post-COVID-19 period was associated with a 27.2% decrease (aOR = 0.728, 95% CI: 0.678–0.783, $P < 0.001$). These findings are presented in Table 3.

Table 3
Univariate and Multivariable logistic regression analyses of predictors associated with PrPD.

Variables	Univariate analysis		Multivariable analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Gender				
Male	Reference			
Female	0.992(0.940–1.048)	0.776		
Age (years)				
< 25	Reference		Reference	
25–44	1.315(1.225–1.412)	< 0.001	1.233(1.145–1.327)	< 0.001
45–64	1.855(1.730–1.990)	< 0.001	1.572(1.457–1.696)	< 0.001
≥ 65	1.734(1.609–1.868)	< 0.001	1.432(1.318–1.555)	< 0.001
Ethnicity				
Han Chinese	Reference		Reference	
Others	0.733(0.571–0.940)	0.014	0.937(0.723–1.214)	0.624
Occupation				
Farmers	Reference		Reference	
Non-farmers	0.660(0.629–0.693)	< 0.001	0.784(0.743–0.827)	< 0.001
Residential status				
Local	Reference		Reference	
Migrant	1.655(1.491–1.836)	< 0.001	1.610(1.447–1.791)	< 0.001
DM				
No	Reference		Reference	
Yes	1.169(1.036–1.319)	0.011	1.003(0.883–1.139)	0.966
HIV				
No	Reference			
Yes	0.639(0.195–2.094)	0.460		
Congregate settings				
No	Reference		Reference	

Variables	Univariate analysis		Multivariable analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Yes	0.772(0.641–0.930)	0.006	1.124(0.926–1.365)	0.238
Case finding				
Active	Reference		Reference	
Passive	5.082(4.417–5.847)	< 0.001	3.904(3.382–4.507)	< 0.001
Treatment category				
New	Reference		Reference	
Previously treated	1.153(1.047–1.270)	0.004	0.939(0.848–1.039)	0.220
Bacteriological results				
Negative	Reference		Reference	
Positive	1.328(1.266–1.394)	< 0.001	1.245(1.181–1.313)	< 0.001
Year				
Pre-COVID-19	Reference		Reference	
During COVID-19	1.413(1.312–1.522)	< 0.001	1.255(1.162–1.356)	< 0.001
Post-COVID-19	0.848(0.794–0.906)	< 0.001	0.728(0.678–0.783)	< 0.001

Discussion

During the 16-year study period (2010–2025), a total of 29,937 PTB cases were notified in Yantai City. The findings indicate a substantial burden of patient delay, with 65.25% of cases experiencing PrPD and a median delay of 26 days (IQR: 9–60). These figures exceed the pooled estimate from a systematic review of mainland China (PrPD proportion: ~57%; median delay: 20–25 days), which noted significant regional heterogeneity[19]. Specifically, the median delay in our study was longer than that reported in Shanghai (18.5 days)[20] and Wuhan[21], but shorter than that in Lishui City (36 days)[22]. Internationally, our median delay was shorter than those reported in Nepal (35 days), Peru (57 days), and Ethiopia's Amhara Region (35 days)[23–25], yet longer than another estimate from Ethiopia[26]. This pattern aligns with a systematic review demonstrating that median patient delays in low- and lower-middle-income countries are substantially longer than in upper-middle-income countries[4].

This study presents a comprehensive analysis of temporal trends in PrPD proportions among PTB patients in Yantai City over 2010–2025. We observed a distinct pattern: the overall 16-year trend was downward (AAPC=-1.36%), but this summary statistic masked a prolonged 13-year gradual increase (APC = 1.55%) that was abruptly reversed by a steep 2-year decline (APC=-18.37%) at the end of the

study period. This underscores the importance of examining segmented trends rather than relying solely on summary measures. The recent downward trend may reflect the impact of intensified health education campaigns, improved primary healthcare accessibility, and enhanced active case detection strategies implemented in the post-COVID-19 period[27]. However, this decline may be susceptible to reversal without sustained investment. To consolidate these gains, tuberculosis control measures—including sustained active screening and patient-centered case management—should be embedded within routine public health preparedness frameworks, supported by long-term financial and human resource commitments[28].

