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Temporal Trends and Heterogeneous Distribution of Tuberculosis Care Delays in Western China: A 21-Year Retrospective Study from a Regional Surveillance System

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Abstract

Background and Objective

Delays in TB care remain a major barrier to effective disease control, particularly in poor and resource-limited areas. Although previous studies have examined diagnostic and treatment delay in different settings, long-term evidence simultaneously evaluating multiple stages of delay and their relationship with treatment outcomes remains limited. This study aimed to investigate the temporal trends, associated factors, and outcome relevance of consultation delay, diagnostic delay, treatment delay, and total delay among patients with pulmonary TB in Ningxia Hui Autonomous Region, China, from 2005 to 2025.

Methods

This retrospective surveillance-based cohort study used data from the Tuberculosis Information Management System of Ningxia. A total of 53,140 patients with pulmonary TB registered between January 1, 2005 and December 31, 2025 were included in the baseline and delay analyses. Consultation delay was defined as the interval from symptom onset to the first medical visit, diagnostic delay as the interval from the first medical visit to confirmed diagnosis, treatment delay as the interval from diagnosis to treatment initiation, and total delay as the interval from symptom onset to treatment initiation. Annual trends in delay indicators were assessed using Joinpoint regression. Group differences were compared using Mann–Whitney U and Kruskal–Wallis H tests. Multivariable linear regression models were used to identify factors associated with each type of delay. Spearman correlation analysis was performed to evaluate the association between delay indicators and unfavorable treatment outcomes.

Results

Among the 53,140 patients, most were male (56.9%), aged 18–44 years (34.9%), farmers/herders/fishers (65.5%), and identified through referral/transfer (48.5%). Consultation delay and total delay showed an overall declining trend during the study period, whereas diagnostic delay and treatment delay remained consistently short. The annual median consultation delay decreased from 33 days in 2005 to 16 days in 2017, but rebounded to 35 days in 2023–2024. Total delay decreased from 45 days in 2005 to 27 days in 2015–2017, then increased to 44–45 days in 2023–2024. Joinpoint analysis showed a significant decline in consultation delay from 2005 to 2019 (APC = − 4.11%, 95% CI: −6.83% to − 1.66%) and in total delay from 2005 to 2015 (APC = − 4.47%, 95% CI: −11.55% to − 0.71%), followed by a significant increase in total delay after 2015 (APC = 4.07%, 95% CI: 2.37% to 11.49%). Longer delays were observed among older patients, farmers/herders/fishers, self-presenting patients, and bacteriologically positive cases, whereas referral/transfer and active screening were associated with shorter delays. Unfavorable treatment outcomes were weakly but significantly negatively correlated with all delay indicators.

Conclusion

The burden of delay in TB care in Ningxia was concentrated mainly before patients first entered the healthcare system, with consultation delay contributing most to total delay. Although the overall trend improved over time, the later rebound indicates that progress in timely TB care remains unstable. Delays were unevenly distributed across patient groups, particularly affecting socially and programmatically disadvantaged populations. These findings highlight the need for earlier symptom recognition, more proactive case-finding, and targeted interventions for high-risk groups to improve patient outcomes, reduce transmission, and strengthen TB control in poor areas of western China.

Introduction

Tuberculosis (TB) remains one of the leading infectious causes of morbidity and mortality worldwide and continues to impose a substantial clinical, public health, and socioeconomic burden, particularly in resource-limited settings [1]. Despite important progress in case detection and treatment coverage, delays along the care pathway—from symptom onset to first healthcare contact, diagnosis, and treatment initiation—remain a major obstacle to effective TB control [1–3]. Such delays may prolong the infectious period, increase the probability of ongoing community transmission, aggravate disease severity, and worsen the financial burden on affected households, especially in poor and medically underserved areas [2, 3]. Therefore, understanding the magnitude, determinants, and consequences of TB-related delays is essential for improving both individual prognosis and population-level TB control.

Over the past two decades, research on TB delay has progressed from simple descriptive studies to more analytically oriented investigations addressing patient pathways, healthcare access, and clinical outcomes. Systematic reviews have shown that delays in TB diagnosis and treatment remain widespread across high-burden countries, although the magnitude and dominant components of delay vary considerably by setting [2, 3]. In China, previous studies have identified a range of factors associated with delayed care, including older age, rural residence, low health literacy, first contact with lower-level health facilities, and differences in case-finding pathways [4, 5]. Recent Chinese studies have also begun to characterize temporal changes in delay and to examine how health system disruptions—such as those during the COVID-19 pandemic—can adversely affect TB detection and pre-treatment timeliness [4, 6]. In addition, region-specific evidence from Ningxia suggests that inadequate TB knowledge and unequal healthcare access remain important barriers to timely care in this setting [6, 7]. Together, these studies indicate that TB delay is a dynamic and multifactorial problem shaped by both patient-level and system-level factors.

However, several important controversies and knowledge gaps remain. First, the literature still lacks consistent operational definitions for different types of delay, particularly for patient delay, diagnostic delay, health system delay, and total delay, which complicates direct comparison across studies and weakens evidence synthesis [2, 3]. Second, the association between delay and treatment outcomes remains controversial. Although prolonged delay is generally assumed to be harmful, some observational studies have reported weak, null, or even counterintuitive associations, likely because of residual confounding,

disease severity bias, survival bias, and differences in case-mix [3, 8]. Third, most available studies from China are cross-sectional, focused on a single stage of delay, or limited to relatively short observation periods [4, 5, 8]. Long-term surveillance-based analyses that simultaneously evaluate temporal trends, determinants, and outcomes are still scarce, especially in poor areas of western China, where geographic barriers, socioeconomic disadvantage, and ethnic diversity may interact to shape care-seeking and treatment pathways in ways that differ from those in more developed regions [4, 6, 7].

To address these gaps, the present study used 21 years of surveillance data from the Tuberculosis Information Management System in Ningxia Hui Autonomous Region, China, to investigate diagnostic and treatment delay among patients with pulmonary TB from 2005 to 2025. Specifically, we aimed to: (1) describe long-term temporal trends in care-seeking, diagnostic, treatment, and overall delays; (2) identify demographic and clinical factors associated with different types of delay; and (3) evaluate the relationship between delay indicators and treatment outcomes. By providing long-term real-world evidence from a poor region in western China, this study seeks to inform more targeted strategies for case finding, early diagnosis, and timely treatment initiation in high-burden and resource-constrained settings.

Methods

2.1 Study design and reporting guideline

This was a retrospective surveillance-based cohort study of patients with pulmonary TB registered in the regional TB control system of Ningxia Hui Autonomous Region, China, between January 1, 2005 and December 31, 2025. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for observational studies [9].

