

HIV–TB co-infection in Liangshan, a resource-limited region of Southwest China: trends and implications in the context of integrated prevention, 2019–2024

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Case Report

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Abstract

Objective

To analyze epidemiological trends and key factors of HIV–TB co-infection in Liangshan Yi Autonomous Prefecture (2019–2024), a resource-limited region in Southwest China, and inform integrated prevention strategies.

Methods

A retrospective analysis was conducted on 3,367 HIV–TB co-infected cases extracted from the National HIV/AIDS and TB surveillance systems. Records were linked via unique identifiers. Descriptive statistics and chi-square tests for trend assessed incidence trends, demographics, transmission routes, treatment outcomes, and drug resistance.

Results

Under the Integrated Prevention and Control of Four Diseases policy and precision prevention and control model, HIV–TB incidence declined from 12.26 to 8.76 per 100,000 ($\chi^2_{\text{trend}}=40.459$, $P < 0.001$), driven by high-burden counties and populations under 45 years (all $P < 0.001$). Patients were predominantly young males (61.10%) and farmers (92.40%). The main HIV transmission routes were heterosexual contact (48.29%) and injection drug use (41.31%), with marked sex and age disparities: injection drug use predominated in males (50.92%) and those aged 30–45 years (50.32%), while heterosexual transmission prevailed in females (77.07%) and older adults (≥ 60 years, 87.62%). Treatment success rate was 81.76%, significantly lower in the elderly (69.52%, $P < 0.05$). Any drug resistance (3.30%) increased from 1.54% to 3.10% ($\chi^2_{\text{trend}}=8.481$, $P_{\text{trend}}=0.004$), driven by rifampicin resistance ($\chi^2_{\text{trend}}=9.890$, $P_{\text{trend}}=0.002$).

Conclusion

Integrated strategies achieved initial success reducing HIV–TB incidence, particularly in high-burden areas and younger populations. Persistent challenges—stagnant incidence and poor outcomes in the elderly, high loss to follow-up (10.87%), rising drug resistance—require targeted interventions: leveraging the Yi “clan” (*Jiazhi*) system, strengthening active screening and nutritional support for older adults, optimizing drug resistance surveillance, and integrating digital health tools.

Background

Tuberculosis (TB) remains a serious global public health threat. According to the World Health Organization, the estimated global TB incidence rate in 2023 was 134 per 100,000 population, a rise from 2020 [1], and still far from the 2025 and 2035 targets set by the End TB Strategy [2]. China, as one of the world's high-burden countries, had an estimated approximately 741,000 new TB cases in 2023, ranking third globally, and the absolute number of newly reported cases remaining a notable public health concern [1].

Within China, Sichuan Province is a key region for persistent TB transmission, with marked spatial heterogeneity in its epidemic distribution [3]. Liangshan Yi Autonomous Prefecture bears one of the heaviest TB burdens in Sichuan. During the 13th Five-Year Plan period (2016–2020), the reported pulmonary TB incidence in Liangshan consistently ranked among the highest in the province. This situation is closely linked to socioeconomic vulnerabilities, including geographic remoteness, economic underdevelopment, and limited healthcare resources [4, 5]. Key populations, including ethnic minorities and children in rural areas—face a disproportionately high TB incidence [6]. This burden is compounded by significantly low vaccination coverage among ethnic minority children, which poses an additional transmission risk [7].

In addition to its high TB burden, Liangshan also faces a severe and long-standing HIV epidemic. As the largest Yi-inhabited area in China and a resource-limited region, its unique socio-cultural context—including relatively open attitudes toward sexuality, very low condom use within marriage, unique marriage customs, and a history of drug production and trafficking—has shaped a complex HIV epidemic landscape [8, 9]. In recent years, the local HIV epidemic shifted from concentrated transmission among high-risk groups (e.g., people who inject drugs) to general population spread, with heterosexual transmission gradually replacing injection drug use as the main route, reflecting the increasing complexity of the local transmission network [10, 11]. This community-based, widespread HIV transmission pattern creates conditions conducive to the synergistic spread of opportunistic infections such as TB.

The convergence of these two epidemics presents a major global public health challenge. They exacerbate each other pathologically: HIV infection not only increases the risk of latent TB reactivation and progression to active disease but also complicates TB diagnosis and treatment, leading to significantly higher mortality among co-infected patients [12, 13]. Globally, TB is the leading cause of death among people living with HIV, with case fatality rates far exceeding those in HIV-negative individuals [1]. Global Burden of Disease studies show that the burden of HIV-TB co-infection falls most heavily on young adults and is strongly negatively correlated with the Socio-demographic Index (SDI) [14]. Low- and middle-income countries with a high disease burden face escalating challenges in clinical diagnosis and treatment delivery [15–19].

These challenges are equally evident in China, where TB is one of the most common opportunistic infections among people living with HIV [20]. Reports from several provinces—including Guangxi and Guizhou—indicate that HIV-TB co-infection has emerged as a critical public health issue affecting local populations [21–24]. This dual epidemic is particularly prominent in Liangshan. As early as 2008, Butuo County became the first county in China where the proportion of reported people living with HIV/AIDS exceeded 1% of the permanent population [25]. Local studies have found an HIV co-infection rate of 14.4% among

hospitalized smear-positive pulmonary TB patients [26]. The two diseases exhibit significant spatial and demographic overlap, with synergistic transmission effects, posing a persistent threat to high-risk groups such as children and ethnic minorities [27–29].

In response to the severe HIV-TB co-infection crisis in Liangshan, the Chinese government launched the Integrated Prevention and Control of Four Diseases (IPC4D) policy in 2021, integrating HIV, TB, hepatitis C, and syphilis into a unified prevention and control framework. At the grassroots level, the multi-sectoral "1 + M + N+P" precision prevention and control model was gradually established: local governments provide coordination and leadership ("1"); township health centers deliver technical support ("M"); village doctors, HIV prevention workers, and maternal and child health workers are responsible for follow-up and health education ("N"); and public security departments assist with epidemiological investigations and patient tracing ("P"). Through integrated planning, information sharing, and coordinated service delivery, this initiative aims to improve patient management efficiency and treatment success rates.

Attributable to targeted policy support and increased financial investment, HIV and TB screening efforts in Liangshan have been systematically expanded, and health education activities have been innovatively promoted to raise public awareness and reduce disease-related discrimination [30]. However, local prevention and control efforts still face considerable challenges: uneven resource allocation, with TB (particularly drug-resistant TB) remaining chronically underfunded; health workforce shortages, excessive workload at the grassroots level, and widespread professional burnout [31]; and timely treatment initiation and patient adherence continue to be affected by disease-related stigma, economic burden, and cultural and language barriers—all of which increase the risk of adverse outcomes for anti-tuberculosis treatment (ATT) [32].

