

ORIGINAL ARTICLE

Association Between Incomplete Sputum Smear Monitoring and Treatment Success in Pulmonary Tuberculosis

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ABSTRACT

Background: The six-month treatment regimen for pulmonary tuberculosis (TB) includes sputum monitoring at months two, five, and six. However, due to patient limitations, healthcare resource constraints, and service disruptions during the COVID-19 pandemic, some patients were unable to complete all three follow-ups. This study aimed to investigate the association between incomplete sputum smear monitoring and treatment success among patients with pulmonary TB.

Design: Retrospective cohort study

Methods: The medical records were analyzed for new or relapsed cases of adult pulmonary TB patients treated at Khon Kaen Hospital between 2021 and 2023. Patients were categorized into two groups: the incomplete monitoring group (missing $\geq$ one smear at months two, five, or six), and the complete group (smears at all three points). The primary outcome was treatment success, defined as cure or treatment completion. Crude analysis was performed using Fisher's exact test. Poisson regression with robust standard errors was used to estimate adjusted relative risk (aRR).

Results: Of 396 patients, 223 were in the incomplete group and 173 in the complete group. The treatment success rate was 100% in the incomplete group and 98.8% in the complete group. The crude relative risk was 1.012 (95% CI: 0.996-1.028). After adjustment for age, sex, comorbidities, smoking, and alcohol use, the association remained in the same direction, with an aRR of 1.015 (95% CI: 0.995-1.036).

Conclusions: Incomplete sputum smear monitoring was not associated with the treatment success rate among pulmonary TB patients.

Keywords: pulmonary tuberculosis, sputum smear monitoring, treatment success

นิพนธ์ต้นฉบับ

ความสัมพันธ์ระหว่างการตรวจเชื้อจากเสมหะไม่ครบและความสำเร็จในการรักษาวัณโรคปอด

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บทคัดย่อ

ที่มา: การรักษาวัณโรคปอดในปัจจุบัน รักษาด้วยยาเป็นเวลา 6 เดือน ร่วมกับการตรวจติดตามเสมหะในเดือนที่ 2, 5 และ 6 อย่างไรก็ตาม ผู้ป่วยบางรายไม่สามารถมาตรวจติดตามครบทั้งสามครั้ง เนื่องจากข้อจำกัดของผู้ป่วย ทรพยากรทางระบบสุขภาพที่จำกัด และการหยุดชะงักของบริการระหว่างการระบาดของโรคโควิด-19 เราจึงทำการศึกษาความสัมพันธ์ของการติดตามตรวจเสมหะไม่ครบตามเกณฑ์กับอัตราความสำเร็จในการรักษาผู้ป่วยวัณโรคปอด

แบบวิจัย: Retrospective cohort study

วัตถุประสงค์และวิธีการ: ใช้ข้อมูลจากเวชระเบียนของผู้ป่วยวัณโรคปอดรายใหม่หรือกลับเป็นซ้ำ ที่เข้ารับการรักษาที่โรงพยาบาลขอนแก่น ระหว่างปี พ.ศ. 2564-2566 ผู้ป่วยถูกจัดเป็นสองกลุ่มตามการติดตามตรวจเสมหะ ได้แก่ กลุ่มไม่ครบ (ขาดการตรวจอย่างน้อยหนึ่งครั้งในเดือนที่ 2, 5 หรือ 6) และกลุ่มครบ (ตรวจครบทั้งสามครั้ง) ผลลัพธ์หลักคืออัตราการรักษาสำเร็จ ซึ่งหมายถึงผู้ที่รักษาหายหรือรักษาครบ โดยได้ทำการวิเคราะห์แบบปัจจัยเดียวด้วย Fisher's exact test และใช้ Poisson regression ที่ปรับค่าเบี่ยงเบนมาตรฐาน (robust SE) เพื่อคำนวณ adjusted relative risk (aRR) โดยควบคุมตัวแปรกวน

