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Research Article

Survival Analysis of Tuberculosis Patients at Bogor Regency Regional Hospital, West Java, Indonesia

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Abstract

Tuberculosis (TB) remains one of the leading causes of mortality globally and continues to pose a significant health burden in Indonesia. Bogor Regency records the highest number of TB cases in West Java, with a mortality rate of approximately 42 deaths per 100,000 population. This study aimed to analyze the survival of TB patients treated at Bogor Regency Regional Hospital from 2021 to 2023 and to identify demographic and clinical factors influencing mortality risk, including age, gender, occupation, anatomical site of TB, comorbidities, TB drug resistance profile, and treatment adherence. Using a retrospective cohort design involving 2,804 patients, survival analysis was conducted via Cox proportional hazards regression, with time-varying covariates applied when the proportional hazards assumption was violated. The mean event time was 29.6 days, with 11.5% of patients experiencing death or treatment failure. The most influential factor was medication adherence (HR = 0.354; $p < 0.001$), followed by comorbidities, age, TB drug resistance, anatomical site, and employment status. Gender and population density showed no significant association. These findings underscore the critical importance of adherence monitoring and early intervention in high-risk patients to improve TB outcomes.

Keywords: Kaplan-Meier; Cox Proportional Hazards Model; Treatment Adherence; Comorbidities; Bogor Regency

Abbreviations

TB: Tuberculosis; MDR: Multi-Drug Resistant; PHM: Proportional Hazard Model; HR: Hazard Ratio; CI: Confidence Interval; WHO: World Health Organization; DOTS: Directly Observed Treatment Short Course

Introduction

Tuberculosis (TB) is a chronic infectious disease caused by Mycobacterium tuberculosis and remains a major global public health concern. Despite advances in diagnosis and treatment, TB ranked as the second leading cause of infectious disease-related mortality worldwide in 2022, following COVID-19. Indonesia ranks second globally in TB burden, with an estimated 969,000 new cases annually and approximately 93,000 deaths per year. Bogor Regency, West Java, reports the highest TB incidence in the province. Multiple studies have identified demographic, socioeconomic, and clinical factors influencing TB survival, including age, comorbidities, treatment adherence, and drug resistance. This study examines survival patterns and associated factors among TB patients at Bogor Regency Regional Hospital between 2021 and 2023, providing evidence to support targeted interventions for reducing TB mortality.

Materials and Methods

Study design

This study employed an analytic observational design with a quantitative approach to analyze the survival of tuberculosis (TB) patients. A retrospective cohort method was used to evaluate the relationship between various risk factors and patient survival time, based on longitudinal data from medical records. The primary outcome was the duration of survival from treatment initiation to the occurrence of death or treatment failure.

Study setting and period

The research was conducted at the TB Clinic, Bogor Regency Regional Hospital, from March to May 2025. Data covered the treatment period between January 2021 and December 2023.

Population and sampling

The target population comprised all TB patients undergoing treatment in Indonesia. The accessible population consisted of patients treated at the Bogor Regency Regional Hospital TB Clinic during the study period. Data were sourced from electronic medical records (EMR), including demographic, clinical, and treatment details.

A total sampling technique was applied, with all patients meeting the inclusion criteria enrolled in the study. Out of 3,410 available patient records, 2,804 met the eligibility requirements.

Inclusion criteria

- Complete medical record data for all study variables.
- Treatment within the period 2021–2023.

Exclusion criteria

- Incomplete medical records.
- Patients residing outside Bogor Regency.

Variables

- **Dependent variable:** Patient survival time (in days), measured from treatment initiation to death or treatment failure (event = 1) or to censoring (event = 0).
- **Independent variables:** Age, sex, employment status, population density, anatomical site of TB (pulmonary/extrapulmonary), comorbidities (HIV/DM), TB type (drug-sensitive/drug-resistant), and treatment adherence.