In this context, analyzing the epidemiological trends of HIV-TB co-infection in Liangshan based on surveillance data serves two key purposes: to evaluate the interim effectiveness of the IPC4D policy and to identify critical weak links in real-world prevention and control practices. By objectively characterizing population-level trends, this analysis can help consolidate and optimize local control strategies and provide important insights for other resource-limited regions with a high burden of HIV-TB co-infection.

Methods

Study design and setting

We conducted a retrospective case study in Liangshan Yi Autonomous Prefecture, Sichuan Province, a resource-limited region in Southwest China with a population of approximately 5.5 million and a dual high burden of HIV and tuberculosis.

Data sources and linkage

Data on HIV and TB cases among permanent residents of Liangshan Prefecture from 2019 to 2024 were obtained from the National Comprehensive HIV/AIDS Information Management System (CRIMS) and the Tuberculosis Information Management System (TBIMS) of the Chinese Center for Disease Control and Prevention. We extracted the TB database from the TBIMS and, in parallel, exported the HIV database (including both the real-time database and historical records from the CRIMS). All data were retrieved by designated personnel and encrypted prior to analysis.

Individual records from the two databases were linked using unique national identification numbers to create an integrated, de-identified database of HIV-TB co-infected cases. Demographic data for Liangshan Prefecture for the period 2019–2024 were obtained from the annual household registration records of the Sichuan Provincial Department of Public Security. For patients with recorded deaths during follow-up, causes of death were supplemented through linkage with the China Cause of Death Reporting System (CDRS) (Fig. 1).

Study population and definitions

Data Cleaning, Study Population and Definitions

We performed data cleaning on records of incident TB cases among permanent residents in Liangshan Prefecture from 2019 to 2024 in the integrated database. Records were excluded if they had incomplete treatment initiation dates, revised diagnoses, or TB infection alone (without HIV co-infection). Ultimately, 3,367 patients with HIV-TB co-infection were included in the analysis. Definitions of HIV/AIDS, TB cases, and treatment outcomes in this study strictly adhered to China's current national health industry standards and technical specifications [33, 34], and were aligned with relevant WHO guidelines [35, 36]. All case information was reported in a standardized manner.

Data analysis

We used SPSS version 30.0 and Excel 2007 to conduct descriptive statistical analyses of annual reported incidence, age, sex, ethnicity, marital status, education level, occupation, probable transmission routes and anti-TB treatment outcomes among the screened co-infected patients. Non-normally distributed continuous data were presented as median with interquartile range (P25, P75). The chi-square test was used for comparison of proportions, and the chi-square test for trend was used to assess temporal changes. Statistical significance was set at $\alpha = 0.05$.

Results

Epidemiological trends and population profile

From 2019 to 2024, a total of 3,367 HIV–TB co-infected cases were identified in Liangshan Prefecture, Sichuan Province. The majority of patients were male: 2,547 cases (75.60%) were male and 820 (24.40%) were female. The median age was 37 years (interquartile range [IQR]: 32–43). The predominant age group was 30–45 years, accounting for 61.10%, followed by 45–60 years (18.40%), 15–30 years (13.60%), < 15 years (3.70%), and ≥ 60 years (3.10%). Most patients were farmers (92.40%), with smaller proportions being students (2.90%), homemakers or unemployed individuals (1.10%), and other occupations.

Against the policy backdrop of integrated prevention such as the IPC4D initiative, the reported incidence of HIV–TB co-infection in Liangshan Prefecture showed a significant downward trend from 2019 to 2024 ($\chi^2_{trend} = 40.459$, $P_{trend} < 0.001$). According to local demographic data, incidence varied significantly across population subgroups over the six years: it was markedly higher in males (15.26 per 100,000) than in females (5.19 per 100,000) ($\chi^2 = 793.847$, $P < 0.001$). Differences in incidence by age group and county were also statistically significant (both $P < 0.001$). The highest incidence was in the 30–45-year age group (33.08 per 100,000), followed by the 45–60-year group (9.88 per 100,000). Butuo County (50.90 per 100,000), Zhaojue County (36.40 per 100,000), Meigu County (17.78 per 100,000), Yuexi County (17.41 per 100,000), and Jinyang County (17.24 per 100,000) ranked as the top five high-burden areas by incidence (Table 1).

Table 1
Reported incidence of HIV–TB co-infection in Liangshan Prefecture, 2019–2024, by demographic and geographic characteristics (*n* = 3,367)

Characteristic	Reported cases, <i>n</i>	Reported incidence (per 100,000)	χ^2 / χ^2_{trend}	<i>P</i> value/ <i>P</i> _{trend} value
Year of report			40.459*	< 0.001
2019	651	12.26		
2020	605	11.35		
2021	570	10.57		
2022	524	9.65		
2023	533	9.72		
2024	484	8.76		
Sex			793.847	< 0.001
male	2547	15.26		
female	820	5.19		
Age group (years)			4097.936	< 0.001
< 15	126	1.51		
15–30	459	5.97		
30–45	2057	33.08		
45–60	620	9.88		
≥ 60	105	2.67		
Place of residence			4927.384	< 0.001
Butuo County	675	50.90		
Zhaojue County	742	36.40		
Meigu County	307	17.78		
Yuexi County	401	17.41		
Jinyang County	225	17.24		
Puge County	202	15.10		
Xide County	163	12.28		
Ganluo County	149	10.26		
Xichang City	190	4.25		
Leibo County	66	3.79		
Mianning county	83	3.39		
Dechang County	42	3.18		
Yanyuan County	65	2.79		
Ningnan County	26	2.14		
Muli Tibetan Autonomous County	9	1.09		
Huidong County	12	0.47		
HuiLi City	10	0.36		
Note: * indicates chi-square test for trend.				

Temporal trends and drivers of decline

Analysis of annual incidence trends among HIV–TB co-infected patients with different characteristics in Liangshan from 2019 to 2024 showed that the overall decline was primarily driven by geographic and age factors.

Geographically, the overall decline was mainly attributable to significant improvements in high-burden counties: Butuo, Zhaojue, Yuexi, Jinyang, and Xide—counties with higher baseline incidence—all showed significant downward trends in average annual reported incidence (all $P_{trend} < 0.05$), whereas counties with lower baseline incidence showed no temporal changes. By age, all age groups under 45 years showed significant declines (all $P_{trend} < 0.001$). For the 45–60-year group, the downward trend approached the threshold of statistical significance ($\chi^2_{trend} = 4.021$, $P_{trend} = 0.045$), while the ≥ 60 -year group showed no significant decline ($\chi^2_{trend} = 2.757$, $P_{trend} = 0.097$). The average annual incidence for both sexes showed downward trends over the six years (both $P_{trend} < 0.001$) (Table 2).