2.2 Study setting

Ningxia Hui Autonomous Region is located in northwestern China and includes both urban and rural areas with substantial geographic, socioeconomic, and healthcare-access disparities. Because the region contains underserved and economically disadvantaged areas, it provides an important setting for evaluating long-term delays in TB care and their determinants under real-world programmatic conditions. The study period spanned 21 years, allowing assessment of secular trends before, during, and after major changes in TB diagnostic capacity and service delivery.

2.3 Data source

Data were extracted from the Tuberculosis Information Management System (TBIMS), the routine electronic surveillance and case-management database used within the regional TB control program. TBIMS captures patient-level information on demographics, dates of symptom onset, first medical visit, diagnosis, treatment initiation, case-finding source, diagnostic classification, and treatment outcomes. In China, pulmonary TB diagnosis in clinical and surveillance practice is based on the national diagnostic standard WS 288–2017, and TB control practice is guided by the national technical regulations for TB prevention and control [10, 11].

Before analysis, the dataset was reviewed for internal consistency, duplicate records, implausible dates, and missing values in key time variables. Variable recoding and outcome grouping followed the predefined data-processing rules used in the statistical file provided by the authors.

2.4 Participants

2.4.1 Eligibility criteria

Patients were eligible for inclusion if they met all of the following criteria:

(1) had pulmonary TB diagnosed according to WS 288–2017;

(2) were registered in TBIMS between January 1, 2005 and December 31, 2025; and

(3) had available records for the dates required to calculate delay indicators, including symptom onset, first medical visit, diagnosis, and treatment initiation.

2.4.2 Study population

A total of 53,140 patients with pulmonary TB were included in the baseline descriptive and delay analyses. For treatment outcome analyses, patients whose diagnosis was subsequently changed and those transferred to rifampicin-resistant or multidrug-resistant TB treatment pathways were excluded, because their treatment course and outcome definitions differed from those of the standard drug-susceptible TB cohort. Records with missing treatment outcome data were excluded only from analyses involving treatment outcomes and were retained in other analyses whenever the relevant variables were complete.

2.4.3 Participant flow

The full source population consisted of all pulmonary TB cases registered during the study period. Patients with incomplete key dates were excluded from the corresponding delay analyses. Patients not eligible for standard treatment outcome assessment, including diagnosis-change cases and those transferred to drug-resistant TB treatment, were excluded from the outcome cohort.

2.5 Variables

2.5.1 Delay indicators

The main study variables were four delay indicators calculated in days from dates recorded in TBIMS. Consultation delay was defined as the interval between symptom onset and the first medical visit; diagnostic delay as the interval between the first medical visit and confirmed diagnosis; treatment delay as the interval between confirmed diagnosis and treatment initiation; and total delay as the interval between symptom onset and treatment initiation.

2.5.2 Demographic and clinical covariates

Demographic and clinical covariates included sex, age at diagnosis, ethnicity, occupation, source of patient identification, and diagnostic result. Age was categorized as 0–17, 18–44, 45–59, 60–74, 75–89, and ≥ 90 years. Ethnicity was classified as Han or ethnic minority. Occupation was grouped as children/preschool children/students, farmers/herders/fishers, houseworkers/unemployed, other occupations, and employed/retired. The source of patient identification was categorized as self-presentation, referral/transfer, contact tracing, active screening/health examination, or other sources. Diagnostic result was categorized as bacteriologically positive, bacteriologically negative, or other results, including non-tuberculous mycobacteria, extrapulmonary TB, tuberculous pleurisy, or cases without bacteriological confirmation.

2.5.3 Treatment outcome

Treatment outcomes were classified according to the Chinese TB control technical regulations [11]. Favorable outcomes included cured and treatment completed, whereas unfavorable outcomes included treatment failure, death during treatment, loss to follow-up, and other unfavorable outcomes. In accordance with the predefined data-processing rules, patients who discontinued anti-TB treatment because of adverse drug reactions were grouped with loss to follow-up for outcome analysis. Patients with diagnosis change or transfer to drug-resistant TB treatment were excluded from the standard treatment outcome analyses.

2.6 Data processing and quality control

Before formal analysis, several data-processing and quality-control procedures were undertaken to improve reproducibility and reduce information bias. First, all records were checked for impossible or illogical chronological sequences, such as diagnosis occurring before the first medical visit or treatment initiation preceding diagnosis. Second, repeated registrations were screened and reconciled according to the unique surveillance record. Third, key variables, including occupation, source of patient identification, ethnicity, diagnostic result, and treatment outcome, were harmonized and recoded into analytically meaningful categories based on the prespecified rules. Finally, records were retained for each analysis only if the variables required for the corresponding model were complete. Because the date of symptom onset depended partly on patient recall, consultation delay and total delay were potentially subject to recall error, which is an inherent limitation of routine surveillance data and was taken into account when interpreting the findings. By contrast, the dates of diagnosis and treatment initiation were recorded by healthcare services and were therefore expected to be more reliable than self-reported symptom onset. This difference should be considered a possible source of differential measurement error.

2.7 Bias control

Because this study relied on routine surveillance data, several potential sources of bias were considered. First, symptom onset was based on patient recall rather than objective documentation, which may have introduced recall bias, particularly for consultation delay and total delay. Second, although the use of a regional surveillance database reduced selective inclusion of cases managed within the formal TB control system, residual confounding from unmeasured factors such as socioeconomic status, distance to healthcare facilities, comorbidities, disease severity, and health literacy could not be excluded. Third, to improve reproducibility and reduce information bias, the dataset was checked for impossible date sequences, duplicate records, and inconsistencies in key variables before formal analysis.

2.8 Statistical analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA), and a two-sided P value < 0.05 was considered statistically significant. Annual temporal trends in delay indicators were evaluated using Joinpoint regression, which identifies significant inflection points in time trends and estimates annual percent change with corresponding 95% confidence intervals [12]. Continuous variables were summarized as medians with interquartile ranges, and categorical variables were presented as frequencies and percentages.