ผลการศึกษา: จากเวชระเบียนผู้ป่วย 396 คน มี 223 คน อยู่ในกลุ่มที่ตรวจเสมหะไม่ครบ และ 173 คน อยู่ในกลุ่มที่ตรวจครบ อัตราการรักษาสำเร็จในกลุ่มที่ตรวจไม่ครบคือ ร้อยละ 100 และในกลุ่มที่ตรวจครบคือ ร้อยละ 98.8 โดยมีค่า relative risk เท่ากับ 1.012 (95%CI: 0.996-1.028) นอกจากนี้ผลการวิเคราะห์โดยใช้ poisson regression ที่ควบคุมอายุ เพศ โรคร่วม การสูบบุหรี่ และการดื่มแอลกอฮอล์ ยังคงให้ผลไปในทิศทางเดียวกัน โดยมี aRR เท่ากับ 1.015 (95%CI: 0.995-1.036)

สรุป: การติดตามตรวจเสมหะไม่ครบตามเกณฑ์ไม่สัมพันธ์กับอัตราความสำเร็จในการรักษาผู้ป่วยวัณโรคปอด

คำสำคัญ: วัณโรคปอด การติดตามตรวจเสมหะ ความสำเร็จในการรักษา

Introduction

Tuberculosis (TB), caused by *Mycobacterium tuberculosis*, predominantly affects the lungs and is known as pulmonary TB.¹ In 2022, the World Health Organization (WHO) recommended three 4-6-month treatment regimens for patients with drug-susceptible TB. However, the standard treatment for new pulmonary TB patients remains the 6-month regimen consisting of 2 months of isoniazid (H), rifampicin (R), pyrazinamide (Z), and ethambutol (E), followed by 4 months of isoniazid and rifampicin (2HRZE/4HR), which globally achieves an approximate 85% treatment success rate.² Monitoring patient response and potential side effects during this 6-month treatment period is crucial, involving regular clinical examinations, chest X-rays, laboratory tests, and sputum smear microscopy and cultures.²

According to WHO guidelines, sputum culture, which has higher sensitivity than sputum smear microscopy, is recommended for treatment monitoring at two key time points, after two months of treatment and at the end of treatment.² This differs from Thailand's approach, which primarily uses sputum smear microscopy. Understanding these differences is important for interpreting treatment outcomes across settings.

Thailand, as one of the 30 high TB burden countries,³ experiences a total TB incidence of 143 per 100,000 population.⁴ For new drug-susceptible pulmonary TB cases, the National Tuberculosis Control Program Guideline, Thailand 2021, recommends the six-month 2HRZE/4HR regimen, along with sputum smear examinations at two, five, and six months after treatment initiation.⁵ These consecutive sputum smear monitoring (SSM) aims to assess individual treatment response and guide doctors in making informed treatment decisions. However, several factors have been known to impede the completion of SSM, especially in limited-resource settings.⁶ Patient-related barriers, such as poor access to reliable public transport, can prevent patients from attending follow-up visits on time. Health system limitations, such as a shortage of trained laboratory technicians in community hospitals, may lead to delays or inability to perform smear microscopy. Moreover, many facilities lack the capacity to perform sputum culture locally, requiring specimens to be referred to external laboratories, which further delays diagnosis and

monitoring. Disruptions during the COVID-19 pandemic—such as appointment cancellations, clinic closures, and reduced services due to quarantine policies—have also exacerbated challenges in maintaining regular patient monitoring. These barriers collectively contribute to missed follow-up visits and incomplete SSM, potentially affecting treatment outcomes.

