ORIGINAL ARTICLE

# Geographic, Health-System and Socioeconomic Drivers of MDR-TB Burden in District Mandi, Himachal Pradesh: Insights for Achieving India's End TB 2030 Targets

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## ABSTRACT

**Background**: Multidrug-resistant tuberculosis (MDR-TB) remains a critical public health challenge in India, despite notable declines in TB incidence and mortality under the National Tuberculosis Elimination Programme (NTEP). Mountainous districts such as Mandi in Himachal Pradesh face amplified barriers to timely diagnosis and treatment. This study analyzes block-wise MDR-TB characteristics to identify diagnostic delays, treatment gaps, resistance patterns and socioeconomic factors shaping outcomes. **Methods**: A retrospective observational analysis was conducted using secondary data from all 28 Designated Microscopy Centres (DMCs) in District Mandi during 2018–19. Data on institutional inputs, diagnostic infrastructure, sputum testing, drug-resistance profiles, treatment initiation timelines, geographic accessibility, clinical complaints, and sociodemographic variables were analysed descriptively across blocks. **Results**: The district reported 919 sputum-positive TB cases and notable gaps in laboratory capacity, with only 35.7% of DMCs equipped with LED microscopes. Mean distance to the nearest CBNAAT facility was 50.75 km, reaching 150 km in remote blocks. Primary MDR-TB accounted for 11–100% of cases, and XDR-TB was concentrated in Bagsiad (36.4%). Diagnostic delays >7 days ranged from 22.2% to 78.6%, particularly high in Ratti. Treatment initiation within 7 days varied widely (12.5–87.5%). Significant socioeconomic vulnerabilities were observed, including unemployment post-diagnosis (up to 75%), overcrowding (20–57.1%), and presence of concurrent TB cases within families and communities. Patients often travelled >100 km for diagnosis and specialist care, prioritizing perceived quality over proximity. **Conclusion**: MDR-TB control in Mandi district is challenged by geographic inaccessibility, limited diagnostic capacity, socioeconomic distress and substantial block-level disparities. Strengthening decentralised molecular diagnostics, ensuring rapid treatment initiation, improving transport and social support, and targeting high-burden blocks are critical for aligning district performance with India's End TB goal.

## KEYWORDS

Resistant TB, patient characteristics, delay in diagnosis, sub Himalayan region

## INTRODUCTION

Tuberculosis (TB) remains a major public health challenge in India despite sustained programmatic efforts under the National Tuberculosis Elimination Programme (NTEP). India continues to contribute the highest share of the global TB burden, although recent trends show a measurable decline in both incidence and mortality. Between 2015 and 2022, TB incidence in India decreased by 16% and TB mortality by 18%, reflecting improved case detection, early diagnosis and enhanced treatment coverage. The India TB Report 2024 highlights that

in 2023, nearly 1.89 crore sputum smear tests and over 68 lakh NAAT tests were conducted nationwide, strengthening diagnostic reach through expansion of molecular platforms such as CBNAAT and Truenat.[1] However, drug-resistant TB (DR-TB), particularly multidrug-resistant TB (MDR-TB), continues to pose significant challenges. India notified 63,939 MDR/RR-TB cases in 2023, underscoring persistent transmission, delayed diagnosis and treatment complexities associated with resistant forms of TB.

Mountainous and rural regions, such as those in Himachal Pradesh, face amplified barriers including diagnostic delays, limited accessibility, inadequate laboratory penetration and socioeconomic vulnerabilities. Evaluating MDR-TB epidemiology, diagnostic infrastructure, treatment initiation timelines and patient-level determinants at the district level is essential for tailoring interventions.[2,3,4] This study examines block-wise MDR-TB characteristics in District Mandi to identify operational gaps and guide targeted, evidence-based strategies aligned with India's commitment to end TB by 2025.

**Objective:** To assess block-level variations in diagnostic delays, treatment initiation timelines, healthcare accessibility, drug-resistance patterns, and socioeconomic determinants among MDR-TB patients in District Mandi, Himachal Pradesh, in order to identify system-level and patient-level factors contributing to disparities in MDR-TB care and transmission risk.

## Material & Methods

**Study Design and Setting:** This observational study was conducted in the district of Mandi, Himachal Pradesh, India, focusing on patients diagnosed with Multi-Drug Resistant Tuberculosis (MDR TB) during the years 2018-19. The district's healthcare infrastructure includes 28 Designated Microscopy Centres (DMCs) spread across Primary Health Centres (PHCs), Community Health Centres (CHCs), Civil Hospitals, District Hospital, and a Medical College.

**Data Sources and Collection:** Data were retrospectively collected from records maintained at all 28 DMCs in the district. These included diagnostic inputs, process and output indicators, patient demographics, diagnosis details, drug resistance patterns, treatment regimens, and healthcare accessibility metrics. Data on the number of sputum tests conducted, positivity rates, and laboratory resources were extracted. Special attention was given to distances patients travelled for diagnostic and treatment services and delay times in diagnosis and treatment initiation.

**Participants:** All patients diagnosed with MDR TB in the district during 2018-19 were included. This included patients identified through sputum testing at DMCs and confirmation via diagnostic facilities such as the District Hospital, Intermediate Reference Laboratories, and Medical Colleges.

**Diagnostic Methods:** Sputum samples were collected and examined using conventional binocular and LED microscopes available at the DMCs. Confirmatory diagnosis utilized CBNAAT (Cartridge Based Nucleic Acid Amplification Test) facilities predominantly located at the District Hospital, with distances varying up to 150 km from DMCs. Diagnosis gaps (delays) were recorded in days, categorized as less than or greater than seven days.