For subgroup comparisons, differences in delay indicators between two groups were assessed using the Mann–Whitney U test, whereas differences across three or more groups were assessed using the Kruskal–Wallis H test, because the delay variables were non-normally distributed. To identify factors associated with delay, separate multivariable linear regression models were constructed for consultation delay, diagnostic delay, treatment delay, and total delay. The dependent variable in each model was the corresponding delay indicator in days. Independent variables were entered according to clinical relevance and the results of univariable analyses. Categorical variables were dummy coded using prespecified reference categories: male for sex, Han for ethnicity, farmers/herders/fishers for occupation, self-presentation for source of patient identification, and bacteriologically positive for diagnostic result. Regression coefficients, standard errors, standardized coefficients, 95% confidence intervals, and P values were reported. Multicollinearity was assessed using tolerance and variance inflation factor. Because delay variables were right-skewed, the regression coefficients were interpreted as approximate adjusted mean differences under the fitted model.

The association between delay indicators and unfavorable treatment outcomes was evaluated in the treatment outcome cohort using Spearman rank correlation analysis, because the delay variables were non-normally distributed and the outcome variable was binary. Correlation coefficients and corresponding P values were reported. Missing data were handled by analysis-specific exclusion. Records missing any key date required to calculate a given delay indicator were excluded from the corresponding delay analysis, whereas records with missing treatment outcome data were excluded only from outcome analyses. No multiple imputation was performed because this was a retrospective surveillance-based study primarily aimed at describing patterns and associations rather than developing predictive models. In accordance with STROBE recommendations, the number of observations included in each analysis should be clearly reported in the final manuscript [9].

Results

3.1 Baseline characteristics of the study population

A total of 53,140 patients with pulmonary TB registered between 2005 and 2025 were included in the baseline analysis. Overall, 30,224 (56.9%) were male and 22,916 (43.1%) were female. The largest age group was 18–44 years (34.9%), followed by 60–74 years (29.7%) and 45–59 years (18.5%). Most patients were Han ethnicity (71.0%), while 29.0% belonged to ethnic minority groups. In terms of occupation, farmers/herders/fishers accounted for the majority of cases (65.5%), followed by employed/retired individuals (13.8%) and houseworkers/unemployed individuals (11.1%). Regarding case-finding pathways, referral/transfer was the most common source of identification (48.5%), followed by self-presentation (33.9%) and contact tracing (14.3%). More than half of the patients were bacteriologically positive (54.1%), whereas 42.5% were bacteriologically negative and 3.4% were classified as having other diagnostic results. (Table 1**)**

Table 1. Baseline characteristics of tuberculosis patients in Ningxia, 2005–2025 (n = 53,140)

Characteristic	No. of cases	Proportion (%)
Gender		
Male	30224	56.9
Female	22916	43.1
Age (years)		
0-17	1815	3.4
18~44	18544	34.9
45~59	9848	18.5
60~74	15763	29.7
75~89	7054	13.3
≥90	116	0.2
Ethnicity		
Han	37722	71.0
Ethnic minority	15418	29.0
Occupation		
Scattered children/kindergarten children/students	3409	6.4
Farmer/herder/fisherman	34793	65.5
Housework/unemployed	5875	11.1
Other occupations	1720	3.2
Fixed occupation/retired	7343	13.8
Patient source		
Direct visit	17991	33.9
Referral/transfer	25753	48.5
Tracing	7609	14.3
Active screening/health examination	961	1.8
Other sources	826	1.6
Diagnostic result		
Pathogen-positive	28741	54.1
Pathogen-negative	22575	42.5
NTM/extrapulmonary TB/tuberculous pleurisy/no etiological result	1824	3.4

3.2 Temporal trends in delay indicators from 2005 to 2025

The annual median consultation delay showed an overall decline from 33 days in 2005 to 16 days in 2017, followed by fluctuations thereafter. It increased to 24 days in 2018, remained between 20 and 25 days during 2019–2022, peaked at 35 days in both 2023 and 2024, and then declined to 25 days in 2025. In contrast, the annual median diagnostic delay remained consistently short throughout the study period, ranging from 0 to 2 days. Treatment delay was also persistently low, with a median of 1 day in the earlier years and 0 days in most years after 2015. The temporal pattern of total delay broadly mirrored that of

consultation delay, decreasing from 45 days in 2005 to 27 days in 2015–2017, then increasing again to 44 days in 2023 and 45 days in 2024 before declining to 36 days in 2025.(Fig. 1**)**

Joinpoint regression identified three phases for consultation delay. From 2005 to 2019, consultation delay showed a significant downward trend (APC = − 4.11%, 95% CI: −6.83% to − 1.66%, *P* = 0.043). From 2019 to 2023, the trend reversed upward (APC = 15.59%), although this change did not reach statistical significance (*P* = 0.106). From 2023 to 2025, consultation delay decreased again (APC = − 12.26%), but this decline was also not statistically significant (*P* = 0.132). For total delay, one joinpoint was identified in 2015. Total delay decreased significantly between 2005 and 2015 (APC = − 4.47%, 95% CI: −11.55% to − 0.71%, *P* = 0.012), then increased significantly between 2015 and 2025 (APC = 4.07%, 95% CI: 2.37% to 11.49%, *P* < 0.001).(Fig. 2**)**

3.3 Univariable analysis of delay indicators across patient subgroups

Univariable analyses showed that consultation delay differed significantly by sex, age group, ethnicity, occupation, source of patient identification, and diagnostic result (all *P* < 0.001). Females had a longer median consultation delay than males (30 vs. 28 days). Across age groups, consultation delay was longest in patients aged 45–59 years and 60–74 years (both 30 days) and shortest in patients aged ≥ 90 years (22.5 days). Farmers/herders/fishers had the longest consultation delay among occupational groups (31 days), whereas employed/retired individuals and children/preschool children/students had shorter delays. By source of case detection, self-presenting patients had the longest consultation delay (32 days), whereas patients detected through active screening/health examination had the shortest delay (12 days). Consultation delay was also longest among bacteriologically positive patients (30 days). (Table 2**)**

Table 2. Univariate analysis of different types of delay among tuberculosis patients in Ningxia, 2005–2025 (n = 53,140)