Operational definitions

- **Survival time:** Duration from treatment initiation to death/treatment failure or censoring.
- **Event:** Death or treatment failure within treatment period.
- **Treatment adherence:** Scored based on completeness of follow-up laboratory tests; ≥75% attendance considered adherent.

Data collection and management

Data were extracted from EMR and coded according to operational definitions. Data cleaning, editing, and coding were performed prior to analysis. Any missing or unclear data were classified as censored observations.

Statistical analysis

Survival analysis was conducted using Kaplan–Meier curves for descriptive estimates and the Log-rank test for bivariate comparisons. For multivariate analysis, the Cox Proportional Hazards (PH) model was applied to estimate hazard ratios (HR) with 95% confidence intervals (CI). If PH assumptions were violated, stratified Cox or time-varying covariate models were used. Model selection was based on the Concordance Index, with the highest index indicating the best fit.

All analyses were performed using SPSS version 23 and RStudio version 2023.06.1. Statistical significance was set at $p < 0.05$.

Results and Discussion

General findings

A total of 2,804 TB patients met the inclusion criteria, with 11.5% experiencing the event of interest (death or treatment failure) during the treatment period, while 88.5% were censored (completed treatment, cured, or lost to follow-up). The mean survival time for censored patients was 174.12 days, while patients experiencing events had a mean survival time of 29.60 days, indicating that most adverse outcomes occurred early in the treatment course.

This early concentration of deaths within the first month highlights the critical importance of close monitoring during the intensive phase of TB therapy. Studies in similar settings have shown that poor adherence, severe comorbidities, and advanced disease stage at diagnosis contribute to early mortality [5].

Kaplan–meier and bivariate analysis

Variable	HR (95% CI)	*p* -value
Age	2.67 (1.84–3.88)	<0.001
Sex	0.97 (0.77–1.22)	0.774
Employment status	1.05 (0.82–1.33)	0.719
Population density	1.04 (0.82–1.31)	0.719
Anatomical site of TB	1.38 (1.10–1.73)	0.006
Comorbidities (HIV/DM)	0.71 (0.55–0.91)	0.009
TB type (Drug-sensitive / Drug-resistant)	2.89 (1.47–5.68)	0.002
Treatment adherence	0.35 (0.28–0.45)	<0.001

Table 1: Bivariate Analysis of Factors Associated with Tuberculosis Patient Survival.

Age

Survival probability differed significantly by age group ($p < 0.001$). Patients aged <19 years had the highest survival rates, followed by those aged 19–40 years, while patients >40 years had the lowest. The hazard ratio (HR) for older adults compared to the youngest group was 2.67, indicating more than double the risk of death or treatment failure.

Older patients often present with weaker immune function, multiple comorbidities, and delayed health-seeking behavior, which are known to worsen TB outcomes [1,2].

Sex

There was no statistically significant difference in survival between males and females (p = 0.774; HR ≈ 0.97). This suggests that, in this population, gender alone did not substantially influence TB mortality when other factors were not controlled. This finding aligns with studies showing that while male sex is often a risk factor for TB, it is confounded by behavioral and socioeconomic factors [3].

Employment status

Employment status was not significantly associated with survival (p = 0.719). While unemployment may be linked to poverty and poorer access to healthcare, in this cohort, the impact appears to be mediated through other clinical and demographic factors.

Population density

No significant difference in survival was found between high and low population density areas (p = 0.719). This contrasts with some literature showing urban overcrowding as a TB risk factor [4], possibly due to uniform access to treatment within the study area.

Anatomical site of TB

Patients with pulmonary TB had significantly lower survival compared to extrapulmonary TB cases (p = 0.006; HR = 1.38). Pulmonary TB patients are more likely to present with advanced respiratory symptoms and higher bacterial loads, increasing the risk of poor outcomes.

Comorbidities (HIV/DM)

Comorbid conditions were significantly associated with poorer survival (p = 0.009; HR = 0.709 for absence vs. presence). While counterintuitive, this finding reflects that patients without recorded comorbidities may have had other undiagnosed conditions or presented later in the disease course. HIV and diabetes are well-documented predictors of TB mortality [6,7].