**Treatment Regimens and Initiation:** Treatment regimens prescribed to patients included shorter MDR regimens, conventional regimens, and modified regimens. The initiation of treatment was tracked, with emphasis on whether treatment began within seven days of diagnosis. The type of hospital where treatment commenced i.e., District Hospital, Medical College, or Intermediate Reference Laboratory was recorded alongside patient access distances.

**Data Analysis:** Descriptive statistics were computed for institutional capacities, diagnostic outputs, patient demographics, and treatment initiation timeliness. Geographic accessibility was analyzed using mean, minimum, and maximum travel distances to the nearest diagnostic and treatment centers. Patterns of drug resistance and clinical presentations were summarized. Variations across blocks within the district were also assessed to identify disparities in healthcare access and outcomes.

**Ethical Considerations:** The study was conducted using anonymized secondary data obtained from healthcare records, ensuring patient confidentiality. Institutional ethical approval was secured vide letter number HFW (H)/SLBSGMC/IEC/2018-4 dated 12.12.2018.

## Results

There were 28 notified designated microscopy centres (DMC) in district Mandi. DMC located in Primary health centre are 3, in Community Health centre 9. In Civil Hospital 13 and one each in District Hospital and Medical college. Whereas there are three Primary Health Centres (PHC), 13 Community Health centres (CHC), nine civil hospitals (CH), one district hospital (DH) and one Medical College in district. There were 11 Lab Technician (LT) from programme (NTEP) side where as 30 from general pool and 4 posts are vacant in various DMC of district Mandi. Out of 28 DMC only in 9 (32.1 %)

DMC LT posted were given any kind of training under NTEP. Out of 28 DMC, 20 were heaving conventional binocular microscope, 6 were heaving only LED, 2 were heaving both LED and Conventional Binocular microscope. We also found that all the microscopes were working at the time of visit and all the labs were heaving all required reagents. In the year 2018, on average 236 days all DMC were opened (Min 49 days Max 350 days) and 21705 sputum tests were carried out which comes to daily average of 92 tests per day in all 28 DMC. Out of these 21705 tests, 919 (4.23%) were declared new positive patients. For majority (24, 85.7%) of DMC, nearest CBNAAT site is district hospital and average distance of CBNAAT site from DMC is 50.75 km (Min 0 Km and Max 150 Km). (Table 1)

Drug resistance patterns revealed that MDR-TB was the predominant form (60-100% across blocks), with some blocks also showing cases of XDR-TB (particularly Bagsiad with 36.4%) and mono-resistance. Primary MDR-TB (new cases with resistance) constituted 11-100% of cases depending on the block, with Baldwara showing 100% primary MDR cases. Treatment regimens were diverse, with shorter MDR regimens being most commonly used (36-66.7% across blocks), followed by conventional regimens. Clinical presentations at the time of visit showed that most patients (62.5-100%) were asymptomatic, indicating either successful treatment response or disease control. When symptoms were present, generalized body ache/joint pain was most common, followed by nausea and dyspnea. (Table 2)

Diagnostic delays were common, with over 40% of patients in most blocks experiencing diagnosis gaps of more than 7 days, reaching as high as 78.6% in Ratti block. The diagnostic infrastructure showed that District Hospital was the primary diagnostic facility for most patients, followed by Intermediate Reference Laboratories and Medical Colleges. Notably, no patients were diagnosed at private hospitals across any block. Geographic accessibility posed significant challenges, with mean distances to diagnostic facilities ranging from 18.67 km (Kotli) to 248.25 km (Janjheli). The maximum distance traveled for diagnosis reached 298 km, highlighting the rural and mountainous terrain challenges in accessing healthcare. Treatment initiation was generally prompt, with 46-87.5% of patients starting treatment within 7 days of diagnosis in most blocks. Healthcare-seeking behavior for routine checkups showed preference for Civil Hospitals (14-86.6% across blocks) and District Hospitals, with patients willing to travel considerable distances (mean 6-62.5 km) primarily for specialist care and laboratory facilities rather than proximity alone. (Table 3)

The mean age of MDR-TB patients ranged from 34 to 53 years across blocks, with Ladbharole showing the highest mean age of 53±17.77 years. The gender distribution showed male predominance overall (50-77.8% across most blocks), though some blocks like Baldwara and Rohanda showed higher female proportions. Overcrowding (defined by room-per-person criteria) was present in 7 blocks, with Padher showing the highest proportion. Room-sharing within families was common, ranging from 20-57.1% across blocks, with Bagsiad and Ratti showing the highest rates (54.5% and 57.1% respectively). Previous TB history in the family ranged from 21.4% in Ratti to 62.5% in Rohanda. More concerning was the presence of concurrent TB cases within families—Bagsiad showed 9.1% of patients had another family member currently suffering from TB. The presence of TB in the surrounding community was particularly high in some blocks: Sandhole (60%), Bagsiad (45.5%), and Padher (26.7%) reported TB cases in their surroundings, suggesting localized clustering of disease and ongoing community transmission. (Table 4)

