Infection and Drug Resistance

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ORIGINAL RESEARCH

Patterns of Drug Resistance and Treatment Outcomes in Drug-Resistant Tuberculosis Patients in Fuyang City: A Three-Year Retrospective Study

Wei Wang[1,*], Yuxin Gao[2,*], Yong Gao[3], Tuantuan Li[4], Yan Liu[4], Xiaowu Wang[4], Xiaoyu Fang[5], Yunyun Ding[4]

[1]Department of Clinical Laboratory, People's Hospital of Fuyang City, Fuyang, Anhui, 236000, People's Republic of China; [2]Departments of Biostatistics-Data Science of Health, UCLA Fielding School of Public Health, Los Angeles, CA, 90024 USA; [3]Department of Clinical Laboratory, The Third People's Hospital of Fuyang City, Fuyang, Anhui, People's Republic of China; [4]Department of Clinical Laboratory, The Second People's Hospital of Fuyang city, Fuyang, Anhui, 236000, People's Republic of China; [5]Department of Pharmacy, Jieshou City People's Hospital, Fuyang, People's Republic of China

*These authors contributed equally to this work

Correspondence: Xiaoyu Fang, Department of Pharmacy, Jieshou City People's Hospital, Fuyang, People's Republic of China, Email fyfxy123456@yeah.net; Yunyun Ding, Department of Clinical Laboratory, The Second People's Hospital of Fuyang city, Fuyang, Anhui, 236000, People's Republic of China, Email fydingyunyun@163.com

Objective: This study aimed to analyze drug resistance patterns and inpatient medication utilization among drug-resistant tuberculosis (DR-TB) patients in Fuyang City (2021–2023), and to identify factors associated with unsuccessful treatment outcomes in multidrug-resistant tuberculosis (MDR-TB) patients, to inform outcome-based local prevention and control strategies.

Methods: A retrospective analysis was conducted on patients who underwent drug susceptibility testing (DST) for Mycobacterium tuberculosis at the Second People's Hospital of Fuyang City from January 2021 to December 2023. Patients with resistance to any first-line anti-tuberculosis drug were included. Chi-square tests were used to compare drug resistance and medication utilization between initial and retreatment cases. Binary logistic regression identified factors associated with MDR-TB treatment outcomes. A p-value < 0.05 was considered statistically significant.

Results: Among 181 DR-TB patients, 120 were initial treatment and 61 retreatment cases. MDR-TB accounted for the highest proportion (40.88%, 74/181). Ethambutol showed the highest resistance prevalence (69.61%), followed by isoniazid (64.64%), rifampicin (51.38%), and streptomycin (33.70%). First-line drugs were used significantly more frequently in initial treatment than retreatment patients ($p < 0.05$). Annual increases were observed in the use of cycloserine, bedaquiline, linezolid, and clofazimine ($p < 0.05$). The treatment success rate among MDR-TB patients was 55.41%. Multivariate logistic regression identified retreatment as an independent risk factor for unfavorable outcomes (OR = 4.524, 95% CI: 1.174–17.435, $p = 0.028$), while a bedaquiline-containing regimen was a protective factor (OR = 0.155, 95% CI: 0.033–0.721, $p = 0.017$). Among the 31 patients receiving bedaquiline-containing regimens, 19 received long-course and 12 short-course treatment.

Conclusion: DR-TB remains a significant burden in Fuyang City, with high first-line drug resistance rates, a high proportion of MDR-TB exhibiting complex resistance profiles, and suboptimal treatment success. Bedaquiline-containing regimens are protective against poor outcomes.

Keywords: drug-resistant tuberculosis, first-line drugs, retreatment, multidrug-resistant tuberculosis, bedaquiline

Introduction

Tuberculosis (TB) remains a severe global public health issue demanding urgent intervention. In 2017, an estimated 1.57 million deaths attributed to TB, including 37,000 in China.[1] According to the World Health Organization (WHO) Global Tuberculosis Report 2025, TB resulted in over 1.2 million deaths globally in 2024, accompanied by approximately 10.7 million newly reported cases.[2] The evolving landscape of anti-TB drug use and TB epidemiology has facilitated the emergence and spread of drug-resistant Mycobacterium tuberculosis (MTB), presenting a major global public health

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threat.[3] To effectively address this challenge, governments and health institutions worldwide require robust surveillance and research on drug resistant tuberculosis (DR-TB).[4] Despite substantial progress in reducing TB incidence and mortality over the past three decades, China continues to rank among the 30 nations globally with the highest TB burden.[5]

The proportion of incident TB cases initially identified as multidrug-resistant or rifampicin-resistant tuberculosis (MDR/RR-TB) has exhibited a progressive decline, decreasing from 4.7% in 2015 to 3.2% in recent years.[2,6,7] In contrast, domestic surveillance data indicate that the prevalence has fluctuated between approximately 3.91% and 4.02% over the recent period. Furthermore, treatment outcomes for MDR-TB remain suboptimal.[8] In 2024, 164,545 people with MDR/RR-TB were enrolled on treatment, marking a 7.0% reduction relative to the 177,017 cases reported in 2023. This corresponds to only 42% of the estimated number of incident MDR/RR-TB cases receiving treatment.[2] On a global scale, the treatment success rate (TSR) for MDR reached 71% in the 2022 cohort, reflecting a substantial enhancement of 21 percentage points compared to the 50% rate observed in 2012, notably, in China, the corresponding TSR was 68%.[9] To effectively address this pressing challenge, China has instituted a robust, multi-tiered framework for tuberculosis prevention and control, as stipulated in the "Technical Specifications for Tuberculosis Prevention and Control (2020 Edition)". Within this structure, specialized hospitals at provincial and prefectural tiers are designated as referral hubs dedicated to the management of drug-resistant tuberculosis (DR-TB), thereby facilitating the concentration of specialized expertise and the delivery of standardized clinical care. Core strategic measures encompass the broadened availability of drug susceptibility testing (DST), the incorporation of novel anti-tuberculosis therapeutics, and the enforcement of proactive drug safety surveillance. Despite these initiatives, mortality associated with multidrug-resistant tuberculosis (MDR-TB) persists at a critically elevated level, with case fatality rates observed within the 15%–20% range.

Provincial surveillance data from Anhui indicate that the aggregate prevalence of MDR-TB among sputum smear-positive tuberculosis patients registered at 7.63% over the 2015–2016 period,[10] subsequently decreasing to 4.20% between 2016 and 2022,[11] are broadly consistent with, or are marginally lower than, the corresponding national estimates.[12] Nevertheless, these provincial-level estimates likely obscure substantial heterogeneity across constituent prefectures, particularly within densely populated areas characterized by extensive population mobility. Fuyang City, the second most populous prefecture in Anhui Province and a major demographic hub in the region, serves as a critical sentinel site for TB surveillance. The Second People's Hospital of Fuyang City, the authors' affiliated institution, functions as the designated regional referral center for MDR-TB, severe tuberculosis, and general pulmonary tuberculosis. This role ensures the aggregation of a representative and concentrated caseload, thereby affording a unique opportunity to scrutinize the real-world management of DR-TB within a high-priority epidemiological context. Our group has previously characterized the clinical profile of non-tuberculous mycobacterial (NTM) pulmonary disease in the same Fuyang cohort,[13] underscoring the importance of accurate differentiation between mycobacterial infections in this region and establishing a foundational understanding of the local mycobacterial epidemiology. Accordingly, the present study was specifically designed to: (1) delineate the drug resistance profiles of DR-TB patients hospitalized within the Fuyang region during the 2021–2023 period; (2) characterize antituberculosis drug utilization patterns within this cohort; (3) assess treatment outcomes among individuals with MDR-TB; and (4) elucidate the specific regimens of bedaquiline-containing regimens. The overarching objective is to furnish enhanced preventive and control methodologies, as well as empirical scientific data, to effectively combat DR-TB within the city's healthcare landscape.