TB type (Drug-Sensitive vs. Drug-Resistant)

Drug-resistant TB (DR-TB) was associated with markedly worse survival (p = 0.002; HR = 2.89). The small proportion of DR-TB cases in the cohort still contributed disproportionately to mortality, consistent with global data showing high DR-TB fatality rates.

Treatment adherence

Non-adherence to treatment was the most powerful predictor of poor survival (p < 0.001; HR = 0.354 for adherent vs. non-adherent patients). Adherence influences drug efficacy, resistance development, and bacterial clearance. This aligns with WHO guidance emphasizing adherence support mechanisms, such as Directly Observed Therapy (DOT).

Multivariate analysis and model selection

Variable	βj	HR	95% CI for HR	SE	z	p-value
Age	0.019	1.020	[1.013, 1.026]	0.003	6.188	<0.001
Sex	-0.046	0.955	[0.727, 1.255]	0.139	-0.328	0.743
Employment status	0.271	1.312	[0.990, 1.739]	0.144	1.886	0.059
Population density	0.119	1.126	[0.897, 1.414]	0.116	1.020	0.308
Anatomical site of TB	-0.478	0.620	[0.471, 0.816]	0.140	-3.411	0.001
Comorbidities (HIV/DM)	-0.363	0.696	[0.522, 0.927]	0.147	-2.476	0.013
TB type (Drug sensitive / Drug resistant)	0.013	1.013	[0.377, 2.723]	0.505	0.025	0.980
Treatment adherence	-1.039	0.354	[0.247, 0.506]	0.182	-5.699	<0.001

Table 2: Multivariate Analysis of Factors Associated with Tuberculosis Patient Survival.

The initial Cox PH model identified treatment adherence, comorbidities, age, TB type, anatomical site, and employment status as significant predictors. The proportional hazards assumption was violated for adherence, prompting the use of a time-varying Cox model, which achieved the best predictive performance (C-index = 0.649) compared to stratified Cox model (C-index = 0.593).

This finding is consistent with survival studies in TB where time-dependent covariates improve model fit by accounting for changes in hazard over time [8]. It reinforces the importance of modeling adherence as a dynamic variable rather than a fixed baseline characteristic.

Overall, treatment adherence emerged as the most critical survival determinant, followed by comorbidities and age. Public health interventions should focus on early detection in older adults, proactive comorbidity management, and rigorous adherence monitoring.

Discussion

The results of this study demonstrated that several factors influenced the survival time of TB patients at Bogor Regency Regional Hospital, Bogor Regency, West Java, Indonesia. The Kaplan–Meier analysis revealed that the survival curve declined most steeply during the first month of treatment, indicating that the highest risk of mortality occurred in the early intensive phase. This finding is consistent with previous studies in various countries that have reported early deaths in TB patients, often due to severe disease at presentation, delayed diagnosis, or late initiation of treatment [1,2]. In this study, the mean survival time for patients experiencing events was markedly shorter compared to censored patients, underscoring the importance of close clinical monitoring during the initial treatment phase.

Age was found to be significantly associated with TB survival. Older patients had a higher hazard of death compared to younger individuals. This may be explained by the fact that aging is associated with a decline in immune function, increased prevalence of comorbidities, and reduced physiological reserve, all of which may impair the body's ability to respond effectively to TB infection. Similar findings have been reported where advanced age was a strong predictor of poor TB outcomes [1,2]. These results suggest that TB control programs should implement more intensive surveillance and tailored interventions for older adults to improve their treatment success and survival.

Sex was not significantly associated with survival in this study, indicating that mortality risk was similar between males and females. Although global TB data often show higher TB incidence among males, mortality differences are not always observed when other clinical and socioeconomic factors are taken into account. This result aligns with other finding, which found no significant difference in TB survival between genders when adjusted for confounding variables [3]. This suggests that in the context of Bogor Regency Regional Hospital, gender-specific interventions may not be as critical as interventions targeting other high-risk factors.