Beyond sputum testing, various patient- and system-level factors have been linked to treatment success. These include age, sex, adherence to medication, tobacco and alcohol use, comorbidities such as HIV infection or diabetes, socioeconomic status, and access to healthcare services.⁷

A large cohort study conducted in India observed that even among successfully treated patients, only 62% completed all sputum examinations.⁸ Additionally, studies conducted in rural areas with limited sample sizes have explored the association between incomplete SSM and unsuccessful treatment outcomes.^{9,10} While a study in Thailand found a strong association between not receiving the 2-month sputum smear examination and unsuccessful treatment, its low sample size and non-specific objective—focused broadly on multiple risk factors rather than a defined process-of-care—limit its interpretability.¹¹ Our study specifically examines the impact of incomplete SSM, defined as missing any scheduled examination at months 2, 5, or 6 on treatment success.

Therefore, our study aimed to investigate the association between incomplete SSM and the treatment success rate in pulmonary TB patients. The findings could help identify patients at risk of poor outcomes due to inadequate monitoring and inform targeted interventions to strengthen follow-up practices.

Methods

Design

This study was a retrospective cohort study. We reviewed medical records of pulmonary TB patients who registered for treatment at Khon Kaen Hospital via the National Tuberculosis Information Program (NTIP) between 2021 and 2023.

Baseline data were collected for eligible patients, including age at diagnosis, sex, weight, height, type of registration (new or relapse), imprisonment status, anti-TB regimen, distance from home to hospital, tobacco use, alcohol

use, comorbidities (including diabetes mellitus, chronic obstructive pulmonary disease, liver disease, and chronic kidney disease), chest X-ray (CXR) results at diagnosis, and bacteriological confirmation test results at diagnosis.

The distance from home to hospital was estimated using Google Maps, based on the patient's current address recorded in the hospital system. The starting point was the subdistrict (tambon) of the residence, and the destination was Khon Kaen Hospital.

The protocol was approved by the Khon Kaen Institutional Review Board (KIRB), reference number KEXP67023, approved March 12, 2024.

Participants

The inclusion criteria for the study were as follows: patients aged 18 years and older with medical records diagnosed with pulmonary TB, including both new cases and relapses, confirmed bacteriologically by any method such as smear microscopy, culture, Xpert Mycobacterium tuberculosis/rifampicin (Xpert MTB/RIF), line probe assay (LPA), or polymerase chain reaction for tuberculosis (PCR for TB).

The exclusion criteria were as follows: patients who were anti-HIV positive, patients with drug-resistant TB identified at the initiation of treatment, and patients receiving treatment regimens other than 2HRZE/4HR or those who started with the 2HRZE/4HR regimen but had a regimen change during treatment. Patients who were anti-HIV positive were excluded to reduce clinical heterogeneity, as co-infection may affect disease presentation, treatment response, and monitoring protocols, and these patients are more likely to receive modified TB treatment regimens. Moreover, medical records of patients who could not be followed up after six months of treatment, such as patients transferred out to other facilities before completing the treatment duration, were excluded from the study. Patients with missing data on specific variables (e.g., CXR findings or individual sputum smear results) were not excluded if they still met the overall inclusion and group classification criteria as defined.

Defining groups

Incomplete SSM: Patients who did not have sputum smear results for all three recommended time points—at 2 months, 5 months, and 6 months

after initiating treatment—were categorized in this group. This included patients who missed one or two of the scheduled sputum smear examinations. However, in cases where patients attended follow-up appointments but were unable to provide a sputum sample due to clinical improvement (e.g., no productive cough), these visits were not considered missed. Clinical improvement was determined based on information recorded by physicians in the medical records, including documented symptom resolution and improved CXR findings. A sputum collection was considered acceptable if performed within two weeks of the scheduled date; this timeframe was consistently applied to all three time points.

Complete SSM: Patients who had sputum smear results documented for all three recommended time points—either on the scheduled date or within the acceptable 2-week window—were categorized in this group. Similarly, if patients attended the follow-up visits but could not produce sputum due to clinical improvement, as verified through symptom resolution and CXR findings in the medical record, these were still counted as monitored.