Variable	Delay in seeking care			Delay in diagnosis			Delay in treatment		
	M(Q_1，Q_3)	*Z*/*H*	*P*	M(Q_1，Q_3)	Z/H	*P*	M(Q_1，Q_3)	*Z*/*H*	*P*
Gender		-7.049	＜0.001		-0.976	0.329		-0.725	0.4
Male	28（10，60）			1（0，5）			1（0，1）		
Female	30（11，63）			1（0，5）			1（0，1）		
Age (years)		227.973	＜0.001		13.865	0.016		32.272	＜0.
0-17	27(12,54)			1（0，4）			1（0，1）		
18~44	27(9,59)			1（0，4）			1（0，1）		
45~59	30(12,64)			1（0，5）			1（0，1）		
60~74	30(12,64)			1（0，5）			1（0，1）		
75~89	26(10,58)			1（0，5）			0（0，1）		
≥90	22.5(7.25,60.75)			0.5（0，4）			0（0，2）		
Ethnicity		-5.978	＜0.001		-9.276	＜0.001		-10.163	＜0.
Han	29（11，62）			1（0，5）			1（0，1）		
Ethnic minority	27(10，60)			1（0，5）			1（0，1）		
Occupation		878.216	＜0.001		82.127	＜0.001		627.173	＜0.
Scattered children/kindergarten children/students	22(7.5，45)			1（0，4）			1(0,1)		
Farmer/herder/fisherman	31(13，64)			1（0，4）			1(0,1)		
Housework/unemployed	22(8,51)			1（0，6）			0(0,1)		
Other occupations	21.5(7,59)			1（0，6）			0(0,1)		
Fixed occupation/retired	21(7,49)			1（0，5）			0(0,1)		
Patient source		852.181	＜0.001		654.209	＜0.001		388.188	＜0.
Direct visit	32(14,66)			1（0，3）			1(0,1)		
Referral/transfer	25(9,57)			1（0，6）			1(0,1)		
Tracing	30(11,64)			0（0，5）			0(0,1)		
Active screening/health examination	12(4,29)			2（0，6）			0(0,1)		
Other sources	20(9,53)			5（1，15）			1(1,1)		
Diagnostic result		358.353	＜0.001		30.463	＜0.001		221.365	＜0.
Pathogen-positive	30(12,65)			1（0，5）			1(0,1)		
Pathogen-negative	26(9,57)			1（0，5）			1(0,1)		
NTM/extrapulmonary TB/ tuberculous pleurisy/ no etiological result	22(9,46)			1（0，5）			0(0,1)		

Diagnostic delay also differed significantly across age, ethnicity, occupation, source of patient identification, and diagnostic result, but not by sex ($P = 0.329$). Median diagnostic delay was generally short across subgroups, with most values ranging from 0 to 5 days. Patients identified through other sources had the longest diagnostic delay, with a median of 5 days, whereas those identified through contact tracing had a median diagnostic delay of 0 days. (Table 2**)**

Treatment delay differed significantly by age, ethnicity, occupation, source of patient identification, and diagnostic result (all $P < 0.05$), but not by sex ($P = 0.469$). The median treatment delay was 1 day in most subgroups, although patients identified through contact tracing and those detected through active screening/health examination tended to have shorter medians of 0 days. (Table 2**)**

Total delay showed a pattern similar to consultation delay and differed significantly by sex, age, ethnicity, occupation, source of patient identification, and diagnostic result. Females had a longer median total delay than males (36 vs. 34 days). The longest total delay was observed among patients aged 60–74 years (37 days) and among farmers/herders/fishers (34 days). By source of identification, self-presenting patients and those identified through contact

tracing had relatively long total delays (37 and 42 days, respectively), whereas patients identified through active screening/health examination had the shortest total delay (18 days). Bacteriologically positive patients had a longer median total delay than the other diagnostic groups (37 days). (Table 2)

3.4 Multivariable analysis of factors associated with consultation delay

In the multivariable linear regression model, older age was independently associated with longer consultation delay (B = 2.701, $P = 0.005$). Using farmers/herders/fishers as the reference group, children/preschool children/students (B = − 17.029, $P < 0.001$), houseworkers/unemployed individuals (B = − 9.967, $P = 0.003$), and employed/retired individuals (B = − 9.122, $P = 0.003$) had significantly shorter consultation delay. Compared with self-presentation, referral/transfer (B = − 7.794, $P < 0.001$), active screening/health examination (B = − 24.980, $P = 0.002$), and other sources (B = − 18.630, $P = 0.026$) were associated with shorter consultation delay. Compared with bacteriologically positive cases, bacteriologically negative cases (B = − 15.079, $P < 0.001$) and those with other diagnostic results (B = − 25.717, $P < 0.001$) also had shorter consultation delay. The model was statistically significant ($F = 16.180$, $P < 0.001$), with an adjusted R^2 of 0.003.(Tables 3 and 4)

Table 3. Assignment of independent variables

Independent variable	Assignment
Gender	Male = 1 (reference); Female = 2
Age (years)	0–17 = 1 (reference); 18–44 = 2; 45–59 = 3; 60–74 = 4; 75–89 = 5; ≥90 = 6
Ethnicity	Han = 0 (reference); Ethnic minority = 1
Occupation	Farmer/herder/fisherman as reference. Dummy variables: scattered children/kindergarten children/students (1,0,0,0); housework/unemployed (0,1,0,0); other occupations (0,0,1,0); fixed occupation/retired (0,0,0,1)
Patient source	Direct visit as reference. Dummy variables: referral/transfer (1,0,0,0); tracing (0,1,0,0); active screening/health examination (0,0,1,0); other sources (0,0,0,1)
Diagnostic result	Pathogen-positive as reference. Dummy variables: pathogen-negative (1,0); NTM/extrapulmonary TB/tuberculous pleurisy/no etiological result (0,1)

Table 4. Multivariate analysis of delay in seeking care among tuberculosis patients (n = 53,140)

Variable	*B*	*SE*	*β*	*t*	*P*	95.0%*CI*		Tolerance	VIF
						Minimum	Maximum		
Constant	70.395	3.67		19.181	<0.001	63.202	77.588		
Age	2.701	0.967	0.013	2.792	0.005	0.805	4.597	0.857	1.166
Occupation (reference: farmer/herder/fisherman)									
Scattered children/kindergarten children/students	-17.029	4.583	-0.018	-3.716	<0.001	-26.011	-8.046	0.833	1.200
Housework/unemployed	-9.967	3.335	-0.013	-2.988	0.003	-16.503	-3.430	0.961	1.041
Fixed occupation/retired	-9.122	3.044	-0.013	-2.996	0.003	-15.089	-3.155	0.952	1.050
Patient source (reference: direct visit)									
Referral/transfer	-7.794	2.099	-0.016	-3.713	<0.001	-11.908	-3.680	0.955	1.047
Active screening/health examination	-24.980	7.871	-0.014	-3.174	0.002	-40.408	-9.553	0.955	1.047
Other sources	-18.630	8.36	-0.010	-2.229	0.026	-35.015	-2.245	0.983	1.018
Diagnostic result (reference: pathogen-positive)									
Pathogen-negative	-15.079	2.111	-0.032	-7.143	<0.001	-19.216	-10.941	0.965	1.036
NTM/extrapulmonary TB/tuberculous pleurisy/no etiological result	-25.717	5.725	-0.020	-4.492	<0.001	-36.939	-14.495	0.967	1.034
Note: $F = 16.180$, $P < 0.001$, $R^2 = 0.003$, adjusted $R^2 = 0.003$.									