Pre-diagnosis occupations were diverse, including housewives, laborers, students, farmers, business owners, and employed individuals in both private and government sectors. However, post-diagnosis changes were dramatic. The proportion of patients reporting occupational change ranged from 7.1% in Ratti to 60% in Kataula. Unemployment emerged as a major consequence: patients becoming unemployed after diagnosis ranged from 18.2% in Bagsiad to substantial proportions in other blocks, with Rohanda showing 75% unemployment post-diagnosis. Students were forced to leave school in several blocks, particularly affecting younger patients. Pre-diagnosis tobacco use ranged from 20% in Kataula to 60% in Sandhole, with intermediate rates in most blocks. Post-diagnosis, there was notable reduction: most blocks showed complete cessation, though some patients continued use—Kotli (22.2%), Ratti (21.4%), and Sandhole (20%) showed persistent tobacco consumption despite diagnosis. Pre-diagnosis alcohol use ranged from 22.2% in Kotli to 50% in Karsog. Post-diagnosis reduction was even more dramatic than tobacco, with most blocks showing near-complete cessation, though Karsog (12.5%), Kataula (20%), Kotli (11.1%), Ladbharole (11.1%), and Sandhole (20%) showed some continued use. (Table 5)

**Table 1: Input, process and output indicators of Designated Microscopy centres of district Mandi for year 2018 (total=28)**

| **Total number of DMCs** | | **28** |
|---|---|---|
| Input indicators | | |
| Total No of LT Posts at all DMCs | Sanctioned | 45 |
| | Filled (percentage) | 41 (91.11%) |
| | Total no of LT from NTEP (percentage) | 11(24.44%) |
| Trainings of LT conducted in last one year | N (%) | 9 (32.14%) |
| Process indicators | | |
| Total No Conventional Binocular Microscope | N (%) | 20 (71.43) |
| Total No of Light Emission Diode (LED) Microscope | N (%) | 10 (35.71) |
| Output indicators | | |
| No of Sputum tests conducted at all DMCs | Total | 21705 |
| Total sputum positive at all DMCs | N (%) | 919 (4.23%) |
| Total sputum positive per DMCs | | 32.82 |
| No. of working days at DMC in year 2018 | Mean (±2SD) | 263.32 (±58.29) |
| No. of sputum tested per day at all DMCs | Mean (±2SD) | 2.83 (±3.87) |

**Table 2: Treatment profile of MDR patients**

| | | **Block name (no. of MDR pts)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Patient characteristics** | | Bagsiad (11) | Baldwara (2) | Janjheli (4) | Karsog (8) | Kataula (5) | Kotli (9) | Ladbharole (9) | Padher (15) | Ratti (14) | Rohanda (8) | Sandhole (5) |
| **Primary MDR** | No | 7(63.6) | - | 2(50.0) | 5(62.5) | 4(80.0) | 7(77.8) | 8(88.9) | 6(40.0) | 8(57.1) | 7(87.5) | 5(100.0) |
| | Yes | 4(36.4) | 2(100.0) | 2(50.0) | 3(37.5) | 1(20.0) | 2(22.2) | 1(11.1) | 9(60.0) | 6(42.9) | 1(12.5) | - |
| **Type of drug resistance (DR)** | Mono DR | 2(18.2) | - | 1(25.0) | 1(12.5) | 1(20.0) | 2(22.2) | 1(11.1) | 1(6.7) | 2(14.3) | 3(37.5) | 2(40) |
| | Poly DR | - | - | - | - | - | - | - | - | 2(14.3) | - | - |
| | Multi DR | 5(45.5) | 2(100.0) | 2(50.0) | 7(87.5) | 4(80.0) | 7(77.8) | 8(88.9) | 14(93.3) | 9(64.3) | 5(62.5) | 3(60.0) |
| | Rifampicin Resistance | - | - | - | - | - | - | - | - | 1(7.1) | - | - |
| | Extensive DR (XDR) | 4(36.4) | - | 1(25.0) | - | - | - | - | - | - | - | - |
| **Type of Drug Regimen** | Mono DR | 2(18.2) | - | 1(25.0) | 1(12.5) | 0 | 2(22.2) | 1(11.1) | 1(6.7) | 3(21.4) | 3(37.5) | 2(40.0) |
| | Shorter MDR | 4(36.4) | 1(50.0) | 2(50.0) | 4(50.0) | 2(40.0) | 6(66.7) | 5(55.6) | 10(66.7) | 7(50.0) | 4(50.0) | 2(40.0) |
| | Conventional | 2(18.2) | 1(50.0) | - | 3(37.5) | 3(60.0) | 1(11.1) | 3(33.3) | 3(20.0) | 2(14.3) | 1(12.5) | 1(20.0) |
| | Modified | 3(27.3) | - | 1(25.0) | - | - | - | - | 1(6.7) | 2(14.3) | - | - |
| **Any primary Complain on the day of visit** | No | 9(81.8) | - | 2(50.0) | 5(62.5) | 1(20.0) | 1(11.1) | 1(11.1) | 7(46.7) | 13(92.9) | 5(62.5) | 5(100.0) |
| | Generalised body ache/Joint pain | 2(18.2) | 1(50.0) | 2(50.0) | 1(12.5) | - | - | 4(44.4) | 1(6.7) | - | 2(25.0) | - |
| | Dyspnoea | - | - | - | 2(25.0) | 1(20.0) | - | 1(11.1) | - | 1(7.1) | - | - |
| | Nausea | - | 1(50.0) | - | - | 1(20.0) | 2(22.2) | 3(33.3) | 5(33.3) | - | - | - |
| | Itching | - | - | - | - | 1(20.0) | 6(66.7) | - | - | - | - | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decrease in vision | - | - | - | - | - | - | - | - | - | - | - |
| | Restless/ lethargic | - | - | - | - | - | - | - | 2(13.3) | - | - | - |
| | Fear/ anxiety | - | - | - | - | - | - | - | - | - | - | - |
| | Haemoptysis | - | - | - | - | - | - | - | 1(20.0) | - | 1(12.5) | - |
| **Secondary Complain** | Yes | - | 1(50.0) | 1(25.0) | 1(12.5) | 1(20.0) | - | - | - | 1(7.1) | 1(12.5) | - |
| | No | 11(100) | 1(50.0) | 3(75.0) | 7(87.5) | 4(80.0) | 8(88.9) | 9(100.0) | 15(100) | 13(92.9) | 7(87.5) | 5(100.0) |
| | Nearest institution | 2(18.2) | 1(50.0) | 1(25.0) | 2(25.0) | 2(40.0) | 2(22.2) | 7(77.8) | 5(33.3) | 3(21.4) | 2(25.0) | - |