Table 2
Annual reported incidence of HIV–TB co-infection in Liangshan Prefecture, 2019–2024 (*n* = 3,367)

Characteristic	2019		2020		2021		2022		2023		2024	
	Cases, <i>n</i>	Incidence (per 100,000)	Cases, <i>n</i>	Incidence (per 100,000)	Cases, <i>n</i>	Incidence (per 100,000)	Cases, <i>n</i>	Incidence (per 100,000)	Cases, <i>n</i>	Incidence (per 100,000)	Cases, <i>n</i>	Incidence (per 100,000)
Place of residence												
Butuo County	156	72.80	139	64.74	71	32.57	104	46.72	94	41.38	111	48.38
Zhaojue County	88	25.84	110	33.49	162	48.25	118	34.66	142	41.15	122	35.01
Jinyang County	64	30.04	36	16.78	45	20.78	26	11.91	32	14.52	22	9.91
Yuxi County	86	22.99	81	21.60	64	16.78	65	16.84	54	13.80	51	12.89
Xide County	47	20.85	21	9.72	29	13.22	24	10.86	22	9.89	20	8.95
Meigu County	50	17.95	49	17.47	44	15.40	56	19.30	60	20.38	48	16.16
Puge County	33	15.12	40	18.26	39	17.54	38	17.00	22	9.74	30	13.10
Ganluo County	33	13.97	19	7.99	31	12.83	22	9.04	28	11.39	16	6.46
Leibo County	21	7.38	19	6.65	9	3.11	4	1.37	6	2.04	7	2.36
Mianning County	20	4.94	23	5.68	12	2.94	7	1.72	12	2.91	9	2.18
Ningnan County	7	3.49	3	1.49	5	2.46	2	0.99	7	3.44	2	0.98
Yanyuan County	13	3.38	16	4.15	10	2.57	10	2.57	9	2.31	7	1.80
Xichang City	21	3.04	42	5.79	34	4.59	33	4.39	34	4.41	26	3.30
Muli Tibetan Autonomous County	4	2.89	1	0.73	0	0.00	1	0.73	2	1.45	1	0.73
Dechang County	5	2.29	2	0.92	11	4.99	11	4.98	5	2.25	8	3.60
Huidong County	3	0.70	2	0.47	1	0.24	2	0.47	1	0.24	3	0.71
Huili City	0	0.00	2	0.43	3	0.65	1	0.22	3	0.65	1	0.22
Age group (years)												
< 15	30	2.12	34	2.40	15	1.07	20	1.44	16	1.16	11	0.81
15–30	105	8.34	97	7.74	73	5.74	68	5.29	66	5.09	50	3.80
30–45	405	39.41	367	35.86	352	34.53	324	31.49	331	31.54	278	26.02
45–60	87	8.92	89	8.77	111	10.40	101	9.34	108	10.07	124	11.63
≥ 60	24	3.80	18	2.88	19	3.02	11	1.71	12	1.74	21	2.90
Sex												
Male	475	17.40	444	16.20	432	15.59	390	13.98	428	15.19	378	13.32
Female	176	6.82	161	6.21	138	5.26	134	5.07	105	3.94	106	3.94

Characteristics of HIV transmission and TB treatment profiles

The HIV transmission routes, anti-TB treatment outcomes, and drug resistance profiles of newly reported HIV–TB co-infected patients in Liangshan from 2019 to 2024 are shown in Table 3. Heterosexual transmission was the predominant HIV route (48.29%), followed by injection drug use (41.31%) and mother-to-child transmission (3.42%); homosexual transmission accounted for the smallest proportion (0.30%).

Regarding anti-TB treatment outcomes, 81.76% of patients completed treatment or were cured, approximately 1.93% were transferred to multidrug-resistant TB (MDR-TB) treatment, 0.80% experienced adverse treatment outcomes (adverse reactions, treatment failure, or TB-related death), and 10.87% were lost to follow-up or had unknown outcomes. Drug resistance testing revealed that 3.30% of co-infected patients had TB drug resistance. Among resistant cases, the main types were resistance to rifampicin (46.85%) and isoniazid (28.83%), followed by MDR-TB (23.42%).

Table 3
Characteristics of HIV transmission routes, anti-TB treatment outcomes, and drug resistance among HIV–TB co-infected patients in Liangshan Prefecture, 2019–2024 (*n* = 3,367)

Characteristic	Cases, <i>n</i>	Proportion (%)
HIV transmission route		
Heterosexual transmission	1626	48.29
Injection drug use	1391	41.31
Sexual contact + injection drug use	137	4.07
Mother-to-child transmission	115	3.42
Unknown	63	1.87
Homosexual transmission	10	0.30
Other	25	0.74
Anti-TB drug resistance		
No drug resistance	3256	96.70
Rifampicin-resistant	52	1.54
Isoniazid-resistant	32	0.95
Multidrug-resistant (MDR)	26	0.77
Pre-extensively drug-resistant	1	0.03
Anti-TB treatment outcome		
Completed treatment or cured	2753	81.76
Transferred to MDR-TB treatment	65	1.93
Adverse TB treatment outcome	27	0.80
Death not due to TB	156	4.63
Lost to follow-up or unknown	366	10.87

Factors associated with HIV transmission and TB outcomes

To further explore the distribution of the above characteristics across different populations, we performed a stratified analysis by sex and age group for HIV transmission routes, drug resistance, and anti-TB treatment outcomes (Table 4). By sex, there were statistically significant differences in HIV transmission routes and anti-TB drug resistance (both *P* < 0.05), while the difference in anti-TB treatment outcomes was not significant ($\chi^2=5.446$, *P* = 0.245). By age group, there were statistically significant differences in HIV transmission routes and anti-TB treatment outcomes (both *P* < 0.05), while the difference in anti-TB drug resistance was not significant ($\chi^2=2.824$, *P* = 0.588).

These differences were primarily manifested in the fact that injection drug use was the predominant HIV route for males, while heterosexual transmission was predominant for females; the proportion of females who completed treatment or were cured was slightly higher than that of males. Regarding age groups, injection drug use was the main HIV route for those aged 30–45 years (50.32%), whereas heterosexual transmission was the main route for all other age groups, notably reaching 87.62% in those aged ≥ 60 years. Importantly, the proportion of patients aged ≥ 60 years who completed treatment or were cured was less than 70% (69.52%), significantly lower than that of other age groups (pairwise comparisons with Bonferroni correction, *P* < 0.05).