Outcomes

The primary outcome was the treatment success rate, calculated as the number of patients who were either cured or treatment completed divided by the total number of patients included in the study. In pulmonary TB treatment, cured refers to patients who were bacteriologically confirmed at diagnosis and later tested negative after completing treatment. Treatment completed refers to patients who completed the prescribed treatment regimen and had no evidence of treatment failure, but did not have bacteriological confirmation of cure at the end of treatment.

Once the treatment success rate was determined, we proceeded to examine its association with incomplete SSM, the main exposure of interest in this study. This association was analyzed using regression techniques, as described in the statistical analysis section.

Secondary outcomes were also collected, which included patient treatment status and CXR findings. At the end of treatment, patient status could be classified as either cured, treatment completed, treatment failed, died, or lost to follow-up. We also collected CXR results before

discharge (at 6 months) and CXR results at 3 months after discharge.

Standard full-size posteroanterior CXRs were performed at the time of diagnosis, 2 months after treatment, 6 months after treatment, and 3 months after discharge. Data collection included findings of consolidation, cavitation, effusion, miliary patterns, nodules, fibrosis, and the proportion of lung involvement. The extent of lung involvement was assessed using the Timika score.¹²⁻¹⁴ Each CXR was evaluated by one radiologist (2nd author) and an experienced pulmonary TB physician (1st author). We assessed inter-rater reliability for CXR characteristics using Cohen's kappa statistic, which yielded a value of 0.61 (95% confidence interval [CI]: 0.43 to 0.79). For the proportion of lung involvement, we utilized intraclass correlation coefficients and obtained a value of 0.94 (95%CI: 0.90 to 0.97). Any discrepancies between the two evaluators were resolved through discussions to reach a consensus. CXR results were collected to compare radiographic improvement between the incomplete and complete SSM groups.

The primary objective of this study was to assess whether incomplete SSM was associated with the treatment success rate, which served as the focus of our analysis.

Statistical analysis

The sample size calculation was based on a previous cohort study⁹, which reported a treatment success rate of 81.6% in the incomplete smear group and 91.8% in the complete smear group. We calculated that 173 patients per group would be required to achieve 80% power to detect the effect of sputum monitoring, with a two-sided alpha level of 0.05.¹⁵

Baseline characteristics and treatment outcomes were presented using descriptive statistics, including mean, median, standard deviation, interquartile range, and frequency (percentage). Baseline characteristics included age, sex, body mass index (BMI), registration type (new or relapse), imprisonment status, distance from home to hospital, tobacco use, alcohol use, comorbidities, initial chest X-ray findings, and type of bacteriological confirmation test.

To compare the two groups, different statistical tests were applied based on the nature of the data. For qualitative variables, either the Chi-

squared test or Fisher's exact test was used, depending on the data distribution. For quantitative variables, the Kolmogorov–Smirnov test was first applied to assess normality. Variables with a normal distribution were compared using the independent sample t-test, while those with a non-normal distribution were analyzed using the Mann–Whitney U test.

To examine the association between incomplete SSM and treatment success, we first performed univariable analysis using simple logistic regression. Variables with a $p < 0.25$, along with other potential confounders based on prior knowledge, were then selected for inclusion in the multivariable model. The final model was constructed using Poisson regression with robust standard errors to estimate adjusted relative risk (aRR).

Descriptive statistics and univariable analysis were performed using jamovi (version 2.6)¹⁶, while Poisson regression with robust standard errors was conducted using RStudio (Version 2024.12.1+563).¹⁷