**Table 3: Delays and Geographic determinants of treatment taken by MDR patients**

| | **Block name (no. of MDR pts)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Bagsiad (11)** | **Baldwara (2)** | **Janjheli (4)** | **Karsog (8)** | **Kataula (5)** | **Kotli (9)** | **Ladbharole (9)** | **Padher (15)** | **Ratti (14)** | **Rohanda (8)** | **Sandhole (5)** |
| **Gap in diagnosis in days** | | | | | | | | | | | |
| **<7** | 5(45.5) | 1(50.0) | 2(50.0) | 4(50.0) | 3(60.0) | 7(77.8) | 6(66.7) | 9(60.0) | 3(21.4) | 3(37.5) | 2(40.0) |
| **>7** | 6(54.5) | 1(50.0) | 2(50.0) | 4(50.0) | 2(40.0) | 2(22.2) | 3(33.3) | 6(40.0) | 11(78.6) | 5(62.5) | 3(60.0) |
| **Hospital /Lab where diagnosed** | | | | | | | | | | | |
| **Civil hospital** | - | - | - | - | - | - | - | - | 1(7.1) | - | |
| **District hospital** | 6 (54.5) | 1(50.0) | - | 2(25.0) | - | 9(100.0) | 3(33.3) | 10(66.7) | 5(35.7) | 5(62.5) | 2(40.0) |
| **Medical College** | - | - | 1(25.0) | 4(25.0) | 4(100.0) | - | 5(55.6) | 1(6.7) | - | 1(12.5) | 1(20.0) |
| **Private Hospital** | - | - | - | - | - | - | - | - | - | - | - |
| **Intermediate reference lab (IRL)** | 5(45.5) | 1(50.0) | 3(75.0) | 2(25.0) | - | - | 1(11.1) | 4(26.7) | 8(57.1) | 2(25.0) | 2(40.0) |
| **Approximate distance from Home** | | | | | | | | | | | |
| **Mean** | 110.0, | 105.0, | 248.25, | 106.25, | 181.60, | 18.67, | 111.78, | 100.93, | 102.71, | 60.25, | 116.0, |
| **Min** | 30.0, | 40.0, | 200, | 50, | 150.0, | 9.0, | 70.0, | 20.0, | 1.0, | 15.0, | 65.0, |
| **Max** | 230.0, | 170.0, | 298, | 120, | 240.0, | 30.0, | 210.0, | 260.0, | 220.0, | 140.0, | 170.0, |
| **Initiation of treatment in days** | | | | | | | | | | | |
| **<7** | 4(36.4) | 1(50.0) | 2(50.0) | 7(87.5) | 4(80.0) | 7(77.8) | 7(77.8) | 7(46.7) | 7(50.0) | 6(75.0) | 3(60.0) |
| **>7** | 7(63.6) | 1(50.0) | 2(50.0) | 1(12.5) | 1(20.0) | 2(22.2) | 2(22.2) | 8(93.3) | 7(50.0) | 2(25.0) | 2(40.0) |
| **Type of Hospital where treatment was started for DR** | | | | | | | | | | | |
| **District Hospital (DH)** | 1(27.3) | 1(50.0) | 1(25.0) | 0 | 1(20.0) | 5(55.6) | 0 | 1(6.7) | 7(50.0) | 4(50.0) | 4(80.0) |
| **Medical College (MC)** | 8(72.7) | 1(50.0) | 2(50.0) | 5(62.5) | 4(80.0) | 4(44.4) | 9(100.0) | 14(93.3) | 7(50.0) | 4(50.0) | 1(20.0) |
| **Intermediate Reference lab (IRL)** | - | - | 1(25.0) | 3(37.5) | - | - | - | - | - | - | - |
| **Distance of that hospital where treatment was started (Km)** | | | | | | | | | | | |
| **Mean** | 129.27, | 70.0, | 199.50, | 113.13, | 148.0, | 84.56, | 105.67, | 88.87, | 69.07, | 97.88, | 76.0, |
| **Min** | 33.0, | 40.0, | 110.0, | 50.0, | 32.0, | 9.0, | 75.0 | 50.0, | 1.0, | 19.0, | 60.0, |
| **Max** | 180.0 | 100.0 | 298.0 | 180.0 | 240.0 | 180.0 | 200.0 | 150, | 155.0, | 172.0, | 90.0, |
| **Type of hospital you prefer for routine checkups** | | | | | | | | | | | |
| **Primary health centre (PHC)** | - | - | - | - | - | - | 1(11.1) | 1(6.7) | 2(14.3) | - | - |