Table 4
Factors associated with HIV transmission routes, drug resistance, and anti-TB treatment outcomes among HIV–TB co-infected patients in Liangshan Prefecture, 2019–2024, by sex and age group (n = 3,367)

Characteristic	Sex		Age group (years)								χ^2	P value
	Male	Female	χ^2	P value	< 15	15–30	30- <45	45 - <60	≥ 60			
HIV transmission route			501.741	< 0.001						2446.684	< 0.001	
Heterosexual transmission	994 (39.03)	632 (77.07)	501.741	< 0.001	2 (1.59)	292 (63.62)	914 (44.43)	326 (52.58)	92 (87.62)	2446.684	< 0.001	
Injection drug use	1297 (50.92)	94 (11.46)	501.741	< 0.001	1 (0.79)	98 (21.35)	1035 (50.32)	245 (39.52)	12 (11.43)	2446.684	< 0.001	
Sexual contact + injection drug use	132 (5.18)	5 (0.61)	501.741	< 0.001	0(0.00)	11 (2.40)	85 (4.13)	41 (6.61)	0(0.00)	2446.684	< 0.001	
Mother-to-child transmission	58 (2.28)	57 (6.95)	501.741	< 0.001	90 (71.43)	25 (5.45)	0(0.00)	0(0.00)	0(0.00)	2446.684	< 0.001	
Unknown	39 (1.53)	24 (2.93)	501.741	< 0.001	25 (19.84)	17 (3.70)	14 (0.68)	6 (0.97)	1 (0.95)	2446.684	< 0.001	
Homosexual transmission	10 (0.39)	0(0.00)	501.741	< 0.001	0(0.00)	4 (0.87)	5 (0.24)	1 (0.16)	0(0.00)	2446.684	< 0.001	
Other	17 (0.67)	8 (0.98)	501.741	< 0.001	8 (6.35)	12 (2.61)	4 (0.19)	1 (0.16)	0(0.00)	2446.684	< 0.001	
Anti-TB drug resistance			4.126	0.042						2.824	0.588	
No drug resistance	2454 (96.35)	802 (97.80)	4.126	0.042	124 (98.41)	446 (97.17)	1990 (96.74)	596 (96.13)	100 (95.24)	2.824	0.588	
Rifampicin-resistant	42 (1.65)	10 (1.22)	4.126	0.042	1 (0.79)	5 (1.09)	36 (1.75)	7 (1.13)	3 (2.86)	2.824	0.588	
Isoniazid-resistant	27 (1.06)	5 (0.61)	4.126	0.042	1 (0.79)	6 (1.31)	17 (0.83)	7 (1.13)	1 (0.95)	2.824	0.588	
Multidrug-resistant (MDR)	23 (0.90)	3 (0.37)	4.126	0.042	0	2 (0.44)	13 (0.63)	10 (1.61)	1 (0.95)	2.824	0.588	
Pre-extensively drug-resistant	1 (0.04)	0(0.00)	4.126	0.042	0(0.00)	0(0.00)	1 (0.05)	0(0.00)	0(0.00)	2.824	0.588	
Anti-TB treatment outcome			5.446	0.245						28.749	0.026	
Completed treatment or cured	2069 (81.23)	684 (83.41)	5.446	0.245	105 (83.33)	384 (83.66)	1698 (82.55)	493 (79.52)	73 (69.52)	28.749	0.026	
Transferred to MDR-TB treatment	54 (2.12)	11 (1.34)	5.446	0.245	1 (0.79)	8 (1.74)	40 (1.94)	13 (2.10)	3 (2.86)	28.749	0.026	
Adverse TB treatment outcome	18 (0.71)	9 (1.10)	5.446	0.245	1(0.80)	2(0.44)	22 (0.32)	2(5.00)	0(0.00)	28.749	0.026	
Death not due to TB	125 (4.91)	31 (3.78)	5.446	0.245	5 (3.97)	13 (2.83)	97 (4.72)	31 (5.32)	10 (9.52)	28.749	0.026	
Lost to follow-up or unknown	281 (11.03)	85 (10.37)	5.446	0.245	14 (11.11)	52 (11.33)	200 (9.72)	81 (13.06)	19 (18.10)	28.749	0.026	
Note: Values in parentheses are column percentages (%).												

Drug resistance trends in the context of integrated prevention

From 2019 to 2024, the overall TB drug resistance rate among HIV–TB co-infected patients in Liangshan was 3.30%. Rifampicin resistance was the most common type (46.85% of resistant cases), followed by isoniazid resistance (28.83%) and MDR-TB (23.42%).

Regarding temporal trends, though it slightly decreased in 2024, the overall drug resistance rate showed a significant upward trend ($\chi^2_{trend} = 8.481$, $P_{trend} = 0.004$), rising from 1.54% in 2019 to 3.10% in 2024, with the highest reported rate in 2023 (4.88%). Analyzing specific resistance types, this upward trend was primarily driven by a significant increase in rifampicin resistance ($\chi^2_{trend} = 9.890$, $P_{trend} = 0.002$). Trends for isoniazid resistance, MDR-TB, and pre-extensively drug-resistant TB were not statistically significant ($\chi^2_{trend} = 0.334$, 2.323, and 0.946, $P_{trend} = 0.853$, 0.127, and 0.331, respectively) (Fig. 1).

Discussion

Liangshan Prefecture in Sichuan Province is an area with a dual high burden of HIV and TB. HIV–TB co-infection in this region warrants particular attention and may provide important insights for other high-burden, resource-limited settings worldwide.

Overall trends in the context of integrated prevention

Against the policy backdrop of the IPC4D policy and “1 + M + N+P” precision prevention and control models, the reported incidence of HIV–TB co-infection in Liangshan showed a significant downward trend from 2019 to 2024 (from 12.26 per 100,000 to 8.76 per 100,000), consistent with reports from other regions in China [37]. However, global burden of disease models and local studies suggest that the age-standardized burden of HIV–TB in low-SDI regions may continue to rise in the coming years [1, 14], indicating that Liangshan's prevention and control achievements need sustained consolidation. Studies have indicated that relying solely on symptom-based screening is insufficient to detect all TB cases, recommending systematic TB screening for people living with HIV during every healthcare encounter to reduce diagnostic delays [38]. This evidence offers valuable insights for optimizing screening strategies in Liangshan.