Multivariable analysis revealed a significant positive association between older age and higher odds of PrPD among PTB patients. This finding is consistent with previous studies identifying older age as a risk factor for PrPD[22, 29], a relationship likely mediated by the interplay of biological vulnerability—such as immunosenescence and atypical symptom presentation—and social barriers to care-seeking, including limited health literacy and restricted mobility. Older adults frequently normalize chronic cough as “expected aging” or attribute it to preexisting respiratory conditions, resulting in prolonged self-treatment and repeated informal healthcare encounters before eventual presentation at a TB-designated facility[30]. These findings suggest that health education interventions should leverage the most trusted information sources among older adults—namely, village doctors and television—to improve early symptom recognition and reduce diagnostic delay. Concurrently, active systematic screening should be embedded within geriatric care settings serving high-risk populations. This dual strategy has the potential to streamline the tuberculosis diagnostic cascade, thereby shortening the interval from symptom onset to treatment initiation[31].

Our findings indicate that farming occupation and migrant residential status are independently associated with higher odds of PrPD. This disparity likely reflects a convergence of farming-specific barriers: lower socioeconomic status, greater geographic distance to facilities, inflexible work schedules limiting care-seeking, and lower health literacy with delayed symptom recognition[32–34]. Migrants likewise showed elevated odds of PrPD relative to local residents, plausibly reflecting the multidimensional barriers imposed by relocation: administrative complexity, restricted insurance coverage, employment insecurity, limited provider knowledge, and linguistic and cultural mismatches[16, 20, 35]. High out-of-pocket costs deter early care-seeking among rural-to-urban migrants, a pattern repeatedly documented in China[36]. This economic barrier is compounded by the lack of health insurance coverage among migrants, who are often concentrated in informal employment and frequently wait to see whether symptoms improve to avoid paying high healthcare costs unnecessarily[37]. To reduce PrPD in this population, integrated interventions—including health education and active screening—should be implemented, and frontline providers should be equipped with enhanced diagnostic capacity for early TB detection[22, 38, 39].

The source of patient identification was strongly associated with PrPD, highlighting the critical role of case detection pathways. Passive case-finding was characterized by sequential transfers between village clinics, township hospitals, and county-designated TB facilities, which underscores the

importance of early symptom recognition before patients enter the vertical TB program. In contrast, active case-finding reduced patient delay, reinforcing the value of community-based screening. Province-wide scale-up of the existing village-doctor incentive program could extend active screening to the most remote townships. Patients with bacteriologically confirmed PTB had higher odds of PrPD than those with bacteriologically negative results. During the early disease phase, a subset of these cases may present with only mild, non-specific symptoms—such as fatigue, intermittent low-grade fever, or mild cough—that are easily overlooked[40]. These symptoms are easily mistaken for those of common respiratory infections or nonspecific fatigue, leading patients to underestimate the severity of their condition and delay care-seeking[41, 42]. Patients with bacteriologically positive results are often unaware of their infectious status and fail to recognize the urgency of early diagnosis and treatment, thereby contributing to ongoing transmission. In contrast, bacteriologically negative patients who receive abnormal chest imaging are more likely to undergo further examinations to clarify the diagnosis, driven by anxiety about the underlying etiology[43].

Our study identified a distinct temporal pattern in PrPD risk throughout the COVID-19 pandemic. During this period, the likelihood of PrPD was 25.5% higher than the pre-pandemic baseline. This increase is consistent with the documented disruption of tuberculosis services in China during the COVID-19 pandemic[27, 28], when city-wide lockdowns, the prioritization of mass nucleic acid testing, and the diversion of healthcare resources toward fever clinics and isolation wards severely compromised routine TB service delivery. Patient-level barriers were also substantial: fear of cross-infection in healthcare settings, mobility restrictions due to quarantine, and the suspension of community-based active screening—a cornerstone of China's vertical TB program. These factors collectively reduced care-seeking behavior[28]. By contrast, post-pandemic PrPD proportions fell below pre-pandemic levels, possibly reflecting the durable benefits of emergency adaptations within China's centralized health system.

Several limitations of this study need to be noted. First, delays were calculated from registry-derived dates, which may misclassify symptom onset for patients with insidious presentations, likely underestimating PrPD. Second, the analysis was limited to variables routinely collected in TBIMS. Key predictors of PrPD—such as household income, education, health insurance type, and health literacy—were unavailable, limiting our ability to fully explain regional variations.