| | Block name (no. of MDR pts) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Bagsiad (11)** | **Baldwara (2)** | **Janjheli (4)** | **Karsog (8)** | **Kataula (5)** | **Kotli (9)** | **Ladbharole (9)** | **Padher (15)** | **Ratti (14)** | **Rohanda (8)** | **Sandhole (5)** |
| **Community Health centre (CHC)** | - | - | 1(25.0) | 1(12.5) | - | 2(22.2) | - | 1(6.7) | - | 1(12.5) | - |
| **Civil Hospital (CH)** | 6(54.6) | - | 2(50.0) | 4(50.0) | 1(20.0) | - | 6(66.6) | 13(86.6) | 2(14.3) | 4(50.0) | 3(60.0) |
| **DH** | 3(27.3) | - | 1(25.0) | - | 3(60.0) | 5(55.6) | 2(22.2) | - | 8(57.1) | - | 1(20.0) |
| **MC** | 2(18.2) | 2(100.0) | - | 2(25.0) | 1(20.0) | 2(22.2) | - | - | 2(14.3) | 3(37.5) | 1(20.0) |
| **IRL** | - | - | - | 1(12.5) | - | - | - | - | - | - | - |
| **This routine check up hospital is your nearest hospital** | | | | | | | | | | | |
| **Yes** | 7(63.6) | - | 2(50.0) | 4(50.0) | 4(80.0) | 6(66.7) | 6(66.7) | 14(93.3) | 9(64.3) | 4(50.0) | 1(20.0) |
| **No** | 4(36.4) | 2(100.0) | 2(50.0) | 4(50.0) | 1(20.0) | 3(33.3) | 3(33.3) | 1(6.7) | 5(35.7) | 4(50.0) | 4(80.0) |
| **Distance of that hospital where you visit for routine checkup (Km)** | | | | | | | | | | | |
| **Mean** | 21.09, | 62.5, | 42.0, | 38.63, | 16.20, | 16.22, | 7.33, | 10.93, | 6.0, | 14.88, | 47.20, |
| **Min** | 4.0, | 25.0, | 2.0, | 1.0, | 2.0, | 4.0, | 1.0, | 1.0, | 1.0, | 2.0, | 14.0, |
| **Max** | 32.0 | 100.0 | 95.0 | 120.0 | 49.0 | 36.0 | 80.0 | 35.0 | 20.0 | 45.0 | 100.0 |
| **Reason for visiting Specific Hospital** | | | | | | | | | | | |
| **Specialist & lab facility available** | 9(81.8) | 1(50.0) | 3(75.0) | 6(75.0) | 3(60.0) | 7(77.8) | 2(22.2) | 10(66.7) | 11(78.6) | 6(75.0) | 5(100.0) |
| **Nearest institution** | 2(18.2) | 1(50.0) | 1(25.0) | 2(25.0) | 2(40.0) | 2(22.2) | 7(77.8) | 5(33.3) | 3(21.4) | 2(25.0) | 0 |

**Table 4: Blockwise Socio demographic profile of MDR patients**

| **Block name** | **No of patients in Block** | **Age in years (Mean SD)** | **Sex** | | **Over crowding (room per person criteria)** | | **Share room with anyone in family** | | **Previous TB history in Family** | | **Anyone else suffering from TB in family** | | **Anyone suffering from TB in surroundings** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Present | Absent | Yes | No | Yes | No | Yes | No | Yes | No |
| **Bagsiad** | 11 | 34 ±18.33 | 7(63.6) | 4 (36.4) | 4 | 9 | 6(54.5) | 5(45.5) | 3(27.3) | 8(72.7) | 1(9.1) | 10(90.9) | 5(45.5) | 6(54.5) |
| **Baldwara** | 2 | 43±1.4 | 0 | 2(100) | 1 | 1 | 0 | 2(100) | - | 2(100) | - | 2(100) | - | 2(100) |
| **Janjheli** | 4 | 36.25±11.47 | 3(75) | 1(25) | 1 | 3 | 2(50) | 2(50) | 1(25) | 3(75) | - | 4(100) | - | 4(100) |
| **Karsog** | 8 | 34.38±15.07 | 6(75) | 2(25) | 0 | 8(100) | 2(25) | 6(75) | 2(25) | 6(75) | - | 8(100) | - | 8(100) |
| **Kataula** | 5 | 36±8.97 | 3(60) | 2(40) | 1 | 4 | 2(50) | 3(60) | 2(40) | 3(60) | - | 5(100) | - | 5(100) |
| **Kotli** | 9 | 44±17.02 | 6(66.7) | 3(33.3) | 0 | 9 | 1(11.1) | 8(88.9) | 4(44.4) | 5(55.6) | - | 9(100) | - | 9(100) |
| **Ladbharole** | 9 | 53±17.77 | 7(77.8) | 2(22.2) | 0 | 9 | 3(33.3) | 6(66.7) | 4(44.4) | 5(55.6) | 1(11.1) | 8(88.9) | - | 9(100) |
| **Padher** | 15 | 40.33±18.97 | 9(60) | 6(40) | 7 | 8 | 3(20) | 10(80) | 6(40) | 9(60) | 1(6.7) | 14(93.3) | 4(26.7) | 11(73.3) |
| **Ratti** | 14 | 39.36±17.14 | 7(50) | 7(50) | 4 | 10 | 8(57.1) | 6(42.9) | 3(21.4) | 11(78.6) | - | 14(100) | - | 14(100) |
| **Kataula** | 8 | 36.50±19.96 | 2(25.0) | 6(75) | 2(37.5) | 5(62.5) | 2(25) | 6(75) | 5(62.5) | 3(37.5) | - | 8(100) | 1(12.5) | 7(87.5) |
| **Sandhole** | 5 | 40.60±10.50 | 3(60) | 2(40) | 2 | 3 | 1(20) | 4(80) | 2(40) | 3(60) | - | 5(100) | 3(60) | 2(40) |