Geographic and demographic drivers of decline

The demographic profile of HIV–TB co-infected patients in Liangshan from 2019 to 2024 was highly concentrated, predominantly involving young adult males (30–45 years) and farmers (92.37%), similar to reports from other countries and Chinese provinces [13, 23, 37, 39]. The decline in incidence in high-burden counties such as Butuo, Zhaojue, Yuexi, and Jinyang was a major driver of the Liangshan's overall decline. This reflects the effectiveness of the Chinese government's strategy of concentrated resource allocation and precision interventions (e.g., expanded screening, community mobilization, multi-sectoral collaboration) in key disease control areas. The significant decline in all age groups under 45 years suggests a good response to prevention and control measures among the younger population. The downward trend in incidence for both sexes indicates that local interventions have achieved good coverage across genders. These findings demonstrate that Liangshan's prevention and control strategies have achieved initial success in key areas and populations, offering valuable lessons for other high-burden regions.

Persistent challenges: the neglected older adults

In stark contrast to the positive trends above, the incidence in the ≥ 60 -year age group showed no significant decline over the six years, and their treatment success rate (69.52%) was significantly lower than that of other age groups. Older patients may face barriers to active participation in screening and regular follow-up due to declining physical function, multiple comorbidities, poverty, and limited healthcare access [40]. Concurrently, weak social support networks—including being empty nesters, widowhood, and adult child out-migration—leave them without adequate supervision and care during treatment. Local studies have shown that low BMI is a strong predictor of death among HIV/AIDS patients [41], and malnutrition is common among the elderly, further increasing the risk of adverse outcomes. Notably, 87.62% of older patients were infected with HIV via heterosexual transmission, indicating that health education and disease prevention efforts related to sexual activity need to be strengthened for this population. Older adults should become a key focus for the next phase of prevention and control efforts, with an urgent need for targeted active screening, simplified treatment procedures, and nutritional support programs.

Transmission route syndemic and its implications

The HIV transmission routes among co-infected patients in this study reveal a deeper “syndemic” pattern: injection drug use predominates in males (50.92%), while heterosexual transmission predominates in females (77.07%); injection drug use is dominant in the 30–45-year age group (50.32%), whereas heterosexual transmission is dominant in all other age groups, reaching 87.62% in those aged ≥ 60 years. This pattern reflects the complexity of HIV transmission within Liangshan's unique socio-cultural context. This syndemic presents multidimensional requirements for prevention and control. First, young adult male farmers face both drug-related risks and difficulties in regular follow-up due to high mobility, necessitating strengthened pre-migration screening and mobile population management [31]. Second, women infected through heterosexual transmission require support to enhance their negotiation skills in sexual activities and access to diverse protective measures [8]. Third, the varying transmission characteristics across age groups call for targeted sexual health education for those aged ≥ 60 years, and integrated interventions—combining drug prevention, sexual health promotion, and family-based approaches—for the “mixed” transmission pattern seen in the 30–45-year age group [42–43].

Treatment outcomes, loss to follow-up, and the threat of drug resistance

The treatment success rate in this study was 81.76%, lower than the provincial average for Sichuan during the same period (89.01%) [4]. The proportion of patients lost to follow-up or with unknown outcomes was 10.87%, far exceeding that in the general TB population and consistent with findings from an international multi-center study [44]. Poor treatment adherence and loss to follow-up in this setting stem from multiple interacting factors. At the patient level, the long treatment duration for TB (especially drug-resistant TB), high medication burden, and frequent adverse drug reactions—compounded by potential additive toxicities when combined with ART [45]—create significant barriers to adherence. These are further exacerbated by low health literacy, economic hardship, and lack of family support [46]. At the health system level, “N”-level personnel such as village doctors and HIV prevention officers, working under the integrated service model, face dramatically increased workloads, understaffing, heavy caseloads, and insufficient funding, leading to less intensive follow-up supervision [31]. These factors may compromise timely follow-up and intervention for patients with poor adherence, such as some older adults. Another local study found a paradoxically higher risk of death among patients followed up at county-level hospitals or above [47], suggesting that reliance solely on higher-level medical institutions is insufficient. Strengthening the tripartite “hospital-community-family” linkage model locally—by promoting consistent medication supervision and supportive care at the grassroots level, and developing objective adherence assessment methods—is needed to address previous shortcomings in long-term follow-up management [48].

Loss to follow-up not only potentially signifies treatment failure but also acts as a breeding ground for drug resistance. Studies indicate that Liangshan's high drug-resistant TB rate—among the highest in China—is primarily due to patient non-adherence rather than primary resistance to drug-resistant strains [31]. The upward trend in the overall drug resistance rate observed in this study, particularly for rifampicin, can be seen as a sentinel event signaling inadequate

treatment adherence among local co-infected patients. Therefore, it is crucial to strengthen drug resistance surveillance among high-risk groups (males, older adults, those with low education, unmarried/divorced individuals, and farmers), promote rapid molecular testing, explore digital health tools to support supervision [48–50], and consider providing tangible support such as transportation subsidies and nutritional packages. Simultaneously, alleviating the workload of grassroots "N"-level personnel is essential to ensure follow-up quality [30, 51]. Through these comprehensive measures, the emergence of additional drug-resistant TB patients can be curbed.

Conclusion

Drawing on surveillance data of HIV–TB co-infection in Liangshan Prefecture from 2019 to 2024, this study provides a comprehensive analysis of epidemiological trends and infection characteristics within the context of integrated prevention. Key findings include a declining incidence trend, supporting the interim effectiveness of the "Four Diseases Co-prevention" policy. The decline was primarily driven by high-burden counties and younger populations, demonstrating the value of targeted precision interventions. The lack of improvement in incidence and low treatment success rate among older adults highlight a critical weak link in current control efforts, while loss to follow-up and emerging TB drug resistance threaten the progress achieved.

Building on these findings, we propose four priorities for comprehensive prevention and control in Liangshan and similar high-burden settings:

Place-based strategies: harnessing indigenous social resources. In high-burden counties such as Butuo and Zhaojue, the workload for grassroots follow-up is immense, with village doctors and HIV prevention officers facing staff shortages. Drawing on the Yi "clan" (*Jiazhi*) system, collaboration with clan leaders could be explored to integrate patient follow-up and medication supervision into traditional social networks, thereby improving intervention sustainability and cultural appropriateness.

People-centered approaches: implementing precision interventions. For older adults, we recommend establishing active screening mechanisms (e.g., integrated into local chronic disease management clinics), providing simplified treatment regimens, and strengthening nutritional support. For women, empowerment through women's health groups and peer education can enhance sexual health autonomy. For young adult male farmers, integrated screening should be delivered around key periods such as pre-migration and Spring Festival return, with improved follow-up for mobile populations.

Resource-optimized initiatives: filling gaps in drug resistance prevention and control. Given that rifampicin resistance continues to drive the increase in overall drug resistance rates, and that local funding for TB (especially drug-resistant TB) remains substantially lower than for HIV, targeted interventions are urgently needed. We recommend expanding rapid drug resistance testing for all HIV–TB patients, establishing dedicated follow-up pathways for drug-resistant cases, and increasing financial support and performance incentives for key diagnostic procedures.