Material and Methods

Study Population and Eligibility Criteria

This retrospective study was conducted at the Second People's Hospital of Fuyang City, Anhui Province, China. We conducted a comprehensive review of all patients who underwent DST at the Clinical Laboratory between January 1, 2021, and December 31, 2023. Following stringent application of the eligibility criteria, a total of 1031 MTB cases underwent DST during the study period. After applying the eligibility criteria, 181 patients with DR-TB were included in the final analysis (Figure 1). The specific inclusion and exclusion criteria are as follows:

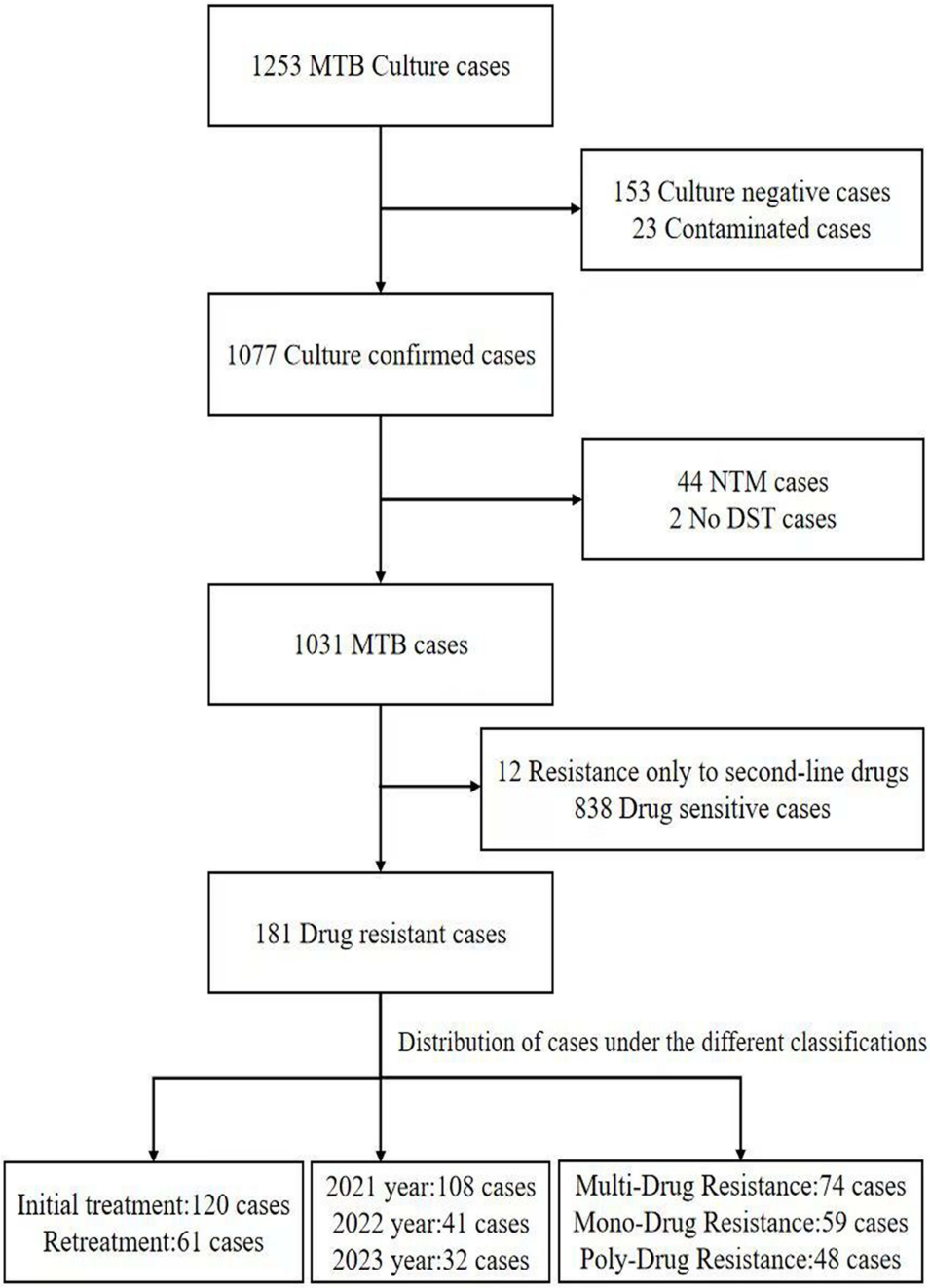

Figure 1 Flow diagram of included DR-TB subjects.
Abbreviations: MTB, Mycobacterium tuberculosis; NTM, Non-Tuberculous Mycobacteria; DST, Drug Susceptibility Testing.

Inclusion criteria: (1) DST results indicating resistance to any first-line anti-tuberculosis drugs; (2) DST specimens were either sputum or bronchoalveolar lavage fluid; (3) Comprehensive availability of clinical, bacteriological, and therapeutic data, ensuring the feasibility of outcome evaluation.

Exclusion criteria: (1) Infection with non-tuberculous mycobacteria (NTM); (2) Severely incomplete clinical records precluding retrieval of key data on drug resistance, medication utilization, or treatment outcomes; (3) Only pulmonary tuberculosis cases were included, all cases of extrapulmonary tuberculosis were excluded.

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Drug Susceptibility Testing

Drug susceptibility testing (DST) was executed utilizing the Mycobacterium tuberculosis Drug Susceptibility Testing Kit, which employs the broth microdilution method based on minimal inhibitory concentration (MIC), procured from Zhengzhou Antu Biological Engineering Co, Ltd, China. The assay was conducted on the BACTEC MGIT 960 liquid culture system. This kit enables susceptibility testing against 13 clinically relevant anti-tuberculosis drugs: rifampicin (R), isoniazid (H), streptomycin (S), ethambutol (E), rifabutin (Rfb), ofloxacin (Ofx), levofloxacin (Lfx), moxifloxacin (Mfx), amikacin (Am), kanamycin (Km), capreomycin (Cm), ethionamide (Eto), and para-aminosalicylic acid (PAS). All procedures were strictly followed according to the manufacturer's instructions. For quality assurance, each experimental batch incorporated the attenuated reference strain Mycobacterium tuberculosis H37Ra (ATCC 25177) as the drug-susceptible control to ensure the validity and reproducibility of the assay. Resistance determination was predicated on the critical concentrations advocated by the World Health Organization (WHO) and delineated in the kit's instructions: H (0.2 μg/mL), R (1.0 μg/mL), E (5.0 μg/mL), S (2.0 μg/mL), Rfb (0.5 μg/mL), Ofx (2.0 μg/mL), Lfx (2.0 μg/mL), Mfx (0.5 μg/mL), Am (1.0 μg/mL), Km (5.0 μg/mL), Cm (2.0 μg/mL), Eto (2.5 μg/mL), PAS (2 μg/mL). For each drug-containing well, the absence of visible colony growth was interpreted as susceptible (S), while the presence of visible colony growth was interpreted as resistant (R). Notably, line probe assay (LPA) was not employed in this investigation; all DST procedures were exclusively conducted using the aforementioned phenotypic liquid culture-based methodology.