Conclusions

This study shows that PrPD among PTB patients is influenced by demographic, clinical, geographic, and health system factors. Targeted interventions are needed for high-risk congregate groups, including older adults, farmers, migrants, and populations in economically disadvantaged regions. Given the care-seeking barriers faced by these populations, community-based active case-finding—including routine health examinations and systematic screening—would likely reduce PrPD. Improving health literacy, removing structural barriers for migrants, and ensuring equitable resource allocation constitute key strategies for effective TB control. Targeted health education for older adults, financial risk protection for rural residents and migrants, and proactive screening would help minimize patient delays and curb

community transmission. Future strategies should prioritize multi-sectoral approaches to early detection, leveraging the resilience of centralized health systems while addressing persistent gaps in community-based screening, with particular attention to structurally vulnerable populations.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Yantai Center for Disease Control and Prevention. As the analysis involved anonymized secondary data from a public health surveillance system for routine surveillance and evaluation, the requirement for informed consent was waived.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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Funding

This work was supported by the Shandong Province Medical and Health Science and Technology Project [grant number 202412050245]; the Shandong Public Health Association Research Project [grant number SDPHA202437]; and the Yantai Municipal Key Medical and Health Discipline of Preventive Medicine.

Author Contribution

LZ designed the overall research, analyzed the data, performed statistical analyses, interpreted the data and wrote the first manuscript. JZ collected and analyzed the data, and supervised the statistical analyses and interpretation. XR, XH and HH collected and analyzed the data. JL, YW conceived and supervised the study, provided critical intellectual input, critically reviewed, edited and approved the final manuscript. All authors reviewed and approved the final manuscript.

Acknowledgments

We are especially grateful to all healthcare workers and surveillance staff throughout Yantai for their tireless efforts in TB case detection, treatment, and reporting.

Data Availability

The data that support the findings of this study are available from the Yantai Center for Disease Control and Prevention, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