3.5 Multivariable analysis of factors associated with diagnostic delay

In the multivariable model for diagnostic delay, ethnic minority patients had a shorter diagnostic delay than Han patients (B = − 17.821, $P < 0.001$). Relative to farmers/herders/fishers, children/preschool children/students (B = − 12.658, $P = 0.003$), houseworkers/unemployed individuals (B = − 9.819, $P = 0.003$), and employed/retired individuals (B = − 6.330, $P = 0.037$) had shorter diagnostic delay. Compared with self-presentation, referral/transfer (B = − 9.903, $P < 0.001$), contact tracing (B = − 15.604, $P < 0.001$), and active screening/health examination (B = − 15.894, $P = 0.042$) were all associated with shorter diagnostic delay. The model was statistically significant ($F = 16.179$, $P < 0.001$), with an adjusted R^2 of 0.002.(Table 5)

Table 5
Multivariate analysis of delay in diagnosis among tuberculosis patients (n = 53,140)

Variable	*B*	*SE*	*β*	*t*	*P*□	95.0%*CI*		Tolerance	VIF
						Minimum	Maximum		
Constant	33.588	1.948		17.245	<0.001	29.771	37.406		
Ethnicity	-17.821	2.27	-0.035	-7.851	<0.001	-22.270	-13.372	0.963	1.038
Occupation (reference: farmer/herder/fisherman)									
Scattered children/kindergarten children/students	-12.658	4.220	-0.013	-2.999	0.003	-20.930	-4.386	0.956	1.046
Housework/unemployed	-9.819	3.311	-0.013	-2.966	0.003	-16.309	-3.330	0.948	1.055
Fixed occupation/retired	-6.330	3.03	-0.009	-2.089	0.037	-12.269	-0.392	0.935	1.070
Patient source (reference: direct visit)									
Referral/transfer	-9.903	2.252	-0.021	-4.399	<0.001	-14.316	-5.490	0.807	1.239
Tracing	-15.604	3.187	-0.023	-4.896	<0.001	-21.851	-9.357	0.820	1.219
Active screening/health examination	-15.894	7.808	-0.009	-2.036	0.042	-31.198	-0.590	0.944	1.059
Note: $F = 16.179$, $P < 0.001$, $R^2 = 0.002$, adjusted $R^2 = 0.002$.									

3.6 Multivariable analysis of factors associated with treatment delay

For treatment delay, contact tracing (B = 2.963, $P < 0.001$) and other sources of identification (B = 0.929, $P = 0.020$) were independently associated with longer delay compared with self-presentation. In contrast, bacteriologically negative patients had a shorter treatment delay than bacteriologically positive patients (B = − 0.670, $P < 0.001$). The treatment-delay model showed overall statistical significance ($F = 164.392$, $P < 0.001$) and an adjusted R^2 of 0.009. (Table 6)

Table 6
Multivariate analysis of delay in treatment among tuberculosis patients (n = 53,140)

Variable	*B*	*SE*	*β*	*t*	*P*□	95.0%*CI*		Tolerance	VIF
						Minimum	Maximum		
Constant	2.014	0.069		29.383	<0.001	1.880	2.149		
Patient source (reference: direct visit)									
Tracing	2.963	0.141	0.091	21.029	<0.001	2.687	3.240	0.997	1.003
Other sources	0.929	0.399	0.010	2.328	0.020	0.147	1.711	0.997	1.003
Diagnostic result (reference: pathogen-positive)									
Negative	-0.670	0.100	-0.029	-6.721	<0.001	-0.866	-0.475	0.999	1.001
Note: $F = 164.392$, $P < 0.001$, $R^2 = 0.009$, adjusted $R^2 = 0.009$.									

3.7 Multivariable analysis of factors associated with total delay

In the total-delay model, ethnic minority status was associated with shorter total delay compared with Han ethnicity (B = − 23.221, $P < 0.001$). Relative to farmers/herders/fishers, children/preschool children/students (B = − 35.996, $P < 0.001$), houseworkers/unemployed individuals (B = − 21.020, $P < 0.001$), and employed/retired individuals (B = − 17.767, $P < 0.001$) had significantly shorter total delay. Compared with self-presentation, referral/transfer (B = − 13.027, $P < 0.001$) and active screening/health examination (B = − 40.249, $P < 0.001$) were associated with shorter total delay. Patients with other diagnostic results also had shorter total delay than bacteriologically positive patients (B = − 25.585, $P = 0.001$). The model was statistically significant ($F = 21.315$, $P < 0.001$), with an adjusted R^2 of 0.003. (Table 7)

Table 7
Multivariate analysis of total delay among tuberculosis patients (n = 53,140)

Variable	*B*	*SE*	*β*	*t*	*P*	95.0%*CI*		Tolerance	VIF
						Minimum	Maximum		
Constant	105.881	2.532		41.823	<0.001	100.919	110.843		
Ethnicity	-23.221	3.237	-0.032	-7.173	<0.001	-29.566	-16.876	0.965	1.037
Occupation (reference: farmer/herder/fisherman)									
Scattered children/kindergarten children/students	-35.996	6.027	-0.026	-5.973	<0.001	-47.809	-24.183	0.955	1.047
Housework/unemployed	-21.020	4.700	-0.020	-4.473	<0.001	-30.231	-11.808	0.959	1.043
Fixed occupation/retired	-17.767	4.319	-0.018	-4.113	<0.001	-26.233	-9.301	0.937	1.067
Patient source (reference: direct visit)									
Referral/transfer	-13.027	2.933	-0.020	-4.441	<0.001	-18.775	-7.278	0.969	1.032
Active screening/health examination	-40.249	11.059	-0.016	-3.639	<0.001	-61.926	-18.572	0.959	1.043
Diagnostic result (reference: pathogen-positive)									
NTM/extrapulmonary TB/tuberculous pleurisy/no etiological result	-25.585	7.937	-0.014	-3.224	0.001	-41.141	-10.029	0.997	1.003
Note: $F = 21.315$, $P < 0.001$, $R^2 = 0.003$, adjusted $R^2 = 0.003$.									

3.8 Association between delay indicators and unfavorable treatment outcomes

Among 48,663 patients included in the treatment outcome analysis, Spearman correlation analysis showed that unfavorable treatment outcomes were significantly but weakly negatively correlated with consultation delay (r = − 0.031, $P < 0.01$), diagnostic delay (r = − 0.013, $P < 0.01$), treatment delay (r = − 0.013, $P < 0.01$), and total delay (r = − 0.031, $P < 0.01$).