Anti-Tuberculosis Drugs

First-line drugs: H, R, E, Pyrazinamide (PZA, Z); Injectable drugs: S, Am, Km, and Cm; Fluoroquinolones are: Ofx, Lfx, Mfx; Second-line oral drugs: Rfb, Rifapentine (Rft) Eto; Prothionamide (Pto); Cycloserine (Cs); PAS; Isoniazid para-aminosalicylate (Pa); Other classes of anti-tuberculosis drugs: Bedaquiline (Bdq); Linezolid (Lzd); Chlorfazimine (Cfz).

Treatment Regimen Classification and Principles

According to the "Technical Specifications for Tuberculosis Prevention and Control in China (2020 Edition)" and World Health Organization (WHO) guidelines,[14] anti-tuberculosis drugs for MDR-TB patients is systematically stratified into three therapeutic classes: Group A (Preferred agents): Levofloxacin or moxifloxacin, bedaquiline, and linezolid; Group B (Second-line preferred agents): Clofazimine, and cycloserine or terizidone; Group C (Add-on agents): Agents that may be added when an effective regimen cannot be composed using Group A and Group B drugs, these encompass ethambutol, delamanid, pyrazinamide, imipenem-cilastatin, meropenem, amikacin (or streptomycin), prothionamide/ethionamide, and para-aminosalicylic acid. A standard anti-tuberculosis treatment regimen is characterized as one comprising a minimum of four active anti-tuberculosis agents, administered over a period of 18 to 20 months. The regimen may be either standardized or tailored to individual patient profiles and drug susceptibility patterns.

Principles of Regimen Design: (1) Hierarchical Drug Selection: The therapeutic regimen should include all available Group A drugs and supplemented by a minimum of one Group B agent. If only one or two Group A drugs can be used, all Group B drugs should be incorporated. If Group A and Group B drugs are insufficient to compose a regimen, Group C drugs may be incorporated as supplementary components. (2) Integration of Treatment History and DST: DST results for H, R, fluoroquinolones (FQs), and second-line injectable agents are relatively reliable. In contrast, the reliability of DST for E, S, and other second-line drugs is comparatively limited. Therefore, regimen design should integrate both DST findings and the patient's treatment history to inform therapeutic decisions. (3) Administration: Oral formulations are preferred over injectable formulations whenever possible. (4) Comprehensive Considerations: The regimen design should account for the local drug resistance profile, anticipated drug tolerability, and potential drug-drug interactions. (5) Safety Surveillance: Active monitoring and appropriate management of adverse drug reactions are essential to minimize the risk of treatment interruption. All treatment regimens in this study were formulated by the expert team of the hospital's Tuberculosis Treatment Center, adhering to the aforementioned guidelines and principles.

Definition of Bedaquiline-containing Regimen: Treatment regimens consisted of at least four active anti-tuberculosis drugs, with bedaquiline as the core oral agent. The treatment duration ranged from 6 to 9 months for short-course

regimens and extended to 18–20 months for long-course regimens. The standard dosage of bedaquiline followed the manufacturer's recommendation (weeks 1–2: 400 mg once daily; weeks 3–24: 200 mg three times per week).

Definitions of Drug Resistance and Treatment Outcomes

All definitions were identified using the WHO guidelines.

Tuberculosis-Related Definitions

DR-TB: Mycobacterium tuberculosis exhibit resistance to one or more first-line anti-tuberculosis drugs.

Mono-Resistant tuberculosis (MR-TB): Mycobacterium tuberculosis exhibits resistance to one first-line anti-tuberculosis drug.

Polydrug-resistant tuberculosis (PR-TB): Mycobacterium tuberculosis exhibits resistance to two or more anti-tuberculosis drugs, excluding resistance to both isoniazid and rifampicin.

MDR-TB: Mycobacterium tuberculosis infection demonstrating in vitro resistance to at least isoniazid and rifampicin.

Pre-extensive drug resistance tuberculosis (pre XDR-TB): On the basis of MDR/RR-TB, shows further resistance to any fluoroquinolones.

Extensive-drug resistance tuberculosis (XDR-TB): XDR-TB represents a severe subset of MDR-TB characterized by additional resistance to any fluoroquinolones (moxifloxacin/levofloxacin) and at least one Group A second-line injectable agent (amikacin, capreomycin, or kanamycin).

Treatment Type Definitions

Initial treatment: No prior antituberculosis treatment or treatment duration of less than 1 month.

Retreatment: History of antituberculosis therapy with ≥1 month of prior treatment.

Treatment Outcome Definitions

Cured: A culture-confirmed TB patient who completed the prescribed full course of treatment with two consecutive negative sputum smear results, including one obtained at treatment completion.

Treatment completed: A patient who completed the prescribed treatment regimen without meeting the criteria for cure or failure.

Died: A patient who died from any cause before starting treatment or during the course of treatment.

Failed: A patient whose sputum smear or culture result is positive at the fifth month of treatment or later (including at the end of the treatment course).

Loss to follow up: A patient who did not initiate treatment or whose treatment was interrupted for two consecutive months or more.

Successful treatment outcomes were defined as cured or treatment completed.

Unsuccessful treatment outcomes were defined as any non-successful outcome, encompassing died, failed, or loss to follow-up.

Follow-Up Procedures

Upon treatment initiation, all enrolled patients were included in an active follow-up cohort. Data were collected from both inpatient and outpatient medical records to ensure comprehensive capture of clinical characteristics, treatment regimens, and follow-up outcomes. Follow-up frequency: During treatment: monthly; Post-treatment completion: at 6 and 12 months.

Data Completeness and Missing Data

This retrospective study relied on routinely collected clinical and laboratory records. Comprehensive data were secured for all enrolled patients regarding the primary variables of interest, encompassing drug resistance profiles, baseline demographics, treatment type, and inpatient medication utilization. For the logistic regression analysis, a complete-case approach was strictly implemented, only patients with fully available data across all model-included variables were

subjected to analysis, with no statistical imputation undertaken. The final regression cohort (n=74) comprised all MDR-TB patients in the cohort, as the core variables for this analysis were fully documented.

Statistical Analysis

Statistical analyses were conducted using SPSS software version 24.0. Categorical data were presented as rates and compared using the Chi-square test. Both univariate and multivariate binary logistic regression analyses were performed with the treatment outcome as the dependent variable (coded as 1 for unsuccessful outcome and 0 for successful outcome). Multicollinearity among independent variables was assessed using the Variance Inflation Factor (VIF). A VIF value of less than 5 was considered to indicate no significant multicollinearity. All independent variables in the univariate analysis were incorporated into the multivariate regression analysis using the entering method. Statistical significance was defined as a two-tailed p-value < 0.05.

Results

Demographic Characteristics of Drug-Resistant Tuberculosis Patients from 2021 to 2023

Table 1 and Figure 1 Among the 181 DR-TB patients, 135 (74.59%) were male with ages ranging from 16 to 88 years. The cohort comprised 120 initial treatment cases and 61 retreatment cases. Demographic characteristics including gender, age, district, occupation, and treatment type showed no significant annual variations across the study period ($p > 0.05$).