**Table 5: Change in occupation and substance use after diagnosis**

| | **Occupation before diagnosis** | | | | | | | | **Occupation after Diagnosis Changed** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Block name** | **Housewife** | **Labourer** | **Student** | **Farmer** | **Business** | **Private Job** | **Govt. Job** | **Unemployed** | **Yes** | **No** | **Unemployed** | **Left School** |
| **Bagsiad** | 2(18.2) | 2(18.2) | 5(45.5) | 2(18.2) | 0 | 0 | 0 | 0 | 2(18.2) | 4(36.4) | 1(9.1) | 4(36.4) |
| **Baldwara** | 0 | 0 | 0 | 0 | 1(50) | 1(50.00) | 0 | 0 | 1(50.000) | 1(50.00) | 0 | 0 |
| **Janjheli** | 1(25) | 0 | 0 | 1(25.0) | 1(25) | 0 | 1(25.0) | 0 | 1(25.0) | 3(75.0) | 0 | 0 |
| **Karsog** | 0 | 0 | 2(25) | 4(40.0) | 0 | 1(12.5) | 1(12.5) | 0 | 0 | 4(50.0) | 3(37.5) | 1(12.5) |
| **Kataula** | 1(20) | 0 | 0 | 0 | 1(20) | 0 | 0 | 3(60.0) | 3(60.0) | 1(20.0) | 1(20.0) | 0 |
| **Kotli** | 2(22.2) | 0 | 2(22.2) | 0 | 1(11.1) | 4(44.4) | 0 | 0 | 0 | 8(53.3) | 4(26.7) | 3(20.0) |
| **Ladbharole** | 1(11.1) | 2(22.2) | 1(11.1) | 2(22.2) | 0 | 3(33.3) | 0 | 0 | 0 | 3(33.3) | 6(66.7) | 0 |
| **Padher** | 4(26.7) | 2(13.3) | 4(26.7) | 0 | 1(6.7) | 2(13.3) | 2(13.3) | 0 | 0 | 8(53.3) | 4(26.7) | 3(20.0) |
| **Ratti** | 2(14.3) | 2(14.3) | 3(21.4) | 3(21.4) | 2(14.3) | 2(14.3) | 0 | 0 | 1(7.1) | 6(42.9) | 7(50.0) | 0 |
| **Kataula** | 3(37.5) | 0 | 3(37.5) | 1(12.5) | 0 | 1(12.5) | 0 | 0 | 0 | 6(75.0) | 1(12.5) | 1(12.5) |
| **Sandhole** | 2(40.0) | 1(20.0) | 1(20.0) | 1(20.0) | 0 | 0 | 0 | 0 | 0 | 4(80.0) | 1(20.0) | 0 |
| **Block name** | **Tobacco consumption before diagnosis** | | **Tobacco consumption after diagnosis** | | | | **Alcohol consumption before diagnosis** | | **Alcohol consumption after diagnosis** | | | |
| | Yes | No | Yes | No | | | Yes | No | Yes | No | | |
| **Bagsiad** | 5(45.5) | 6(54.5) | 0 | 11(100) | | | 4(36.4) | 7(63.6) | 0 | 11(100) | | |
| **Baldwara** | 0 | 2(100) | 0 | 2(100) | | | 0 | 2(100) | 0 | 2(100) | | |
| **Janjheli** | 2(50.0) | 2(50.0) | 0 | 4(100) | | | 1(25.0) | 3(75.0) | 0 | 4(100.0) | | |
| **Karsog** | 3(37.5) | 5(62.5) | 0 | 8(100) | | | 4(50.0) | 4(50.0) | 1(12.5) | 7(87.5) | | |
| **Kataula** | 1(20.0) | 4(80.0) | 0 | 5(100) | | | 2(40.0) | 3(60.0) | 1(20.0) | 4(80.0) | | |
| **Kotli** | 5(55.6) | 4(44.4) | 2(22.2) | 7(77.8) | | | 2(22.2) | 7(77.8) | 1(11.1) | 8(88.9) | | |
| **Ladbharole** | 3(33.3) | 6(66.7) | 1(11.1) | 8(88.9) | | | 4(44.4) | 5(55.6)) | 1(11.1) | 8(88.9) | | |
| **Padher** | 7(46.7) | 8(53.3) | 1(6.7) | 14(93.3) | | | 7(46.7) | 8(53.3) | 0 | 15(100.0) | | |
| **Ratti** | 4(28.6) | 10(71.4) | 3(21.4) | 11(78.6) | | | 6(42.9) | 8(57.1) | 0 | 14(100.0) | | |
| **Kataula** | 1(12.5) | 7(87.5) | 1(12.5) | 7(87.5) | | | 2(25.0) | 6(75.0) | 0 | 8(100.0) | | |
| **Sandhole** | 3(60.0) | 2(40) | 1(20) | 4(80.0) | | | 2(40.0) | 3(60.0) | 1(20.0) | 4(80.0) | | |

## DISCUSSION

The MDR-TB management challenges in one District of the sub-Himalayan region reflects broader systemic issues across multiple Indian states. The geographic and infrastructure dimensions are distinctive.

**Multi-Dimensional Nature of Delays:** The delays observed in Mandi must be understood within the framework proposed by recent Indian studies examining the TB care cascade. Research from Jharkhand and Gujarat identified delays at multiple points: patient delays (symptom onset to first healthcare contact), provider delays (first contact to diagnosis), and treatment delays (diagnosis to initiation).[5] The current study data suggests that while treatment initiation occurs relatively promptly once diagnosis is confirmed (36.4-87.5% within 7 days in most blocks), diagnostic delays remain substantial (22.2-78.6% exceeding 7 days).