Discussion

Overview of the main findings

This study aimed to investigate the long-term trends, associated factors, and outcome relevance of TB care delays in a poor area of western China using 21 years of surveillance data. Overall, consultation delay and total delay decreased markedly over time, whereas diagnostic delay and treatment delay remained consistently short, indicating that the main burden of delay occurred before patients first sought medical care. The study also showed that delay was unevenly distributed across patient groups, with longer delays observed among older patients, farmers/herders/fishers, self-presenting patients, and bacteriologically positive cases, while referral/transfer and active screening were associated with shorter delays. In addition, although delay indicators were significantly associated with unfavorable treatment outcomes, these associations were weak and negative in direction. A notable feature of this study is that it simultaneously assessed multiple stages of delay over a 21-year period within a single regional surveillance system, demonstrating that consultation delay accounted for most of the overall delay burden and that the temporal pattern of improvement was not entirely stable, with a rebound observed in the later years.

Temporal changes in different types of delay

The temporal pattern of TB care delay has been reported previously, and there is relatively consistent evidence that patient-side delay remains the dominant component of overall delay in many settings, whereas delays after entry into the healthcare system have become shorter with improvements in diagnostic capacity and service organization [1, 3, 12, 13]. Previous studies from China and other high-burden countries have shown that the greatest contribution to total delay usually occurs before the first healthcare contact rather than after clinical presentation. For example, a study from Hubei reported that patient delay was substantially longer than diagnostic and treatment delay, suggesting that healthcare-seeking behavior was the main barrier to timely TB care [3]. Similarly, a trend study from northwest China found that the risk of diagnostic delay decreased over time, reflecting gradual improvements in the regional TB control system [12]. International evidence has also shown that, although treatment initiation and diagnostic procedures have become more efficient in many settings, prolonged delay before the first medical visit remains common, especially in socioeconomically disadvantaged populations [13]. In addition, the COVID-19-related study from Ningxia indicated that pre-treatment delay increased during periods of health system disruption, further suggesting that the patient-entry stage is particularly sensitive to external shocks [1]. In line with these observations, our study found that consultation delay and total delay decreased markedly over the 21-year study period, whereas diagnostic delay and treatment delay remained consistently short throughout most years, indicating that the major burden of delay was concentrated before patients first sought medical care. This finding suggests that, in the study setting, the later stages of the TB care pathway were relatively efficient once patients entered the healthcare system, while the principal bottleneck remained at the stage of symptom recognition and healthcare seeking. A possible explanation is that, over time, the expansion of designated TB services, improved diagnostic accessibility, and more standardized treatment pathways may have reduced delays within the health system itself, but these improvements may not have

fully translated into earlier care-seeking at the community level. Persistent barriers such as low symptom awareness, financial constraints, transportation difficulties, stigma, and delayed perception of disease severity may therefore continue to prolong the interval before first presentation. Another notable feature of our findings is that, despite the long-term downward trend, consultation delay and total delay rebounded in the later years of the study period. This pattern may reflect the fact that gains in TB care timeliness are not necessarily stable and may be disrupted by broader contextual factors, including changes in healthcare accessibility, public health emergencies, and fluctuations in care-seeking behavior. Thus, although our results are generally consistent with previous evidence showing that patient-side delay remains the main contributor to overall delay, they further highlight the long-term persistence and instability of this problem in poor areas of western China.

Heterogeneity of delay across patient subgroups

The unequal distribution of TB-related delay across patient subgroups has been reported in previous studies and is generally regarded as an established finding, although the specific contribution of bacteriological status remains less consistently described across settings [4, 6, 13, 14, 15]. Earlier studies from China have shown that older age and disadvantaged social position are important correlates of delayed care. In a large multicentre retrospective cohort study, patient-pathway complexity and repeated contacts before definitive diagnosis were associated with prolonged diagnostic delay, highlighting that delay is not uniformly distributed even after patients enter the healthcare system [6]. A study from Hubei similarly found substantial variation in delay according to case-finding pathway, with patients identified through routine healthcare-seeking processes tending to experience longer delays than those detected through more organized pathways [13]. In northwest China, Chen et al. reported that delay patterns differed by demographic and clinical characteristics, and smear-positive patients had longer delays than smear-negative patients [4]. International evidence from diverse settings, including a study from tropical Australia, has similarly identified factors such as remote residence, indigenous ethnicity, and atypical presentations as contributors to diagnostic delay [16]. Lin et al., using routine TB service data from several provinces in China, also found that patient delay was more common among socioeconomically vulnerable populations, particularly those living in rural settings and with limited access to timely care [15]. In contrast, evidence from active case-finding studies suggests that organized screening can shorten the time to detection by identifying cases earlier in the disease course and among individuals who might not otherwise present promptly to health services [17]. In our study, delay was likewise unevenly distributed across patient groups: longer delays were observed among older patients, farmers/herders/fishers, self-presenting patients, and bacteriologically positive cases, whereas referral/transfer and active screening were associated with shorter delays. These findings reinforce the view that delay is shaped not only by biological presentation but also by social vulnerability and the route through which patients are brought into care. A plausible explanation is that older patients and farmers/herders/fishers may have poorer symptom recognition, lower health literacy, greater transportation barriers, and more limited access to medical services, all of which can prolong the interval before appropriate care is obtained. The shorter delays observed among referral/transfer and active-screening cases are also biologically and programmatically plausible, because these pathways are more likely to identify patients earlier, including those with milder, subclinical, or less advanced disease who have not yet experienced prolonged self-initiated delay. Another noteworthy finding in our study is that bacteriologically positive cases had longer delays, which may at first seem counterintuitive given their higher bacillary burden. One possible explanation is that bacteriological positivity in routine programmatic data may partly reflect a more advanced stage of disease that emerges after a longer symptomatic period rather than a factor that accelerates care seeking. This interpretation is supported by prior work showing that longer delay is associated with more severe clinical presentation and a higher probability of smear positivity [4, 18]. Overall, our results are largely consistent with previous evidence, but they further emphasize that the burden of delay in poor areas of western China is concentrated in socially and programmatically disadvantaged groups and that case-finding strategy substantially modifies the timeliness of TB care.