Differences in the Type of Drug Resistance Between Initial and Retreatment Patients

Table 2 In this cohort, DR-TB patients were stratified by resistance patterns. MDR-TB constituted the predominant category (40.88%, 74/181), encompassing 9 extensively drug-resistant (XDR-TB) cases and 28 pre-XDR-TB cases. Notably, MDR-TB prevalence exhibited significant disparity between initial and retreatment patients (30.83% vs 60.65%;

Table 1 Demographic Characteristics of DR-TB Patients From 2021 to 2023 [n(%)]

Characteristics	Overall (n=181)	2021 (n=108)	2022 (n=41)	2023 (n=32)	*p*-value
Gender					0.178
Male	135 (74.59)	78 (72.22)	29 (70.73)	28 (87.50)	
Female	46 (25.41)	30 (27.78)	12 (29.27)	4 (12.50)	
Age					0.853
14-30	30 (16.57)	16 (15.31)	8 (19.51)	6 (18.75)	
31-44	35 (19.34)	20 (18.02)	9 (21.95)	6 (18.75)	
45-59	49 (27.07)	29 (27.93)	9 (21.95)	11 (34.38)	
≥60	67 (37.02)	43 (38.74)	15 (36.59)	9 (28.12)	
District					0.266*
Local[a]	163 (90.06)	97 (89.81)	35 (85.37)	31 (96.88)	
Nonlocal[b]	18 (9.94)	11 (10.19)	6 (14.63)	1 (3.12)	
Occupation					0.379*
Farmer	145 (80.11)	84 (77.78)	32 (78.05)	29 (90.63)	
Student	6 (3.32)	3 (2.78)	2 (4.88)	1 (3.12)	
Others	30 (16.57)	21 (19.44)	7 (17.07)	2 (6.25)	
Treatment type					0.885
Initial treatment	120 (66.30)	72 (66.67)	26 (63.41)	22 (68.75)	
Retreatment	61 (33.70)	36 (33.33)	15 (36.59)	10 (31.25)	

Notes: *Fisher's Exact Test; Local[a]: Patients with registered residence (hukou) within the administrative jurisdiction of Fuyang City, Anhui Province; Nonlocal[b]: Patients with registered residence outside Fuyang City, including other prefectures in Anhui Province and other provinces.

Table 2 Differences in the Type of Drug Resistance Between Initial and Retreatment Patients [n(%)]

Types of Resistance	Total (n=181)	Initial Treatment (n=120)	Retreatment (n=61)	*p*-value
Mono-drug resistance	59 (32.60)	41 (34.17)	18 (29.51)	0.527
Multi-drug resistance	74 (40.88)	37 (30.83)	37 (60.65)	<0.001
Poly-drug resistance	48 (26.52)	42 (35.00)	6 (9.84)	<0.001

$p < 0.05$). Conversely, polydrug-resistance TB demonstrated higher incidence in initial treatment patients, with a marked discrepancy compared to retreatment cases (35.00% vs 9.84%; $p < 0.05$).

Differences in the Drug Resistance Patterns of Drug-Resistant Tuberculosis Patients Between Initial and Retreatment Patients

Table 3 Among first-line antitubercular drugs, ethambutol demonstrates the highest prevalence of drug resistance, followed in hierarchical order by isoniazid, rifampin, streptomycin, and rifabutin. Among second-line drugs, fluoroquinolone antibiotics exhibit the most pronounced resistance patterns, ranked in descending order as ofloxacin > moxifloxacin > levofloxacin. Statistically significant differences in resistance rates to rifampicin, streptomycin, amikacin, and rifabutin were observed between initial and retreatment patients ($p < 0.05$).

The Differences in Inpatient Medication Utilization Between Initial and Retreatment Drug-Resistant Tuberculosis Patients

Table 4 and Figure 2 The overall inpatient medication utilization rate of first-line drugs in DR-TB patients was relatively high. Among antituberculosis inpatient medication utilization settings, the prescription rates of first-line agents—

Table 3 Differences in the Drug Resistance Patterns of DR-TB Patients Between Initial and Retreatment Patients [n(%)]

Resistance Status		Overall n=181	Initial Treatment n=120	Retreatment n=61	*p*-value
First-line drugs					
	R	93 (51.38)	49 (40.83)	44 (72.13)	<0.001
	H	117 (64.64)	75 (62.50)	42 (68.85)	0.164
	S	61 (33.70)	33 (27.50)	28 (45.90)	0.013
	E	126 (69.61)	90 (75.00)	36 (59.02)	0.147
Second-line injectable drugs					
	Am	11 (6.08)	4 (3.33)	7 (11.48)	0.045*
	Km	12 (6.63)	5 (4.17)	7 (11.48)	0.109*
	Cm	22 (12.15)	13 (10.83)	9 (14.75)	0.443
Second-line oral drugs					
	Eto	22 (12.15)	18 (15.00)	4 (6.56)	0.107
	PAS	12 (6.63)	7 (5.83)	5 (8.20)	0.465
	Rfb	53 (29.28)	25 (20.83)	28 (45.90)	<0.001
Fluoroquinolone drugs					
	Ofx	45 (24.86)	24 (20.00)	21 (34.43)	0.110
	Mfx	40 (22.10)	22 (18.33)	18 (29.51)	0.202
	Lfx	32 (17.68)	16 (13.33)	16 (26.23)	0.149

Note: *Fisher's Exact Test.

Abbreviations: R, Rifampicin; H, Isoniazid; S, Streptomycin; E, Ethambutol; Rfb, Rifabutin; Am, Amikacin; Km, Kanamycin; Cm, Capreomycin; Eto, Ethionamide; PAS, Para-aminosalicylic acid; Ofx, Ofloxacin; Mfx, Moxifloxacin; Lfx, Levofloxacin.

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Table 4 The Differences in Inpatient Medication Utilization Between Initial and Retreatment DR-TB Patients [n(%)]

Medicine		Overall n=181	Initial Treatment n=120	Retreatment n=61	p value
First-line drugs					
	H	107 (59.12)	84 (70.00)	23 (37.70)	<0.001
	R	91 (50.28)	76 (63.33)	15 (24.59)	<0.001
	Z	102 (56.35)	74 (61.67)	28 (45.90)	0.043
	E	117 (64.64)	90 (75.00)	27 (44.26)	<0.001
Second-line injectable drugs	Am	19 (10.50)	6 (5.00)	13 (21.31)	<0.001
Second-line oral drugs					
	Eto	1 (0.55)	1 (0.83)	0	0.958
	Pto	11 (6.08)	4 (3.33)	7 (11.48)	0.045*
	Cs	85 (46.96)	45 (37.50)	40 (65.57)	<0.001
	Pa	2 (1.10)	2 (1.67)	0	0.551*
	Rft	20 (11.05)	12 (10.00)	8 (3.11)	0.528
Fluoroquinolone drugs					
	Lfx	82 (45.30)	50 (41.67)	32 (52.46)	0.168
	Mfx	49 (27.07)	27 (22.50)	22 (36.07)	0.052
Other classes of drugs					
	Bdq	34 (18.78)	19 (15.83)	15 (24.59)	0.154
	Lzd	88 (48.62)	44 (36.67)	44 (72.13)	<0.001
	Cfz	67 (37.02)	32 (26.67)	35 (57.38)	<0.001

Note: *Fisher's Exact Test.