Technology- and support-integrated efforts: improving adherence management efficiency. Digital health tools (medication reminder apps, wearable devices) can be deployed to support supervision, with family engagement. Concurrently, tangible support such as transport subsidies and nutritional supplements can reduce patient burden, while task rationalization and performance incentives can alleviate burnout among frontline workers.

Global evidence indicates that HIV–TB co-infection control is closely tied to socioeconomic development. In low-SDI settings, disease control is particularly challenging, and expanding treatment coverage alone is insufficient to rapidly reduce disease burden [20]. The Liangshan experience shows that policy integration and targeted resource investment can achieve meaningful progress, but sustained success requires a systemic approach: strengthening grassroots diagnostic capacity, optimizing health system support, improving education for key populations, and improving service accessibility. Future research should prioritize tracing and characterizing patients lost to follow-up to generate further evidence for optimizing follow-up management and care retention.

Abbreviations

ART: Antiretroviral therapy; ATT: Anti-tuberculosis treatment; BMI: Body mass index;CDRS: China Cause of Death Reporting System; CRIMS: National Comprehensive HIV/AIDS Information Management System; HIV: Human Immunodeficiency Virus; IPC4D: Integrated Prevention and Control of Four Diseases; IQR: Interquartile range; MDR-TB: Multidrug-resistant tuberculosis

SDI: Socio-demographic Index; TB: Tuberculosis; TBIMS: Tuberculosis Information Management System; WHO: World Health Organization.

Declarations

Ethics Declarations

Ethics Approval and Consent to Participate

The study protocol was reviewed and approved by the Ethics Committee of the Sichuan Center for Disease Control and Prevention (Approval No. SCCDCIRB-2026-002). The need for individual informed consent was waived due to the retrospective, anonymized nature of the routine surveillance data, in accordance with the committee's guidelines.

Consent for Publication

Not applicable.

Availability of Data and Materials

The data that support the findings of this study are available from the Liangshan 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. Data are, however, available from the corresponding authors upon reasonable request and with permission of the Liangshan Center for Disease Control and Prevention.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

B.X.F. and W.J. contributed equally to conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing – original draft, and writing – review & editing. Y.G. contributed to conceptualization, data curation, formal analysis, investigation, methodology, and supervision. S.J.H. and F.S.S. were responsible for conceptualization, data curation, software, visualization, and writing – original draft. W.R.B., W.Y.B., and F.X.Y. contributed to conceptualization, data curation, formal analysis, investigation, and project administration. P.R. and L.R.J. served as co-corresponding authors, overseeing conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, and writing – review & editing. All authors read and approved the final manuscript.

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References

1. Hu XY, Gao JT. Interpretation of WHO Global Tuberculosis Report 2024. *J Tuberc Lung Dis.* 2024;5(6):500–4.
2. World Health Organization. End TB Strategy. https://apps.who.int/gb/ebwha/pdf_files/EB146/B146_10-ch.pdf. Geneva:World Health Organization. 2019. Accessed 2026-02-28. Accessed 28 Feb 2026.
3. Li T, Cheng Q, Li C, et al. Evidence for heterogeneity in China's progress against pulmonary tuberculosis: uneven reductions in a major center of ongoing transmission, 2005–2017. *BMC Infect Dis.* 2019;19:615.
4. Lu J, Li T, Wang DX, et al. Epidemiological characteristics of tuberculosis in Sichuan during the 13th five-year plan period. *Dis Surveillance.* 2021;36(11):1147–51.
5. Wei W, Xia L, Wu J, et al. The Environmental and Socioeconomic Effects and Prediction of Patients With Tuberculosis in Different Age Groups in Southwest China: A Population-Based Study. *JMIR Public Health Surveill.* 2023;9:e40659.
6. Yu XR, Wang SJ, Yang XM, et al. Analysis of changes in reporting and diagnosis of pulmonary tuberculosis among children in Liangshan Yi Autonomous Prefecture, Sichuan Province from 2019 to 2021. *Chin J Prev Med.* 2023;57(8):1153-1159.
7. Liang L, Xiong Q, Wei Z, et al. Characteristics and predictors of mortality among infants and toddlers hospitalized with tuberculosis: a ten-year case series study in Sichuan, China. *BMC Infect Dis.* 2025;25:785.
8. Zhang L, Liu L, Lai W, et al. "Comprehensive HIV/AIDS programs in Sichuan". *HIV/AIDS in China: Epidemiology, Prevention and Treatment*. Singapore: Springer Singapore, 2019: 629-651.