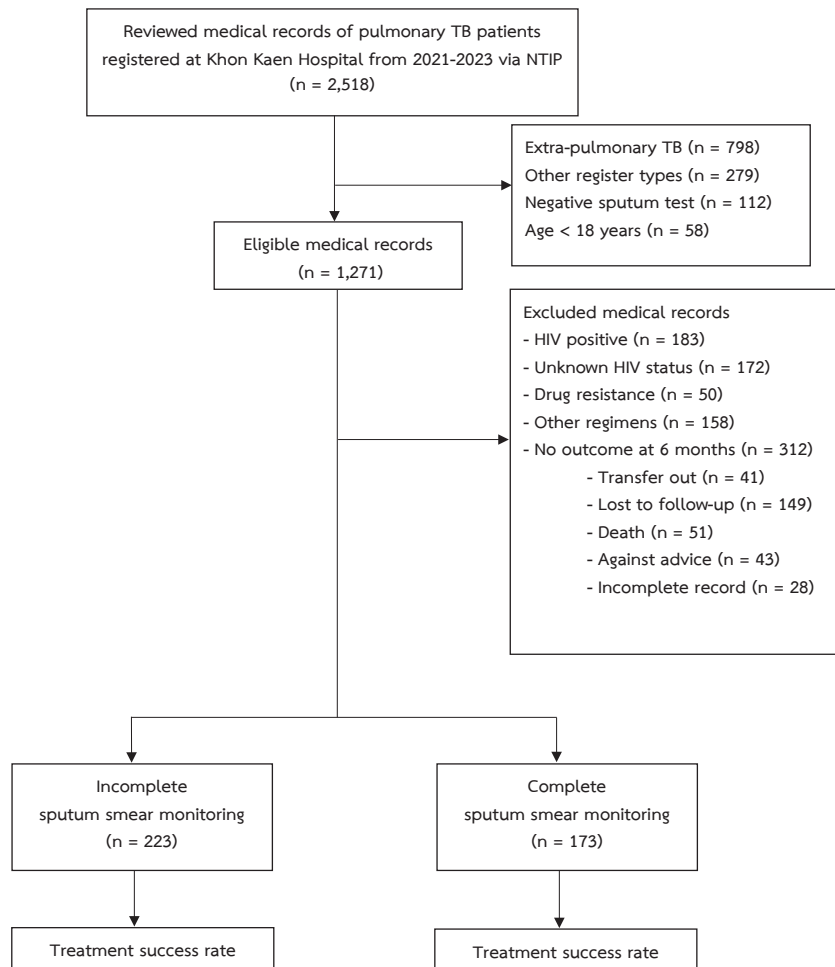
Results

Participants

Overall, we reviewed records for 2,518 patients and found 1,271 that met the eligibility criteria. After applying the exclusion criteria, we categorized 223 records into the incomplete SSM group and 173 records into the complete SSM group (Figure 1).

Baseline characteristics of the study population are summarized in Table 1. The mean age was similar between the incomplete and complete groups (51.0 ± 16.0 years vs. 49.7 ± 15.2 years; $p = 0.395$). The proportion of males was significantly higher in the complete group compared to the incomplete group (76.9% vs. 61.4%; $p = 0.001$). Mean body mass index (BMI) was approximately 20 kg/m² in both groups, and nearly all patients in both groups were classified as new cases, with no significant difference between groups. A significantly higher proportion of imprisoned individuals was observed in the complete SSM group compared to the incomplete group (16.8% vs. 5.4%; $p < 0.001$).

Median distance from home to hospital was similar between the incomplete and complete groups (9.6 km vs. 8.9 km; $p = 0.261$). Presence of comorbidities including diabetes, chronic ob-



*TB: tuberculosis, NTIP: National Tuberculosis Information Program, HIV: human immunodeficiency virus

Figure 1. Study flow

structive pulmonary disease, liver disease, and chronic kidney disease was comparable between groups (all $p > 0.05$). Likewise, tobacco use (never, former, current) and alcohol use were not significantly different between the groups.

Chest x-ray (CXR) findings at diagnosis, including the presence of specific lesions, did not significantly differ between groups. However, the median proportion of lung involvement (50% vs. 30%; $p = 0.007$) and the median Timika score (50 vs. 37.5; $p = 0.010$) were significantly higher in the complete SSM group. The bacteriological confirmation methods and sputum AFB smear results at diagnosis were similar across both groups.