Abbreviations: R, Rifampicin; H, Isoniazid; E, Ethambutol; Z, Pyrazinamide; Rft, Rifapentine; Am, Amikacin; Eto, Ethionamide; Pto, Prothionamide; Cs, Cycloserine; Pa, Isoniazid para-aminosalicylate; Mfx, Moxifloxacin; Lfx, Levofloxacin; Bdq, Bedaquiline; Lzd, Linezolid; Cfz, Chlorfazimine.

specifically, H, R, Z, and E —exhibited significantly higher utilization in initial treatment patients compared to retreatment cases. Conversely, second-line drugs, including Am, Cs, Lzd, Cfz, and Pto, demonstrated markedly elevated prescription frequencies in retreatment patients, with statistically significant differences observed between the two cohorts ($p<0.05$). When analyzing inpatient medication utilization trends across consecutive years (2021–2023), this study revealed that the prescription rates of first-line agents including H, R, and Rft demonstrated a significant annual decline, while second-line medications such as Cs, Bdq, Lzd, and Cfz exhibited a concomitant increase, with statistically significant differences observed between those years ($p < 0.05$).

The Spectrum of Drug Resistance in 74 Multidrug-Resistant Tuberculosis Patients

Table 5 Among 74 MDR-TB patients, 33 distinct drug resistance profiles were identified. The number of drug-resistant agents ranged from 2 to 12. Among these cases, 41.89% (31/74) demonstrated resistance to six or more antituberculosis drugs, indicating a significant prevalence of multidrug-resistant strains. The three most prevalent resistance patterns were: rifampin + isoniazid + streptomycin + ethambutol + rifabutin (10 cases); rifampin + isoniazid (9 cases); rifampin + isoniazid + streptomycin + ethambutol + ofloxacin + moxifloxacin + levofloxacin + rifabutin (7 cases).

Treatment Outcomes of Multidrug-Resistant Tuberculosis Patients

Table 6 Among the 74 MDR-TB patients retrospectively analyzed, a successful treatment outcome—defined as cure or treatment completion—was attained by 55.41% of the cohort. Unsuccessful treatment outcome comprised 2 died, 23 instances of loss to follow-up, and 8 cases with failed treatment.

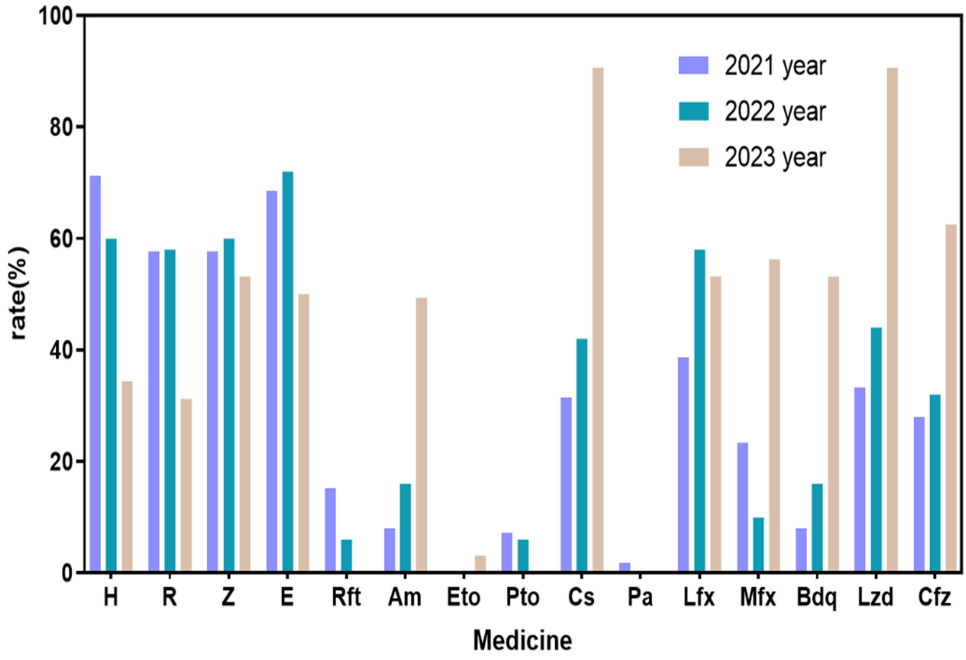

Figure 2 Inpatient medication utilization in DR-TB patients from 2021 to 2023.
Abbreviations: H, Isoniazid; R, Rifampicin; Z, Pyrazinamide; E, Ethambutol; Rft, Rifapentine; Am, Amikacin; Eto, Ethionamide; Pto, Prothionamide; Cs, Cycloserine; Pa, Isoniazid para-aminosalicylate; Lfx, Levofloxacin; Mfx, Moxifloxacin; Bdq, Bedaquiline; Lzd, Linezolid; Cfz, Chlorfazimine.

Univariate and Multivariate Binary Logistic Regression Analysis of Factors Affecting Treatment Outcomes in Multidrug-Resistant Tuberculosis Patients

Tables 7 and 8 Both univariate and multivariate binary logistic regression analyses were performed with the treatment outcome as the dependent variable (coded as 1 for unsuccessful outcome and 0 for successful outcome). All independent variables from the univariate analysis were incorporated into the multivariate regression analysis using the entering method. The independent variables comprised the following categorical data: gender, age, district, occupation, treatment category (initial/retreatment), presence of concurrent lung infections, pulmonary cavitation, comorbidities, resistance to fluoroquinolones, XDR/pre-XDR TB status, resistance to all first-line drugs (FLDs), and the use of bedaquiline-containing regimen (Table 7). In the univariate logistic regression analysis, the age (≥60 years; OR = 4.848, 95% CI:

Table 5 The Spectrum of Drug Resistance in 74 MDR-TB Patients [n(%)]

	Drug Resistance Spectrum	n	%
2 kinds of resistance drugs			
	R + H	9	12.16
3 kinds of resistance drugs			
	R + H + E	3	4.05
	R + H + Rfb	3	4.05
	R + H + S	2	2.70
	R + H + Eto	1	1.35
4 kinds of resistance drugs			
	R + H + E + Rfb	3	4.05
	R + H + E + Ofx	2	2.70
	R + H + S + E	2	2.70
	R + H + S + Rfb	2	2.70
	R + H + S + PAS	2	2.70

(*Continued*)

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Table 5 (Continued).

	Drug Resistance Spectrum	n	%
5 kinds of resistance drugs			
	R + H + S + E + Rfb	10	13.50
	R + H + S + E + Cm	1	1.35
	R + H + Ofx + Lfx + Mfx	1	1.35
	R + H + S + Cm + Rfb	1	1.35
	R + H + S + PAS + Rfb	1	1.35
6 kinds of resistance drugs			
	R + H + E + Ofx + Lfx + Mfx	1	1.35
	R + H + E + Ofx + Eto + Rfb	1	1.35
	R + H + Am + Km + Cm + PAS	1	1.35
7 kinds of resistance drugs			
	R + H + S + E + Mfx + PAS + Rfb	2	2.70
	R + H + S + E + Ofx + Lfx + Mfx	2	2.70
	R + H + S + E + Ofx + Mfx + Rfb	2	2.70
	R + H + S + E + Ofx + Eto + Rfb	1	1.35
	R + H + E + Ofx + Lfx + Mfx + Cm	1	1.35
8 kinds of resistance drugs			
	R + H + S + E + Ofx + Lfx + Mfx + Rfb	7	9.46
	R + H + S + Ofx + Mfx + Am + Km + Rfb	2	2.70
	R + H + S + E + Am + Km + Cm + PAS	1	1.35
	R + H + E + Ofx + Lfx + Mfx + Cm + Eto	1	1.35
9 kinds of resistance drugs			
	R + H + S + E + Ofx + Lfx + Mfx + Eto + Rfb	2	2.70
	R + H + S + E + Ofx + Lfx + PAS + Eto + Rfb	1	1.35
	R + H + S + E + Am + Km + Cm + Eto + PAS	1	1.35
10 kinds of resistance drugs			
	R + H + S + E + Ofx + Lfx + Mfx + Am + Km + Rfb	3	4.05
12 kinds of resistance drugs			
	R + H + S + E + Ofx + Lfx + Mfx + Am + Km + Cm + PAS + Rfb	1	1.35
	R + H + E + Ofx + Lfx + Mfx + Am + Km + Cm + Eto + PAS + Rfb	1	1.35

Notes: Each drug resistance pattern listed represents the resistance profile of a single patient; The column "n" indicates the number of patients exhibiting that specific combination.