9. Yang SJ, Luo M, Zhang SH, et al. Overview on culture and customs related to AIDS epidemic and prevention among Yi people in Liangshan. *Chin J AIDS STD*. 2017; 23(3): 271-274.
10. Yang H, Li Y, Xu M, et al. The Update of HIV-1 Prevalence and Incidence and Spatio-Temporal Analyses of HIV Recent Infection Among Four Sub-Groups in Sichuan, China During Surveillance Period Between 2016 and 2022. *Infect Drug Resist*. 2023;16:6535-6548.
11. Meng JY, Chen WZ, Zeng YL. Investigation of Decreasing Gender Ratio of Reported HIV/AIDS Cases in Liangshan Yi Autonomous Prefecture, Sichuan Province—Based on a Mixed Methods Study [dissertation]. Chengdu: Chengdu Medical College; 2025.
12. Li Y, Li X. Epidemic status and research progress of AIDS/tuberculosis double infection. *Chin Foreign Med Res*. 2022;20(16):181-4.
13. Wu H, Zhu L, Bao R, et al. Global prevalence of HIV and Mycobacterium tuberculosis co-infection: A systematic review and meta-analysis of 371 included articles. *Public Health*. 2025;249:106034.
14. Tian X, Wang C, Hao Z, et al. Global, regional, and national burden of HIV and tuberculosis and predictions by Bayesian age-period-cohort analysis: a systematic analysis for the global burden of disease study 2021. *Front Reprod Health*. 2024;6:1475498.
15. Zhang SX, Wang JC, Yang J, et al. Epidemiological features and temporal trends of the co-infection between HIV and tuberculosis, 1990–2021: findings from the Global Burden of Disease Study 2021. *Infect Dis Poverty*. 2024;13:59.
16. Preethi DP, Vanisree D, Parameswari K, et al. Determination of HIV Status in Truenat Positive Tuberculosis Patients-An Observational Study. *Clin Microbiol*. 2024;14(6):37-8.
17. Rabelo LDBC, Oliveira K, Sobral R, et al. Estudo epidemiológico dos casos de coinfeção HIV/Tuberculose no Brasil entre os anos de 2019-2023. *Braz J Implantol Health Sci*. 2024;6(2):2155-66.
18. Huang A, Chen HJ, Li JL, et al. Prevalence and treatment of patients with TB and HIV co-infection in Guizhou province, 2011-2020. *Chin J Public Health*. 2023;29(5): 633-8.
19. Chen C, Fu H, Liu YL, et al. Analysis on disease burden and epidemiological trends of HIV/AIDS co-infection with drug-resistant tuberculosis in China on the global perspective [J]. *Chin J Dis. Control Prev*. 2025;29(8): 949-55.
20. Li L, McGoogan JM, Wu Z. Common HIV co-infections in China: HBV, HCV, and TB. *HIV/AIDS in China: Epidemiology, Prevention and Treatment*. Springer; 2019:63-73.
21. Jiang X, Bai YL, Ma JJ. Screening and Treatment of TB/HIV Co-infection in Jilin Province from 2016 to 2022. *Chin J Public Health Eng*. 2024;23(5):598-601+606.
22. Abuduwalli K, Aihaiti Y, Wang MZ, et al. Analysis of epidemiological features of TB/HIV co-infection in Xinjiang from 2011 to 2020 [J]. *Bull Dis Control Prev*. 2025;40(1):34-8.
23. Zhang X, Lang SL, Xu LJ, et al. Analysis of epidemic characteristics and treatment of HIV-TB co-infection in Inner Mongolia Autonomous Region, 2016-2023. *Chin J Antituberc*. 2024;46(S1):50-5.
24. Zhang P, Zhao AH, Gao M, et al. Analysis of epidemiological characteristics of TB/HIV co-infection in Henan Province from 2016 to 2021 [C]. In: *Proceedings of the 34th National Academic Conference of the Chinese Antituberculosis Association; 2023*. Henan Provincial Center for Disease Control and Prevention.
25. Liu Z, Tang X, Liu Y, et al. HIV prevention and health poverty alleviation — Liangshan Prefecture, Sichuan Province, China, 2017–2020. *China CDC Wkly*. 2021;3(52):1109–1114.
26. Wang T, Zhou C, Shang L, et al. Comorbidity and drug resistance of smear-positive pulmonary tuberculosis patients in the Yi autonomous prefecture of China: a cross-sectional study. *BMC Infect Dis*. 2023;23:586.
27. Wang D-M, An Q, Yan Q, et al. Clinical characteristic, common sites, and geographical distribution of pediatric tuberculosis patients in Southwest China. *Front Public Health*. 2024;12:1234567.
28. Wang DM, An Q, Yang Q, et al. Epidemiology of drug-resistant tuberculosis among hospitalized children with tuberculosis in southwest China, 2017–2024. *Front Microbiol*. 2025;16:1609146.
29. Wang DM, An Q, Yang Q, et al. Prevalence and related factors of TB/HIV co-infection among hospitalized children with tuberculosis in Southwest China. *Front Cell Infect Microbiol*. 2025;15:1571291.
30. Li J, He JG, Li T, et al. Analysis of feasibility and effectiveness of the implementation of strengthened tuberculosis management model in Liangshan Yi Autonomous Prefecture, Sichuan Province. *J Tuberc Lung Dis*. 2022;3(6):540-5.
31. Bi R, Pei R, Jike C, et al. Healthcare workers' experiences with integrated HIV and TB prevention in Liangshan, China: a qualitative exploration of barriers and enablers. *Front Public Health*. 2025;13:1615781.
32. Liao R, Hu L, Yu J, et al. Association between TB delay and TB treatment outcomes in HIV-TB co-infected patients: a study based on the multilevel propensity score method. *BMC Infect Dis*. 2024 Apr 30;24(1):457.
33. National Health Commission of the People's Republic of China. Diagnosis for AIDS and HIV infection: WS 293-2019. 2019. <http://www.nhc.gov.cn/wjw/s9491/201901/a8c9a79c2e134c81b6ddfd5c245fc232.shtml>. Accessed 28 Feb 2026.
34. Chinese Center for Disease Control and Prevention. Technical guidelines for tuberculosis prevention and control in China. 2022. <http://www.chinacdc.cn/jkzt/crb/zl/jhb/jsbw/202204/P020220414343625456660.pdf>.
35. WHO. Definitions and reporting framework for tuberculosis—2013 revision: updated December 2014 and January 2020. World Health Organ. 2013. <https://www.who.int/publications/i/item/9789241505345>. Accessed 28 Feb 2026.
36. WHO. WHO case definitions of HIV for surveillance and revised clinical staging and immunological classification of HIV-related disease in adults and children. World Health Organ. 2007. <https://iris.who.int/handle/10665/43699>. Accessed 28 Feb 2026.

37. Li J, Li T, Li Y, et al. Epidemiological characteristics and influencing factors of hospitalized patients with TB/HIV co-infection in high HIV/AIDS prevalence areas. *Chin J AIDS STD*. 2020;26(5):530-3.
38. Cui Z, Huang F, Liang D, et al. Tuberculosis among Ambulatory People Living with HIV in Guangxi Province, China: A Longitudinal Study. *Int J Environ Res Public Health*. 2022;19(19):12280.
39. Wang C, Shi Y, Liu Y, et al. Coinfection of hepatitis B, tuberculosis, and HIV/AIDS in Beijing from 2016 to 2023: a surveillance data analysis. *BMC Infect Dis*. 2025;25:584.
40. Hu YX, Wang Y, Fang SL, et al. Analysis of the burden of polypharmacy and its influencing factors among elderly tuberculosis patients in Guizhou province. *Chin J Pharm*. 2023;34(9):1126-30.
41. Ren J, Jia S, Che S, et al. Analysis of the survival conditions and influence factors of antiretroviral therapy for drug users with HIV/AIDS in Liangshan Prefecture from 2010 to 2019. *Chin J Dis Control Prev*. 2023;27(6):661-668.
42. Yuan D, Liu M, Jia P, et al. Prevalence and determinants of virological failure, genetic diversity and drug resistance among people living with HIV in a minority area in China: a population-based study. *BMC Infect Dis*. 2020;20:443.
43. Yang N, Chen C, He J, et al. Treatment outcome and its associated factors among HIV-MTB co-infected patients in Sichuan, China: a retrospective study. *Medicine*, 2022, 101(48): e32006.
44. Bastard M, Sanchez-Padilla E, du Cros P, et al. Outcomes of HIV-infected versus HIV-noninfected patients treated for drug-resistance tuberculosis: Multicenter cohort study. *PLoS One*. 2018;13(3):e0193491.
45. Singh A, Prasad VR, Balasubramanian N, et al. Drug-Resistant Tuberculosis and HIV Infection: Current Perspectives. *HIV/AIDS - Res Palliat Care*. 2020;12:9-31.
46. Bi R, Dou L, Pei R, et al. A mixed-methods study on healthcare workers' perceptions of treatment adherence among HIV-TB co-infected patients in a multi-disease prevention policy context. *Front Public Health*. 2025;13:1704215.
47. Zhuoma L, Zeng Y, Yu G, et al. Survival of HIV infected patients receiving antiretroviral therapy in four counties in Liangshan Prefecture. *Chin J AIDS STD*. 2022;28(2):133-137.
48. Liao R, Tang Z, Zhang N, et al. Discrepancies between self-reported medication in adherence and indirect measurement adherence among patients undergoing antiretroviral therapy: a systematic review. *Infect Dis Poverty*. 2024 Jul 5;13(1):51.
49. Sossen B, Kubjane M, Meintjes G. Tuberculosis and HIV coinfection: Progress and challenges towards reducing incidence and mortality. *Int J Infect Dis*. 2025; Published online.
50. Feng Y, Ge L, Cheng W, et al. Survival time and influencing factors among people living with HIV in Guilin City, Guangxi, China: a retrospective cohort study (1996–2022). *Front Public Health*. 2026;13:1575990.
51. Chen YY, Liu XH, Wang YL, et al. Initial drug resistance of mycobacterium tuberculosis in HIV patients with tuberculosis in Henan. *Chin J AIDS STD*. 2021;27(1):14-16.