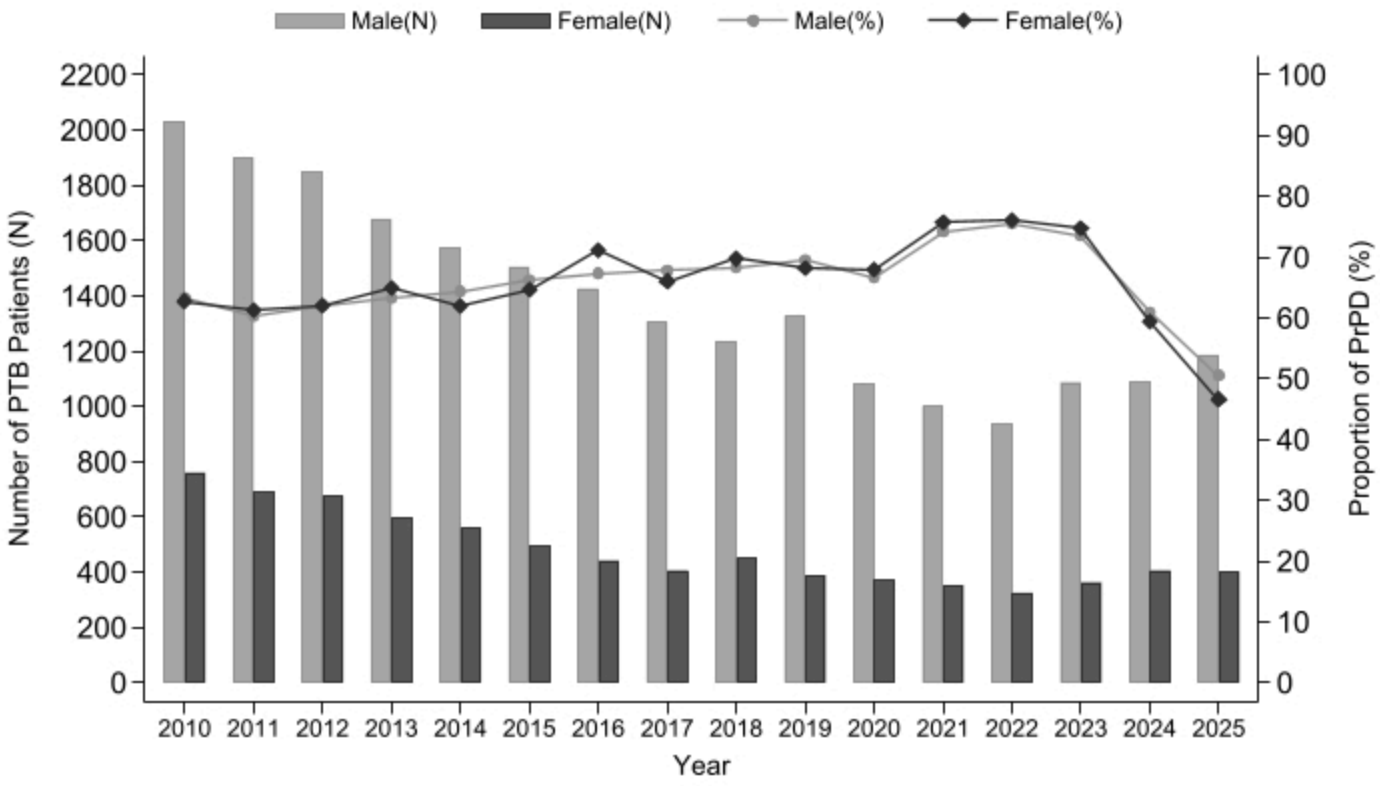


Figure 1

Trends in the number of PTB patients and the proportion of PrPD by gender, Yantai City, 2010–2025

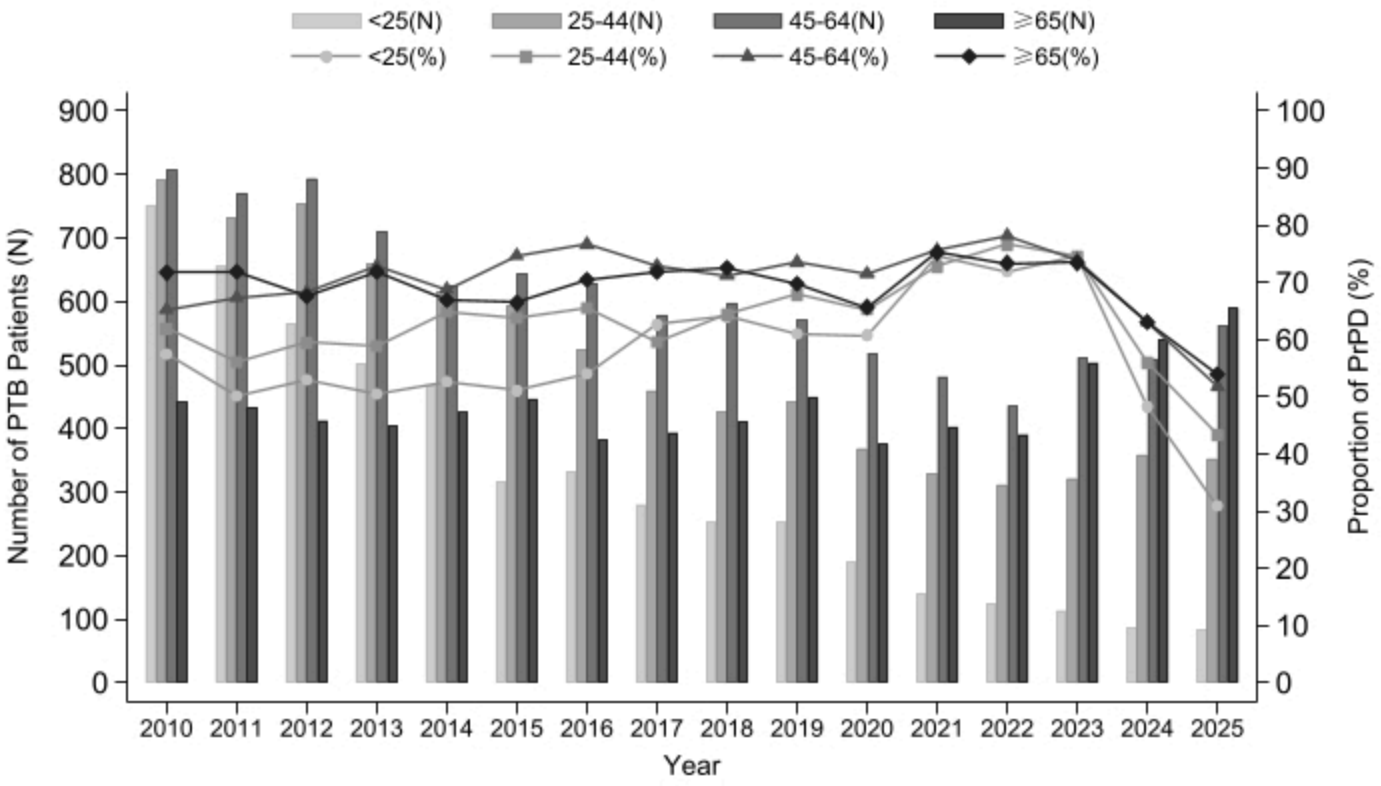


Figure 2

Trends in the number of PTB patients and the proportion of PrPD by age group, Yantai City, 2010–2025