Abbreviations: R, Rifampicin; H, Isoniazid; S, Streptomycin; E, Ethambutol; Rfb, Rifabutin; Am, Amikacin; Km, Kanamycin; Cm, Capreomycin; Eto, Ethionamide; PAS, Para-aminosalicylic acid; Ofx, Ofloxacin; Mfx, Moxifloxacin; Lfx, Levofloxacin.

Table 6 Treatment Outcomes of MDR-TB Patients (n = 74)

Treatment Outcomes	n (%)
Successful Treatment outcomes	41 (55.41)
Cured	26 (35.14)
Completed	15 (20.27)
Unsuccessful Treatment Outcome	33 (44.59)
Died	2 (2.70)
Failed	8 (10.81)
Loss to follow Up	23 (31.08)

Table 7 Variables and Assignment

Variable Name	Variable	Assignment Status
Treatment outcome	Y	Successful Outcome:0; Unsuccessful Outcome:1
Gender	X1	Female:0; male:1
Age	X2	≤30:0; 31–44:1; 45–59:2; ≥60:3
District	X3	Local:0; nonlocal:1
Occupation	X4	Farmer:0; student:1; others:3
Treatment type	X5	Initial treatment:0; retreatment:1
Combine lung infections	X6	No:0; Yes:1
Pulmonary Cavitation	X7	No:0; Yes:1
Comorbidity	X8	No:0; Yes:1
Resistance to FQs	X9	No:0; Yes:1
XDR/pre-XDR TB	X10	No:0; Yes:1
Resistance to all 5 FLDs	X11	No:0; Yes:1
Bedaquiline-containing regimen	X12	No:0; Yes:1

Abbreviations: FQs, Fluoroquinolones; FLDs, First-line drugs (Rifampicin, Isoniazid, Streptomycin, Ethambutol).

1.063–22.107), retreatment (OR = 3.467, 95% CI: 1.323–9.803), resistance to FQs (OR = 3.718, 95% CI: 1.410–9.804), and XDR/pre-XDR TB (OR = 2.734, 95% CI: 1.061–7.049) were identified as risk factors for unsuccessful treatment outcomes in MDR-TB patients. Conversely, Bedaquiline-containing regimen demonstrated a protective effect (OR = 0.192, 95% CI: 0.065–0.563; $p < 0.05$). All variables in the final model had VIF < 5. In the multivariable logistic regression analysis, retreatment emerged as an independent risk factor for unsuccessful treatment outcomes in MDR-TB patients (OR = 4.524, 95% CI: 1.174–17.435), whereas bedaquiline-containing regimen demonstrated a protective effect on treatment outcomes (OR = 0.155, 95% CI: 0.033–0.721) (Table 8).

Composition and Duration of Bedaquiline-Containing Regimens in MDR-TB Patients (n=31)

Table 9 Of the 74 individuals diagnosed with MDR-TB enrolled in the present investigation, 31 (41.89%) were administered a therapeutic regimen incorporating bedaquiline. As detailed in Table 4, these regimens were stratified into short-course (6–9 months) and long-course (18–20 months) types. The short-course regimen was implemented in 12 patients, with the predominant therapeutic combinations comprising Bdq + Lzd + Mfx + Cs + Z (n=7) and Bdq + Lzd + Lfx + Cs + Z (n=3). Long-course regimens were used in 19 patients with more complex resistance profiles. The most frequently adopted combinations in this cohort were Bdq + Lzd + Lfx + Cs + Z (n=9) and Bdq + Lzd + Cfz + Cs (n=5). Notably, the duration of bedaquiline administration was consistently 24 weeks across all cases.

Discussion

The World Health Organization (WHO) has outlined an elimination strategy for TB, setting dual objectives to reduce annual incidence to under 10 cases per 100,000 population while achieving 90.00% and 95.00% reductions in incidence and mortality rates, respectively.[15] However, the emergence of DR-TB constitutes a critical impediment to sustained progress in global TB control initiatives,[16] and a quarter of its fatalities are attributed to antimicrobial resistance.[17] Characterizing antimicrobial resistance profiles in tuberculosis patients is critical not only for evaluating the efficacy of contemporary TB control strategies but also for informing the rational design of next-generation therapeutic regimens.

According to our findings, the overall prevalence of resistance to at least one first-line anti-tuberculosis drug was determined to be 17.56% (181/1031), The prevalence of drug-resistant TB observed in this study is lower compared to regions such as Zhejiang (23.10%),[18] Sichuan (23.59%),[19] and Dalian (31.1%),[20] but higher than reported in Northern Iran and South Korea (6.12% and 13.55%, respectively).[21,22] These disparities may stem from variations in sample selection criteria, sample sizes, diagnostic methodologies, and the temporal scope of data collection—factors that collectively introduce potential biases into the comparative analysis. Analysis of drug resistance types among 181

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Table 8 Univariate and Multivariate Binary Logistic Regression Analysis of Factors Affecting Treatment Outcomes in MDR-TB Patients

Variable	Successful Outcome (n=41)	Unsuccessful Outcome (n=33)	Univariate		Multivariate	
			OR (95% CI)	p-value	OR (95% CI)	p value
Gender						
Female	13 (31.71)	6 (18.18)	Referent			
Male	28 (68.29)	27 (81.82)	2.089 (0.694–6.292)	0.190	2.318 (0.519–10.345)	0.271
Age						
≤30	8 (19.51)	3 (9.09)	Referent			
31-44	10 (24.39)	4 (15.15)	1.067 (0.183–6.213)	0.943	0.367 (0.038–3.516)	0.385
45-59	12 (29.27)	6 (21.21)	1.333 (0.256–6.940)	0.732	0.210 (0.022–1.969)	0.172
≥60	11 (26.83)	20 (54.55)	4.848 (1.063–22.107)	0.041	0.506 (0.055–4.691)	0.549
District						
Local	39 (95.12)	30 (90.91)	Referent			
Nonlocal	2 (4.88)	3 (9.09)	1.950 (0.306–12.419)	0.480	3.692 (0.227–60.023)	0.359
Occupation						
Farmer	33 (80.49)	30 (90.91)	Referent			
Student	1 (2.44)	1 (3.03)	1.100 (0.066–18.373)	0.947	1.683 (0.003–819.149)	0.869
Others	7 (17.07)	2 (6.06)	0.314 (0.061–1.632)	0.168	0.216 (0.026–1.757)	0.152
Treatment type						
Initial treatment	26 (63.41)	11 (33.33)	Referent			
Retreatment	15 (36.59)	22 (66.67)	3.467 (1.323–9.803)	0.011	4.524 (1.174–17.435)	0.028
Combine lung infections						
No	18 (43.90)	15 (45.45)	Referent			
Yes	23 (56.10)	18 (54.55)	0.939 (0.374–2.361)	0.894	0.839 (0.232–3.031)	0.788
Pulmonary Cavitation						
No	10 (24.39)	10 (30.30)	Referent			
Yes	31 (75.61)	23 (69.70)	0.742 (0.265–2.077)	0.570	1.278 (0.302–5.412)	0.739