Figures

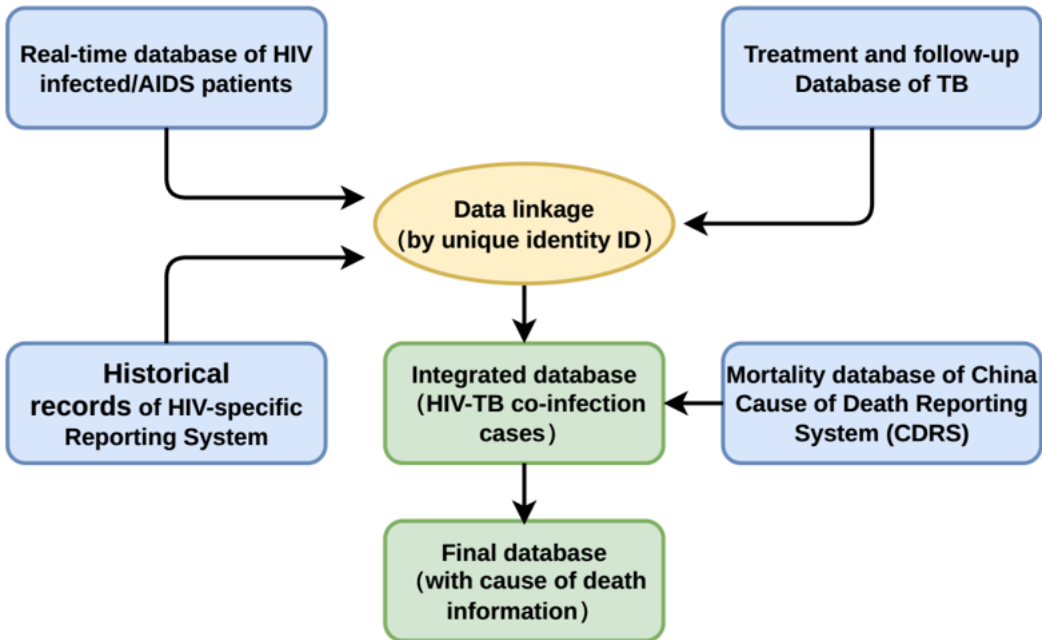


Figure 1

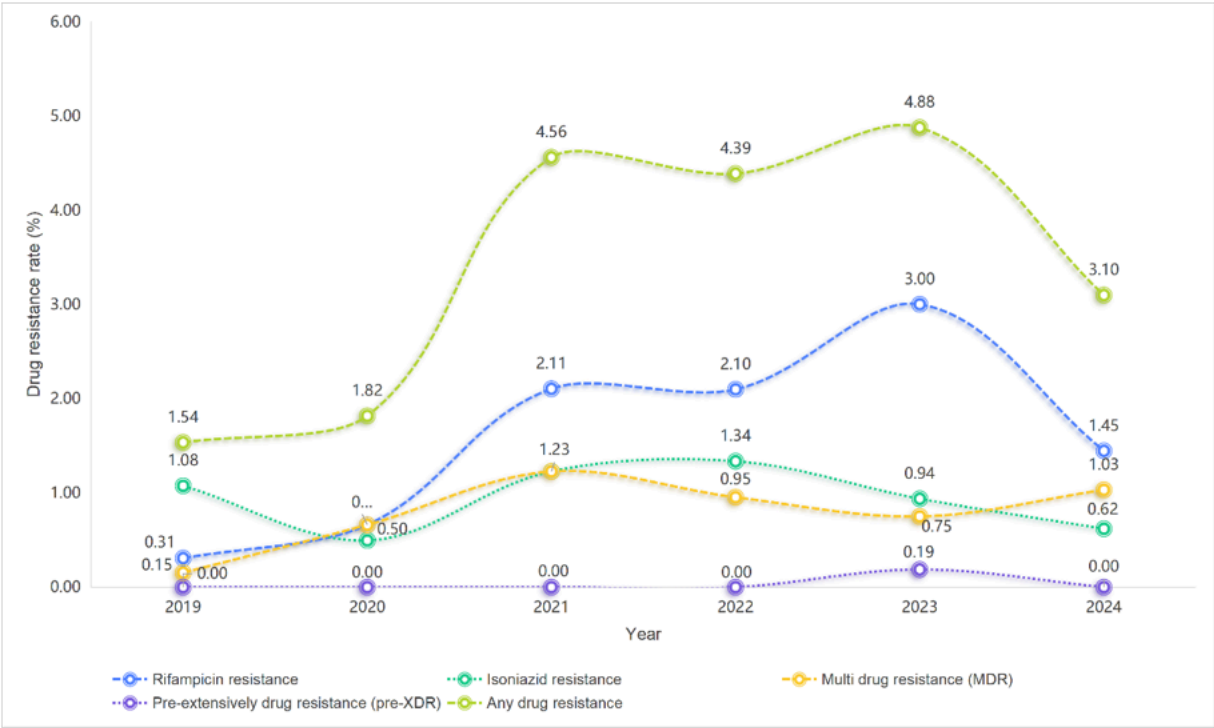


Figure 2

Figure 1. Trends in anti-TB drug resistance patterns among HIV–TB co-infected patients in Liangshan Prefecture, 2019–2024