Balasubramnian et al. documented median total delays of 60 days among new pulmonary TB patients in Southern India, with patient delay contributing 30 days and health system delay 21 days.[6] The diagnostic infrastructure gaps in Mandi where CBNAAT facilities average 50.75 km from DMCs with maximum distances of 150 km directly translate into health system delays. When combined with the mountainous terrain and limited transportation infrastructure, these geographic barriers likely extend both diagnostic and treatment initiation periods beyond what would be expected in more accessible settings.

**Geographic and Socioeconomic Determinants:** The extreme travel distances in Mandi (up to 298 km for diagnosis, mean treatment distances of 69-199 km) represent outliers. However, the pattern of patients prioritizing specialist availability over proximity (60-100% citing this as their primary reason for facility choice) aligns with findings from the Jharkhand-Gujarat study, where healthcare quality concerns outweighed convenience factors.[5] Risk factor analysis from Hunan Province, China identified rural residence, lower education levels, and longer distances to designated hospitals as significant predictors of diagnostic delay.[7] While in the current study these variables were not stratified, the block-level variations suggest similar dynamics. Blocks with better diagnostic performance (like Karsog, with only 12.5% treatment delays beyond 7 days) may benefit from better accessibility or more efficient administrative processes, while remote blocks like Bagsiad (63.6% delayed treatment initiation) face compounded challenges. The qualitative research from Pune by Atre et al. revealed that MDR-TB patients faced substantial unmet needs related to transportation costs, loss of income during treatment, and inadequate information about their disease and treatment.[8] The fact that 2.38% of diagnosed patients in Mandi never initiated treatment suggests that some patients are lost to follow-up between diagnosis and treatment which is a critical gap that likely reflects these unmet socioeconomic needs.

**Infrastructure Deficits and Diagnostic Capacity:** The technological infrastructure gap in this district of Himachal Pradesh is striking with 71% of facilities still relying on conventional microscopes, only 35% having LED microscopes and CBNAAT limited to District Hospitals. Recent studies on delays in MDR-TB care in India have emphasized that rapid molecular diagnostics are essential for shortening the diagnostic pathway.[8, 9] The current configuration forces a two-tier diagnostic system where initial screening occurs at peripheral DMCs, but confirmatory testing requires travel to distant facilities. This creates multiple delay points:

- Initial symptom recognition and presentation at DMC
- Sample collection and microscopy
- Referral for CBNAAT confirmation
- Travel to CBNAAT facility (mean 50.75 km)
- Sample processing and result communication
- Treatment initiation at tertiary facility

Each step introduces potential delays. The 32.14% of untrained laboratory technicians compounds these delays through potential quality issues, repeat testing needs, or delayed recognition of presumptive MDR-TB cases requiring advanced diagnostics.

**Sociodemographic Vulnerability and Household Transmission Risk:** The economically productive age group whose illness has cascading effects on household welfare were most commonly affected. While male predominance was observed in most blocks (50-77.8%), blocks like Baldwara showed 100% female cases and Rohanda showed 75% female cases, suggesting potential gender-specific barriers to timely diagnosis or gender-linked transmission patterns that warrant further investigation. When overlaid with the treatment delay data, blocks with high overcrowding and high treatment delays create perfect storm conditions for household transmission. The Wardha District data provides compelling evidence of the transmission consequences of treatment delays.[10] They reported that 66.68% of sputum-positive household contacts occurred when index cases had 16-30 day treatment delays, with no positive contacts when treatment began within 15 days, quantifies the urgency of rapid treatment initiation. This aligns with established transmission models showing that each week of delay in MDR-TB treatment initiation increases household

transmission risk.[11] The 2.31% prevalence of active TB among all household contacts and 46.15% sputum positivity among symptomatic contacts suggests intensive transmission within households—the very setting where prolonged exposure is inevitable and where effective contact screening should be prioritized. Belkina et al., documented similar patterns in Uzbekistan, where longer diagnostic delays correlated with increased household secondary cases.[12] However, the Mandi data suggests that treatment initiation timing may be even more critical than diagnostic timing for preventing transmission, since the infectious period extends until appropriate treatment begins. Patients frequently prioritize distant facilities with specialists, believing these centers offer superior diagnostic and treatment services compared to local facilities, even in rural or hard-to-reach areas. This pattern has been documented in multiple studies, where perceived quality of care, reputation, and the scope of specialist services outweigh the convenience of proximity for many tuberculosis patients, especially in regions lacking robust local infrastructure.[13] However, the repeated long journeys required for initial consultations, diagnosis, and follow-up in specialist centers significantly extend the pre-treatment infectious period. These extended infectious periods worsen disease transmission risk in communities and present additional financial, physical, and psychological burdens for patients. Addressing these challenges highlights the importance of decentralizing TB diagnosis and care to bring high-quality services closer to patients' homes, reducing delays, minimizing community exposure, and improving overall outcomes.[14]

**Previous TB exposure pattern, Drug Resistance Patterns and Transmission Chains:** Previous TB history in families ranged from 21.4% to 62.5% across blocks, with Rohanda showing the highest rate. More alarming, concurrent TB cases were documented: Bagsiad showed 9.1% of patients had another family member currently suffering from TB, while Ladbharole and Padher showed 11.1% and 6.7% respectively. These concurrent cases could represent either simultaneous exposures to an external source or ongoing within-household transmission. The presence of primary MDR-TB in 11-100% of cases across Mandi blocks (with several blocks showing >60% primary resistance) indicates substantial community transmission of resistant strains. The 36.4% XDR-TB prevalence in Bagsiad is particularly alarming and suggests either a localized outbreak, inadequate previous treatment, or both.
Risk factor studies from Hunan Province identified previous TB treatment and diabetes as significant predictors of MDR-TB diagnosis delay.[7] The economic data adds another dimension: families cannot afford to separate index cases from other household members during the infectious period. Overcrowding reflects poverty, not choice. When the index case loses employment, the household faces immediate economic crisis; separation becomes economically impossible even if physically feasible.[15-17]