Sputum monitoring

In the incomplete SSM group, it was found that the majority did not have sputum tests at month five, with a total of 189 patients. Among

these, 128 patients were scheduled for sputum follow-up in month four instead of month five.

Primary outcome

The treatment success rate was 100% in the incomplete SSM group and 98.8% in the complete SSM group, showing no significant difference between the groups ($p = 0.190$) (Table 2). The relative risk was 1.012 (95% CI: 0.996-1.028).

Simple logistic regression was used for univariable analysis to explore other potential confounders. Table 3 shows that no other factors, except for former tobacco use, were associated with the treatment success rate when considering a p -value threshold of less than 0.25. However, we conducted multivariable analysis using Poisson regression with known confounders, in addition to tobacco use, to ensure the validity of the results.

Table 1. Baseline characteristics of participants

Characteristics	Incomplete sputum smear monitoring (N = 223)	Complete sputum smear monitoring (N = 173)	P-value
Clinical characteristics			
Age (years)	51.01 + 15.96	49.66 + 15.24	0.395
Male, n (%)	137 (61.43)	133 (76.87)	0.001
Body mass index (kg/m ²)	20.23 + 3.49	20.10 + 3.82	0.734
Register type – no. (%)			0.595
New	210 (94.17)	165 (95.38)	
Relapse	13 (5.83)	8 (4.62)	
Imprisonment – no. (%)	12 (5.38)	29 (16.76)	< 0.001
Median home-to-hospital distance (km)	9.60 (3.10-21.50)	8.90 (3.10-21.20)	0.261
Co-morbidities – no./total, n (%)	99/218 (45.41)	73/147 (49.66)	0.425
Diabetes	64/218 (29.36)	53/147 (36.05)	
Chronic obstructive pulmonary disease	4/218 (1.83)	4/147 (2.72)	
Liver disease	9/218 (4.13)	4/147 (2.72)	
Chronic kidney disease	9/218 (4.13)	6/147 (4.08)	
Tobacco use – no./total, n (%)			0.456
Never	162/215 (75.35)	104/145 (71.72)	
Former	12/215 (5.58)	6/145 (4.14)	
Current	41/215 (19.07)	35/145 (24.14)	
Alcohol use – no./total, n (%)			0.052
Never	163/215 (75.81)	99/145 (68.28)	
Former	3/215 (1.40)	8/145 (5.52)	
Current	49/215 (22.79)	38/145 (26.20)	
Chest X-ray at diagnosis			
Lesion – no./total no. (%)			0.687
Normal	9/196 (4.59)	5/143 (3.50)	
Consolidation	68/196 (34.69)	49/143 (34.27)	
Cavitation	26/196 (13.27)	22/143 (15.38)	
Nodules	76/196 (38.78)	54/143 (37.76)	
Miliary	11/196 (5.61)	11/143 (7.69)	
Pleural effusion	5/196 (2.55)	1/143 (0.70)	
Abscess	0	1/143 (0.70)	
Pneumothorax	1/196 (0.51)	0	
Median proportion of lung involvement (%)	30.00 (25.00-50.00)	50.00 (25.00-75.00)	0.007
Median Timika score (score)	37.50 (25.00-75.00)	50.00 (25.00-90.00)	0.010
Bacteriological confirmation at diagnosis			
Sputum AFB – no. (%)	149 (66.82)	118 (68.21)	0.333
Scanty	18 (12.08)	11 (9.32)	
1+	36 (24.16)	31 (26.27)	
2+	35 (23.49)	24 (20.34)	
3+	60 (40.27)	52 (44.07)	
GeneXpert (MTB detected) – no. (%)	52 (23.32)	40 (23.12)	
Real-time PCR (MTB detected) – no. (%)	18 (8.07)	14 (8.09)	
Line probe assay (MTB detected) – no. (%)	0	1 (0.58)	
Unknown**	4 (1.79)	0	

AFB, acid-fast bacilli; MTB, Mycobacterium tuberculosis

*Plus-minus values are means ± SD.; **some patients were diagnosed at other healthcare facilities, and their lab test results were not available.