Comorbidity						
No	24 (58.54)	14 (42.42)	Referent			
Yes	17 (41.46)	19 (57.58)	1.916 (0.757–4.850)	0.170	1.620 (0.418–6.278)	0.485
Resistance to FQs						
No	29 (70.73)	13 (39.39)	Referent			
Yes	12 (29.27)	20 (60.61)	3.718 (1.410–9.804)	0.008	5.562 (0.291–106.382)	0.254
XDR/pre-XDR TB						
No	25 (60.98)	12 (36.36)	Referent			
Yes	16 (39.02)	21 (63.64)	2.734 (1.061–7.049)	0.037	1.134 (0.071–18.166)	0.929
Resistance to all FLDs						
No	23 (56.10)	20 (60.61)	Referent			
Yes	18 (43.90)	13 (39.39)	0.831 (0.327–2.109)	0.696	0.354 (0.078–1.597)	0.177
Bedaquiline-containing regimen						
No	19 (46.34)	24 (72.73)	Referent			
Yes	22 (53.66)	9 (27.27)	0.192 (0.065–0.563)	0.003	0.155 (0.033–0.721)	0.017

Abbreviations: FQs, Fluoroquinolones; FLDs, First-line drugs (Rifampicin, Isoniazid, Streptomycin, Ethambutol).

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Table 9 Composition and Duration of Bedaquiline-Containing Regimens in MDR-TB Patients

Regimen Type	Drug Combination	Number of Patients
Short-course regimen		
	Bdq + Lzd + Mfx + Cs + Z	7
	Bdq + Lzd + Lfx + Cs + Z	3
	Bdq + Lzd + Lfx + Cfz	2
Long-course regimen		
	Bdq + Lzd + Lfx + Cs + Z	9
	Bdq + Lzd + Cfz + Cs	5
	Bdq + Lzd + Cfz + Z	3
	Bdq + Lzd + Lfx + Cs + Cfz	2

Abbreviations: Bdq, Bedaquiline; Lzd, Linezolid; Mfx, Moxifloxacin; Lfx, Levofloxacin; Cfz, Chlorfazimine; Cs, Cycloserine; Z, Pyrazinamide.

participants revealed that MDR-TB was the most prevalent one, accounting for 40.88% (74/181). Compared to a survey conducted in Pakistan,[23] the proportion of MDR-TB in this study was significantly lower (40.88% vs 64.10%). Firstly, Pakistan, being a global high-burden TB country, has a more intricate transmission chain of drug-resistant tuberculosis, the irregular use of second-line drugs in this country further complicates the issue.[24] Additionally, the sample characteristics exhibited significant heterogeneity. However, compared with Beijing Chest Hospital,[25] the proportion of MDR in this study is indeed higher. This discrepancy may be attributed to a variety of factors, including sample selection, regional differences, characteristics of the patient population. The study revealed a higher proportion of retreatment patients among MDR-TB cases, whereas initial treatment patients constituted a significantly larger proportion in Poly-drug resistance (PDR-TB) cases, with statistical significance observed between the groups. Patients with prior exposure to anti-tuberculosis pharmacotherapy exhibit a heightened propensity for acquired drug resistance, a condition multifactorial in origin that may stem from suboptimal treatment regimens, subtherapeutic dosing, premature discontinuation of therapy, or patient non-adherence to prescribed treatment protocols.[26] Many studies have found that retreatment is one of the risk factors for the development of drug-resistant tuberculosis.[2,16,27–29] Therefore, maintaining heightened surveillance for retreatment TB cases is critical, necessitating prompt detection and systematic management of drug-resistant strains through optimized therapeutic regimens and targeted infection control strategies to preserve treatment efficacy and curb transmission. Consistent with findings from a survey conducted in Xinjiang,[30] the proportion of PDR-TB observed in our study was significantly higher among initial treatment patients (35.00%) than among retreatment patients (9.84%). Polydrug resistance in initial treatment patients represents an “intermediate” resistance phenotype that has not yet progressed to MDR-TB. These patients may harbor strains with resistance mutations that confer lower fitness costs or are less likely to accumulate additional resistance without further drug pressure. The present study investigated the resistance of first-line drug among 181 DR-TB patients, notably, the observed resistance rates ranked as follows: Ethambutol (E) > Isoniazid (H) > Rifampicin (R) > Streptomycin (S) > Rifabutin (Rfb). The resistance profile to first-line anti-tuberculosis drugs documented in this investigation diverges conspicuously from patterns reported in preceding studies,[12,22,29] particularly regarding ethambutol. Notably, our data revealed the highest prevalence of ethambutol resistance, whereas other studies have suggested the ethambutol with comparatively lower resistance rates. The drug resistance rate to EMB (ethambutol) in China is gradually increasing, reaching nearly 17.2% among retreatment TB patients.[12] Specific codons within the embB gene, particularly positions 306 and 406, have been implicated in ethambutol resistance mechanisms. Mutations at these sites or reduced gene expression serve to enhance bacterial tolerance to the drug.[31,32] Alterations in bacterial membrane permeability can impede ethambutol uptake, thereby contributing to enhanced drug resistance.[33] This study reveals that the prevalence of resistance to second-line anti-tuberculosis drugs remains a significant clinical challenge. Among injectable agents, capreomycin demonstrated the highest resistance rates, whereas ethionamide exhibited the most pronounced drug resistance among oral agents. This study demonstrates that fluoroquinolones (FQs) exhibited the highest resistance rates among non-first-line anti-tuberculosis agents, with

resistance prevalence ranging from 17.68% to 24.86%. FQs are indispensable components of second-line anti-tuberculosis regimens for MDR-TB treatment, primarily targeting DNA gyrase subunits A (GyrA) and B (GyrB). These critical enzyme targets are encoded by the gyrA and gyrB genes.[34–36] FQs are broad-spectrum antibiotics frequently employed in clinical practice. Consequently, the risk of drug resistance in tuberculosis (TB) patients has also increased proportionally. Therefore, the clinical use of fluoroquinolones in TB patients should be more strictly managed to reduce the emergence of drug-resistant TB at the source.[35]