Employment status was also not significantly related to TB survival in this study. Although unemployment is often associated with poverty, poor nutrition, and limited healthcare access, the lack of statistical significance here may reflect the relatively uniform access to treatment provided by the hospital regardless of employment status. This differs from some studies that link unemployment to poor TB outcomes, indicating that socioeconomic impacts may be mediated by the local healthcare delivery model.

Population density did not significantly influence survival, suggesting that urban overcrowding did not substantially affect mortality risk in this cohort. This contrasts with research which found that patients living far from healthcare facilities in densely populated areas had worse TB outcomes [4]. The difference may be due to the relatively small geographic coverage of Bogor Regency Regional Hospital's service area, where travel distance to the facility is generally short.

The anatomical site of TB was significantly associated with survival. Patients with pulmonary TB had a shorter survival time compared to those with extrapulmonary TB. Pulmonary TB patients are generally more infectious and may present with more severe respiratory symptoms, larger bacillary loads, and greater lung damage, increasing the likelihood of poor treatment outcomes. This finding aligns with global TB reports, which note higher mortality in pulmonary TB compared to extrapulmonary forms.

Comorbidity status was also significantly associated with survival. Interestingly, patients without recorded comorbidities had lower survival compared to those with documented comorbidities such as HIV or diabetes. This may be due to incomplete detection of comorbidities in medical records, meaning that some patients categorized as having no comorbidities may actually have undiagnosed conditions contributing to mortality risk. Nevertheless, the role of HIV and diabetes as major contributors to TB mortality is well documented [6,7]. HIV infection weakens the immune system, while diabetes impairs macrophage function and delays bacterial clearance, both of which worsen TB prognosis.

TB type was a strong predictor of survival. Patients with drug-resistant TB (DR-TB) had a much higher hazard of death compared to those with drug-sensitive TB. This reflects the global trend in which DR-TB is associated with longer treatment duration, more toxic drug regimens, and lower treatment success rates. The proportion of DR-TB in this cohort was relatively small, yet it accounted for a disproportionate number of deaths, consistent with WHO reports and studies in high-burden settings.

Treatment adherence emerged as the most important determinant of survival. Patients who adhered to treatment had significantly higher survival probabilities than those who did not. This finding is in line with WHO guidelines and several studies which highlight that poor adherence contributes to ongoing bacterial replication, treatment failure [5], and the development of drug resistance. In this study, non-adherence was most common in the early phase, which coincides with the period of highest mortality. This suggests that interventions such as Directly Observed Treatment, Short-course (DOTS) should be intensified during the initial months of therapy.

Multivariate analysis using the Cox Proportional Hazards model confirmed that adherence, comorbidities, age, TB type, anatomical site, and employment status were significant predictors of survival. The proportional hazards assumption was violated for adherence, indicating that its effect on hazard changed over time. Therefore, a time-varying Cox model was applied, which provided the highest concordance index (C-index = 0.649). This supports findings which demonstrated that time-dependent modelling improves prediction accuracy for TB survival outcomes [8].

Conclusion

This study identified treatment adherence as the most influential factor in TB patient survival, followed by comorbidities, age, TB type, anatomical site, and employment status. Gender and population density were not significantly associated with survival.

The use of a time-varying Cox model provided the best predictive accuracy, emphasizing the dynamic effect of adherence over the treatment period.

Key implications

- Enhancing adherence through DOTS and patient support programs could markedly reduce early mortality.
- Screening and management of comorbidities, particularly HIV and diabetes, are essential to improving treatment outcomes.
- Early case detection in older adults and high-risk groups should be prioritized.
- Targeted interventions addressing these factors could improve TB control strategies in Bogor Regency and similar high-burden settings.

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Conflict of Interest

The authors declare no conflict of interest related to this study.

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