After adjusting for age, sex, comorbidities, tobacco use, and alcohol use, the incomplete SSM group still showed no significant difference

compared to the complete SSM group in terms of treatment success rate. The aRR was 1.015 (95%CI: 0.995–1.036).

Table 2. Treatment outcomes of pulmonary tuberculosis patients

Characteristics	Incomplete sputum smear monitoring (N = 223)	Complete sputum smear monitoring (N = 173)	P-value
Treatment success rate, n (%)	223 (100)	171 (98.84)	0.190
Cured, n (%)	42 (18.83)	13 (7.51)	
Completed, n (%)	181 (81.17)	158 (91.33)	
Failed, n (%)	0 (0.00)	2 (1.16)	
Died, n (%)	0 (0.00)	0 (0.00)	
Chest X-ray before discharge			
Lesion – no./total, n (%)			0.115
Normal	24/212 (11.32)	28/166 (16.87)	
Consolidation	15/212 (7.08)	23/166 (13.86)	
Cavitation	6/212 (2.83)	4/166 (2.41)	
Nodules	128/212 (60.38)	81/166 (48.80)	
Miliary	0 (0.00)	0 (0.00)	
Fibrosis	37/212 (17.45)	30/166 (18.07)	
Pleural effusion	2/212 (0.94)	0 (0.00)	
Median proportion of lung involvement (%)	10.00 (5.00-25.00)	10.00 (5.00-25.00)	0.828
Median Timika score (score)	10.00 (5.00-25.00)	10.00 (5.00-25.00)	0.804
Chest X-ray at 3 months after discharge			
Lesion – no./total, n (%)			0.212
Normal	18/125 (14.40)	16/89 (17.98)	
Consolidation	11/125 (8.80)	7/89 (7.87)	
Cavitation	3/125 (2.40)	0	
Nodules	62/125 (49.60)	34/89 (38.20)	
Miliary	0	1/89 (1.12)	
Fibrosis	30/125 (24.00)	31/89 (34.83)	
Pleural effusion	1/125 (0.80)	0	
Median proportion of lung involvement (%)	10.00 (5.00-25.00)	10.00 (5.00-25.00)	0.523
Median Timika score (score)	10.00 (5.00-25.00)	10.00 (5.00-25.00)	0.316

Secondary outcomes

CXR findings before discharge, including the presence of various lesions, showed no significant differences between the two groups. The median proportion of lung involvement and the median Timika score were similar between the groups before discharge ($p = 0.828$ and $p = 0.804$, respectively).

At three months after discharge, CXR findings remained comparable, with no significant differences in lesions, the median proportion of lung involvement, or the Timika score ($p = 0.523$ and $p = 0.316$, respectively). However, despite the lack of statistically significant differences, the downward trend in Timika scores suggests radiographic improvement in both groups. (Table 2)

Discussion

Our study found no significant difference in the treatment success rates of pulmonary TB patients between those with incomplete SSM

and those with complete monitoring. Although most patients in the incomplete SSM group did not have sputum tests in the fifth month, many underwent sputum testing in the fourth month as part of routine clinical management. This deviation from national guidelines may reflect a pragmatic adaptation to real-world resource limitations.

Interestingly, our study found a slightly lower treatment success rate in the complete SSM group compared to the incomplete group, although the difference was not statistically significant. One possible explanation is that patients in the complete monitoring group may have had more severe disease at baseline. As shown in Table 1, they had significantly higher Timika scores (median 50 vs. 37.5) and a greater proportion of lung involvement (50% vs. 30%) on CXR at diagnosis.