Association between delay indicators and unfavorable treatment outcomes

The relationship between TB-related delay and treatment outcome remains controversial rather than fully settled, because previous studies have reported inconsistent findings across populations and study designs [7, 19–22]. Several studies have supported the conventional assumption that longer delay is associated with worse prognosis. For example, Lee et al. reported in a nationwide retrospective cohort that longer treatment delay was associated with lower treatment completion and higher mortality, particularly among older patients [19]. Gebreegziabher et al. also found that longer total delay was associated with unfavorable treatment outcomes in a cohort study, suggesting that prolonged delay may contribute to disease progression before effective therapy is started [20]. Likewise, Virenfeldt et al. showed that treatment delay was associated with greater clinical severity at the time of diagnosis, supporting the biological plausibility that prolonged untreated disease may worsen subsequent outcomes [21]. However, not all studies have shown a straightforward harmful effect. In a retrospective study from Shandong, Zhu et al. found that the association between diagnostic delay and prognosis was more complex than expected and not always strongly adverse [7]. Earlier work by Vree et al. even reported that high mortality during TB treatment did not increase with longer diagnostic delay and might appear lower in patients with longer delay, indicating that the observed association could be distorted by selection effects [22]. In our study, although all delay indicators were significantly associated with unfavorable treatment outcomes, these associations were weak and negative in direction. This finding suggests that, in routine surveillance data, delay does not necessarily behave as a simple linear predictor of poor prognosis. A plausible explanation is that patients with severe or rapidly progressive disease may present earlier because of more alarming symptoms, thereby having shorter measured delays but worse outcomes, whereas patients with milder or less aggressive disease may experience longer delays yet still achieve relatively favorable treatment results. In addition, residual confounding by disease severity, comorbidities, adherence, nutritional status, and healthcare access may influence both delay and outcome. Survival bias may also contribute, as some patients with very severe disease may die before completing the usual diagnostic pathway and therefore be incompletely represented in delay analyses. For these reasons, our findings do not imply that delay is harmless; rather, they indicate that the observed relationship between delay and treatment outcome in surveillance-based studies is likely to be confounded by differences in case mix and clinical presentation, and thus should be interpreted with caution.

Long-term multi-stage assessment and temporal instability of delay patterns

The value of evaluating multiple stages of TB-related delay over a long observation period within a single surveillance system has not been fully addressed in most previous studies, and the temporal instability of improvement remains insufficiently described. Existing studies have more often focused on a single component of delay, a relatively short time window, or a specific phase of the care pathway rather than simultaneously examining consultation, diagnostic, treatment, and total delay within one consistent regional dataset [4, 6, 13, 23, 24]. Earlier evidence has shown that patient-side delay frequently constitutes the largest share of total delay. A systematic review by Sreeramareddy et al. found that, across many settings, the interval before first healthcare contact was often longer and more variable than the time spent within the health system after presentation [24]. Similarly, Yang et al. reported from Hubei that delays in care seeking contributed substantially more to the overall delay burden than subsequent diagnostic and treatment steps [13]. In northwest China, Chen et al. demonstrated that the risk of delay declined over time, but their analysis primarily addressed diagnostic delay rather than the entire cascade of delay stages [4]. Zhang et al. described patient pathways to diagnosis in a multicentre Chinese cohort and highlighted the complexity of pre-diagnostic trajectories, but the study was not designed to evaluate long-term secular trends [6]. More recently, Wang et al. reported that patient delay in Wuhan declined over a decade, although the extent of improvement differed across subgroups, suggesting that temporal gains were not uniform even within one city [23]. In addition, the COVID-19 study from Ningxia showed that pre-treatment delay increased during the pandemic, indicating that previously achieved improvements in timeliness could be disrupted under adverse system conditions [5]. Against this background, our study adds a distinctive perspective by simultaneously assessing multiple stages of delay over a 21-year period within a single regional surveillance system, showing that consultation delay accounted for most of the overall delay burden, whereas diagnostic delay and treatment delay remained consistently short in most years. Another notable finding was that the temporal pattern of improvement was not completely stable, with a rebound in consultation delay and total delay observed in the later years. This suggests that progress in TB care timeliness should not be interpreted as a linear or irreversible process. A plausible explanation is that long-term improvements in diagnostic tools, referral mechanisms, and standardized treatment services may have shortened post-contact delays, while barriers operating before healthcare entry—such as symptom under-recognition, access constraints, social vulnerability, and changing healthcare-seeking behavior—remained more difficult to eliminate. The later rebound may also reflect the cumulative effect of external disruptions, including public health emergencies, changes in service accessibility, or widening disparities between more accessible and less accessible populations. Therefore, compared with previous studies, our findings not only confirm the dominant contribution of consultation delay to the overall burden but also highlight that the trajectory of improvement is dynamic and potentially fragile, especially in poor areas with persistent structural barriers.

Limitations

This study has several limitations. First, because it was based on retrospective surveillance data, the analysis depended on the accuracy and completeness of routinely recorded information, and misclassification or recording errors could not be fully excluded. This may have introduced measurement bias and affected the precision of the estimated delay indicators and their associations. Future studies should strengthen data validation procedures and incorporate prospective quality-control mechanisms. Second, some key time points, particularly symptom onset, were based on patient recall rather than objective records, which may have led to recall bias, especially for consultation delay and total delay. Such bias could have resulted in either overestimation or underestimation of the true duration of delay. Prospective studies with standardized symptom diaries or structured interviews at first presentation would help improve the accuracy of delay measurement. Third, although the study included several demographic and clinical variables, important potential confounders such as socioeconomic status, education, distance to health facilities, comorbidities, disease severity, stigma, and health literacy were not available in the surveillance database. As a result, the multivariable models had limited explanatory power, and residual confounding may have influenced both the observed subgroup differences and the association between delay and treatment outcomes. Future research should incorporate more detailed individual- and system-level variables to better explain heterogeneity in delay. Fourth, the observed associations between delay indicators and unfavorable treatment outcomes were weak and negative in direction, and these findings should be interpreted cautiously because they may reflect selection bias, survival bias, and confounding by disease severity rather than a true protective effect of longer delay. More robust analytical approaches, including multivariable outcome models, time-to-event analyses, and causal inference methods, are needed to clarify the relationship between delay and prognosis. Fifth, the study was conducted in a single regional surveillance system in a poor area of western China, and the findings may not be fully generalizable to other provinces or countries with different health service structures, social contexts, or TB epidemiology. Multicenter studies across diverse settings would therefore be valuable to assess the external validity of these findings. Finally, although the long study period was a major strength, changes in diagnostic technologies, case-finding strategies, and health policies over time may also have influenced delay patterns, making direct comparison across years more complex. Future studies could address this by using period-stratified analyses or policy-sensitive models to better distinguish secular trends from programmatic changes.