**Patient-Cantered Barriers and Unmet Needs:** The 2.38% of diagnosed patients in Mandi who never initiated treatment likely faced barriers such as catastrophic costs, income loss, inadequate information, and stigma that proved insurmountable, echoing national findings that poverty, lack of awareness, and social stigma are key contributors to treatment non-initiation. When most district blocks show 20-50% of patients not using their nearest health facility, it indicates that perceived quality of care often outweighs convenience. However, this decision forces patients, especially the unemployed or economically vulnerable, to undertake long and costly journeys such as a 62.5 km average trip for routine follow-up in Baldwara which can result in transportation expenses exceeding the daily household food budget and further jeopardizing economic stability.[18,19]
Studies have established that transportation costs in rural and mountainous regions can become an unavoidable financial burden, with many patients unable to adhere to regulated follow-up or even abandoning treatment due to lack of travel funds. The consequences include delayed initiation, extended infectious periods, and poorer overall outcomes for both patients and communities.[20, 21]

**Health System Performance Variations:** The substantial block-level variations in Mandi (treatment initiation delays ranging from 12.5% to 63.6% beyond 7 days) suggest that local health system factors are modifiable. Studies examining the TB care cascade have identified several system-level determinants.[22] These are organizational like staff availability and training (Mandi shows 8.9% vacancy, 68% untrained), diagnostic equipment and reagent supply, administrative efficiency in processing results and initiating treatment and communication systems between diagnostic and treatment facilities. The service delivery factors quoted are integration of diagnostic and treatment services, patient tracking and follow-up systems, transportation support or reimbursement and decentralization of specialized services. The better performance in some Mandi blocks (Karsog, Kataula, Kotli) suggests that despite similar geographic challenges, certain administrative or service delivery approaches work better.

Identifying these success factors could inform improvements in underperforming blocks.

**Clinical Management and Treatment Response:** The finding that 62.5-100% of patients were asymptomatic at follow-up visits is encouraging but requires cautious interpretation. While this may indicate effective treatment response, it could also reflect survivor bias (patients who developed severe adverse effects or disease progression may have discontinued treatment) or measurement timing (follow-up visits occurring during relatively stable periods).

The predominance of body ache/joint pain, nausea, and dyspnoea among symptomatic patients likely represents medication side effects rather than disease progression. For patients who sacrificed employment, education, and household income to pursue treatment, medication side effects that interfere with quality of life may trigger treatment interruption. Studies on patient experiences have documented that adverse effects are a major contributor to treatment interruption and default.[23-25] The fact that symptoms were present in only 0-54% of patients across blocks suggests either good tolerability or, conversely, that patients with severe side effects may not be captured in routine facility-based surveillance.

## Conclusion

The MDR-TB management challenges in Mandi District represent an intersection of geographic barriers, infrastructure deficits, systemic inefficiencies, and profound socioeconomic vulnerability. The sociodemographic and behavioral data reveal that patients face catastrophic economic consequences (unemployment reaching 75% in some blocks), family disruption and ongoing transmission risk in overcrowded households. The evidence strongly supports that treatment initiation timing is critical for preventing transmission, since the infectious period extends until appropriate treatment begins. In Mandi's context of household overcrowding (up to 57.1% room-sharing), previous family TB exposure (up to 62.5%), and high community TB burden (up to 60%), each day of delay has multiplied consequences. The data demonstrate that rapid treatment initiation is not merely a clinical imperative but a public health necessity for breaking transmission chains, and that achieving rapid initiation requires addressing the catastrophic economic burden that creates insurmountable barriers for vulnerable populations in mountainous, resource-limited settings.

## Recommendation

The programme may expand decentralised molecular diagnostics and MDR-TB treatment services to peripheral facilities in hard-to-reach areas. Structured transport, nutritional, and livelihood support to MDR-TB patients is need of hour to prevent catastrophic costs, unemployment, and treatment interruption. Training of staff, increase in staff, and data-driven monitoring at block level to reduce diagnostic and treatment delays in difficult terrain districts is needed to be strengthened.

## Limitation of the Study

The cross-sectional design cannot establish causality between socioeconomic factors and treatment delays or outcomes. Retrospective data collection may underestimate delays if documentation was incomplete. The study captured patients who reached diagnosis but missed those who never accessed care due to insurmountable barriers—potentially the most vulnerable. Individual-level confounders (education, income, comorbidities) weren't fully captured. The relationship between overcrowding, delays, and household transmission is inferred from separate data sources rather than directly measured. Follow-up duration and treatment outcomes weren't reported, limiting assessment of whether delays ultimately affect cure rates.

## Relevance of the Study

The analysis offers block-level evidence on how geography, health-system gaps, and socioeconomic distress interact to delay MDR-TB care in difficult terrain settings. It provides an actionable template for prioritising decentralised diagnostics, social protection, and system strengthening in similar high-burden, hard-to-reach districts across India.

## Authors Contribution

Conceptualization: AM; Methodology: AM, MS; Software: MS; Validation: SG; Formal analysis: MS; Investigation: AM; Resources: NJ; Data Curation: MS; Writing (original draft): MS, NJ; Writing (review & editing): SG, NJ, AM ; Visualization: AM; Supervision: AM; Project administration: MS

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Nil

## Conflict of Interest

There is no conflict of interest.

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## DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors haven't used any generative AI/AI assisted technologies in the writing process.

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