One plausible explanation for the absence of an association is that SSM primarily assists physicians in assessing treatment response and guiding clinical decisions, rather than being a de-

Table 3. Univariable analysis of factors associated with the treatment success rate

Variables	Crude odds ratio	95% Confidence interval	P-value
Age (years)	0.98	0.90-1.08	0.707
Sex			
Male	N/A	N/A	0.995
Female	1.00		
Body mass index (kg/m ²)	1.17	0.73-1.88	0.506
Register type			
New	N/A	N/A	0.995
Relapse	1.00		
Imprisonment			
Yes	N/A	N/A	0.996
No	1.00		
Home-to-hospital distance (km)	1.19	0.82-1.70	0.359
Co-morbidities			
Yes	N/A	N/A	0.996
No	1.00		
Tobacco use			
Former	0.06	0.00-1.07	0.056
Current	N/A	N/A	0.996
Never	1.00		
Alcohol use			
Former	N/A	N/A	1.000
Current	N/A	N/A	0.995
Never	1.00		
Timika score at diagnosis	1.00	0.96-1.05	0.991
Sputum smear monitoring			
Incomplete	N/A	N/A	0.996
Complete	1.00		

N/A (not applicable) indicates that the odds ratio cannot be calculated due to extremely large coefficients.

All values in the table were obtained from simple logistic regression.

Tobacco and alcohol use were analyzed using "never" as the reference category.

terminant of treatment success in itself. In our setting, even when patients missed scheduled sputum examinations, clinicians generally continued the standard treatment regimen to completion. Given that the majority of our patients had drug-susceptible TB and received the full course of the 2HRZE/4HR regimen, the likelihood of achieving successful outcomes remained high regardless of monitoring completeness. This aligns with previous findings that standard treatment remains effective for non-resistant TB cases even with limited bacteriological monitoring.¹⁸

Our findings contrasted with some previous studies that have shown a strong association between incomplete sputum monitoring and unsuccessful treatment outcomes. For instance, Nakaggwa et al. (2016) found that incomplete SSM was associated with an unadjusted odds ratio of 2.5 for treatment failure in Uganda.⁹ Similarly, a study from Thailand in 2021 demon-

strated a strong association between missing sputum smear examinations and unsuccessful treatment outcomes, with an adjusted hazard ratio of 18.40.¹¹ However, our study supported the findings of a 2019 study in Uganda using propensity score-matched analysis, which reported no significant association between SSM completion and treatment success rate.¹⁰

One of the strengths of our study was the large sample size and comprehensive data collection from a high-burden TB setting in an urban area, which enhances the generalizability of our findings. Additionally, the use of Poisson regression to adjust for potential confounders strengthens the validity of our results. However, our study had some limitations. The retrospective design might introduce bias, and incomplete records could affect the accuracy of our findings. Other unobserved confounders, such as drug compliance, days of drug interruption, and side effects

from TB drugs, were not measured. These factors might affect the treatment outcomes.

Future studies should consider prospective designs to minimize bias and ensure more accurate data collection. In addition to exploring the overall impact of sputum monitoring on treatment outcomes, future research should also investigate the minimum number and optimal timing of sputum smear examinations required to maintain high treatment success rates, particularly in settings with limited resources. Identifying which follow-up points provide the greatest clinical value could help refine national TB program guidelines and support more efficient patient management.

Conclusions

In conclusion, incomplete SSM did not compromise treatment success in pulmonary TB patients when appropriate clinical management and follow-up were ensured, suggesting flexibility may be acceptable in resource-limited settings.

Highlight

1. Incomplete sputum smear monitoring (SSM) was not associated with treatment success in pulmonary TB patients (aRR 1.01, 95% CI: 0.995-1.036).
2. Treatment success remained high in both groups (100% vs. 98.8%) even though nearly all patients with a missed month-5 test underwent testing in month 4 instead.
3. Findings support that standard TB treatment can remain effective despite incomplete follow-up sputum monitoring in resource-limited settings.

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