Few researchers at home and abroad have conducted statistical analyses of inpatient medication utilization for DR-TB patients. The author believes that, for DR-TB patients, it is essential not only to understand their drug resistance patterns but also to guide their medication use. In our cohort, first-line drugs H, R, Z, and E were administered to both initial and retreatment patients, albeit with significantly different frequencies. Among initial treatment patients, H, R, Z, and E utilization rates ranged from 61.67% to 75.00%, whereas in retreatment patients, these rates were substantially lower (37.70%–45.90%; $p < 0.05$ for all four drugs). Although the standard regimen for drug-susceptible tuberculosis comprises these four first-line agents,[37] the present study cohort consisted exclusively of patients with confirmed resistance to first-line anti-tuberculosis drugs. This discrepancy reflects two fundamental challenges: the limited availability of effective therapeutic options for resistant strains, and the insufficient evidence base supporting alternative regimens for patients with resistance to key first-line drugs such as rifampicin, as well as for those with complex MDR-TB.[38] The management of DR-TB remains a persistent clinical challenge in pulmonary medicine, with ongoing discussions among researchers regarding optimal therapeutic strategies.[39] This difficulty arises not only from the aforementioned limitations but also from the broader context of constrained treatment options for complex resistance patterns and the suboptimal safety profiles of certain legacy second-line drugs.[40] In our cohort of 181 DR-TB patients, the second-line injectable drug amikacin was administered in 10.50% (19/181) of cases. Other second-line drugs, including Pto, Cs, Mfx, Lzd, and Cfz, were used significantly more frequently in retreatment patients than in those receiving initial treatment. Notably, annual utilization of key second-line agents, particularly Cs, Bdq, Lzd, and Cfz, increased progressively over the study period. The second-line injectable antitubercular agents, including kanamycin, amikacin, capreomycin, and fluoroquinolones such as ofloxacin and levofloxacin, constitute essential components of the treatment regimen for multidrug-resistant Mycobacterium tuberculosis.[41] The patterns of second-line drug utilization observed in this study are consistent with both the Chinese Tuberculosis Prevention and Control Guidelines and the WHO recommendations, underscoring the essential role of second-line agents in all-oral regimens for the treatment of DR-TB.[42] In view of the current situation of anti-tuberculosis and the observed inpatient medication utilization patterns, a more detailed and scientific planning of medication strategy is crucial.[43] The drug resistance profile of MDR-TB patients in this institution exhibits a complex and diverse nature. An examination of the resistance patterns among 74 MDR-TB cases uncovered 33 distinct combinations, with the extent of drug resistance varying between 2 and 12 kinds of drugs. The high drug resistance prevalence coupled with heterogeneous resistance profiles constitute primary obstacles to achieving optimal treatment outcomes in MDR-TB patients.

The prognosis of patients with MDR-TB remains substantially poorer than that of those with drug-susceptible tuberculosis,[37,44,45] in part because many therapeutic regimens fail to achieve durable cure in a considerable proportion of cases and are associated with highly unfavorable safety profiles.[46] Therefore, it is critical to determine treatment success rates and analyze prognostic factors in MDR-TB patients. Our analysis of prognostic outcomes in 74 MDR-TB patients revealed a treatment success rate of 55.41%, which aligns closely with contemporary national and regional data: the WHO-reported national figure for China during 2017–2022 (55.9%) and provincial statistics from Hunan (57%).[12,47] However, this efficacy falls short of the World Health Organization's benchmark standard of 75% and compares unfavorably to treatment success rates documented in international contexts, notably those reported in northwestern Ethiopia (63%) and Pakistan (74.3%).[48,49] The loss-to-follow-up rate among MDR-TB patients in this study was 31.08%, comparable to findings from Hunan Province,[47] yet significantly higher than that reported by Liu et al in Beijing.[50] Notably, this elevated attrition rate constituted a substantial contributor to the suboptimal treatment success observed in our cohort. Based on these findings, our findings suggest that implementing a structured follow-up protocol wherein primary care physicians at the patient's registered residence maintain regular communication with the patient to emphasize the critical importance of treatment continuation. This proactive engagement aims to improve therapeutic adherence and mitigate risks associated with interrupted anti-TB

regimens. In the univariate logistic regression analysis, retreatment (OR = 3.467, 95% CI: 1.323–9.803, p = 0.011) was identified as a risk factor for unsuccessful treatment outcomes in MDR-TB patients. In the multivariable logistic regression analysis, retreatment emerged as an independent risk factor for unsuccessful treatment outcomes (OR = 4.524, 95% CI: 1.174–17.435, p = 0.028). This finding aligns with numerous prior studies demonstrating that prior treatment history is strongly associated with adverse outcomes in individuals with drug-resistant tuberculosis.[51–53] A history of previous tuberculosis treatment may be associated with a longer duration of illness, more extensive lung parenchymal damage, and poorer overall health status, all of which contribute to an increased risk of unfavorable outcomes. The bedaquiline-containing regimen (OR = 0.155) was independently associated with successful treatment outcomes in patients with MDR-TB. Bedaquiline, the prototypical aryl-quinoline drug, gained FDA approval in 2012 for treating MDR-TB.[41,54] This novel agent selectively targets mycobacterial energy metabolism by inhibiting ATP synthase, exhibiting high specificity for the bacterial enzyme. This exquisite selectivity minimizes the risk of target-based toxicity in humans.[54,55] A study in China found that wider use of bedaquiline-containing regimens could significantly reduce the burden of MDR-TB.[56] Bedaquiline was approved in China in 2016 for the treatment of adults with multidrug-resistant tuberculosis (MDR-TB), with its subsequent clinical implementation in 2018 signifying a pivotal advancement in the national strategy to contain DR-TB. In the present study, 31 patients (41.89%, 31/74) received a bedaquiline-containing regimen, wherein long-course protocols (18–20 months) were predominant, constituting 61.3% (19/31) of the cohort. In all regimens, bedaquiline was administered for a fixed duration of 24 weeks, consistent with the approved dosing schedule and current recommendations.[57] This standardization facilitates treatment monitoring and safety assessment, particularly regarding QT interval prolongation—a concern that remains relevant with bedaquiline-containing regimens.[58] The predominant short-course combination was Bdq + Lzd + Mfx + Cs + Z (n = 7), whereas the most frequently employed long-course regimen was Bdq + Lzd + Lfx + Cs + Z (n = 9). These combinations align with the principle of constructing regimens with at least four effective drugs for MDR-TB treatment: prioritizing all Group A agents (bedaquiline, linezolid, and levofloxacin or moxifloxacin), followed by Group B agents (clofazimine and cycloserine), and supplementing with Group C agents, such as pyrazinamide, as clinically indicated.[14]

Limitations

Several limitations of this study should be acknowledged. First, the retrospective, single-center design limits the generalizability of our findings. Second, the relatively small sample size, particularly for subgroup analyses of MDR-TB patients (n=74), may have limited statistical power to detect smaller effect sizes. Third, drug susceptibility testing was not available for some second-line drugs (eg, bedaquiline and linezolid), precluding analysis of resistance to these newer agents. Finally, molecular characterization of resistance mechanisms was not performed, limiting our understanding of the genetic basis of the observed resistance patterns. Future multicenter prospective studies with larger cohorts and comprehensive molecular profiling are warranted to validate and extend our findings.

Conclusion

The management of DR-TB patients remains a critical priority in global TB control initiatives. In Fuyang, although the overall incidence of DR-TB is low, the proportion of MDR-TB cases is notably high, accompanied by suboptimal treatment success rates. Retreatment was identified as an independent risk factor for unfavorable outcomes, while bedaquiline-containing regimens demonstrated a strong protective effect. Based on these findings, we propose the following targeted recommendations for the Fuyang Center for Disease Control and Prevention (CDC) to fortify local TB control endeavors: institute systematic surveillance and comprehensive management protocols for retreatment cases; expand the accessibility of bedaquiline-based regimens as the therapeutic linchpin for MDR-TB; and initiate localized surveillance mechanisms to detect emerging drug resistance, with particular emphasis on bedaquiline. Implementation of these evidence-based strategies is essential to improve treatment outcomes, curb transmission, and ultimately alleviate the burden of drug-resistant tuberculosis in Fuyang City.

Data Sharing Statement

The datasets generated and analyzed during the current study are available from the corresponding author Yunyun Ding upon reasonable request.

Ethical Approval

This study was conducted in accordance with the ethical standards set forth in the Declaration of Helsinki and was approved by the Ethics Committee of the Second People's Hospital of Fuyang City (20250630096). Due to the retrospective design, the Ethics Committee formally waived the requirement for written informed consent from participants or their legal representatives, a decision ratified upon formal review. Patient data underwent rigorous de-identification to ensure confidentiality and anonymity throughout analysis and reporting. No personally identifiable information was accessed or utilized at any research stage.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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