Conclusion

This 21-year surveillance-based study showed that the overall burden of delay in TB care in a poor area of western China was concentrated mainly in the pre-contact stage, with consultation delay contributing far more to total delay than delays after entry into the healthcare system. Although delay indicators generally improved over time, the observed rebound in later years indicates that progress in timely TB care remains vulnerable and uneven across patient groups. Older patients, farmers/herders/fishers, self-presenting patients, and bacteriologically positive cases were more likely to experience prolonged delay, highlighting persistent inequalities in access to timely diagnosis and treatment.

These findings have important implications. For patients, reducing delay means earlier diagnosis, earlier treatment, lower disease severity, and a better chance of avoiding prolonged suffering and adverse outcomes. For clinicians and TB control providers, the results suggest that improving diagnostic efficiency alone is not sufficient; greater attention must be directed toward earlier symptom recognition, timely healthcare seeking, and more proactive case-finding among high-risk and socially vulnerable populations. For society and public health systems, shortening delay is essential not only for improving individual prognosis but also for reducing ongoing transmission, narrowing health inequalities, and strengthening the resilience of TB control programs in

resource-limited settings. Overall, this study underscores the need for patient-centered, community-oriented, and system-sensitive strategies to promote earlier entry into care and sustain long-term improvements in TB control.

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Institutional Review Board of the Fourth People's Hospital of Ningxia Hui Autonomous Region (2024-QSY-004). The study was conducted in accordance with the Declaration of Helsinki. Because the study was based on de-identified retrospective surveillance data collected during routine programmatic practice, the requirement for informed consent was waived by the Institutional Review Board of the Fourth People's Hospital of Ningxia Hui Autonomous Region.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form (such as individual details, images, or videos). All data presented are aggregated or de-identified.

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contribution

GL and JL: Formal analysis, Writing—review & editing, Conceptualization.GL and HW: Investigation, Writing—review & editing, Data curation, Methodology, Resources. JL: Data curation, Investigation, Methodology, Resources, Writing—review & editing. LW: Data curation, Formal analysis.

Data Availability

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors,, Jiangping Li (lijp@nxmu.edu.cn).

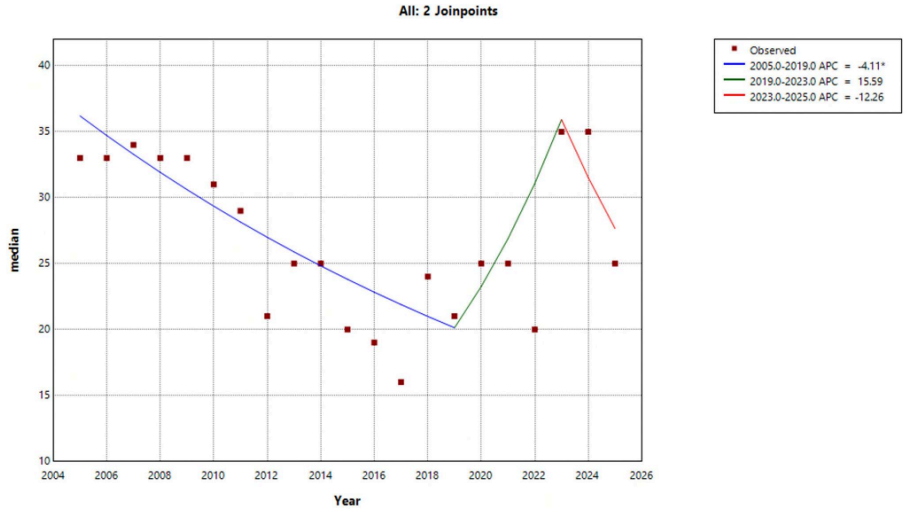
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Figures

Figure1.



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 2 Joinpoints.

Estimated Joinpoints

Joinpoint	Estimate	Lower CI	Upper CI
1	2019	2008	2020
2	2023	2017	2023

Annual Percent Change (APC)

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI	P-Value
1	2005	2019	-4.1072*	-6.8324	-1.6624	0.042791
2	2019	2023	15.5888	-7.4284	31.3882	0.106379
3	2023	2025	-12.2568	-23.6316	6.7229	0.131974

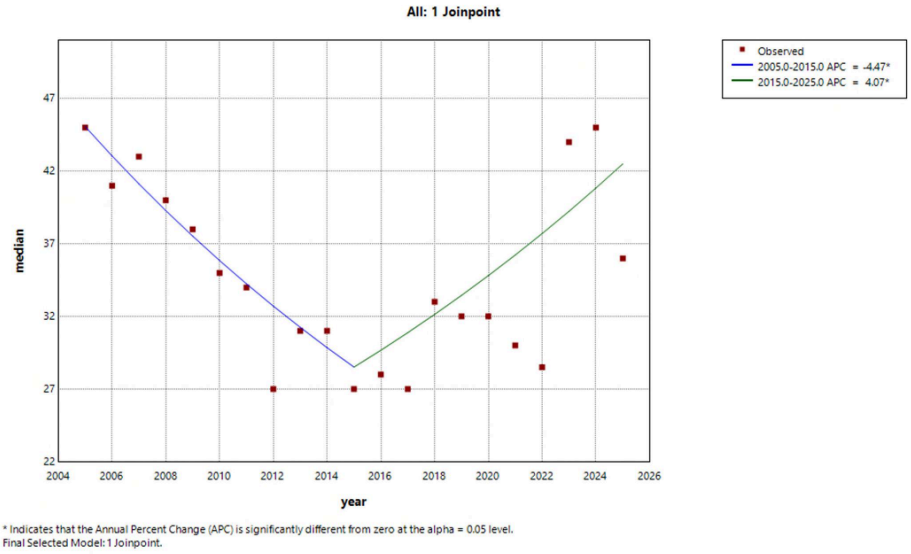
* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
-- Test Statistic not available for the Empirical Quantile metho See Help to Learn More

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI	P-Value
1	2005	2019	-4.1072*	-6.8324	-1.6624	0.042791
2	2019	2023	15.5888	-7.4284	31.3882	0.106379
3	2023	2025	-12.2568	-23.6316	6.7229	0.131974

Figure 1

Legend not included with this version.

Figure2.



Joinpoint	Estimate	Lower CI	Upper CI
1	2015	2011	2021

Segment	Lower Endpoint	Upper Endpoint	APC	Lower CI	Upper CI	P-Value
1	2005	2015	-4.4739*	-11.5490	-0.7092	0.012398
2	2015	2025	4.0718*	2.3695	11.4896	< 0.000001

Figure 2

Legend not included with this version.