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# Analysis of Treatment Period for TB Patients Using The Kaplan-Meier Method

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**Abstract**

This study analyzes the treatment duration of tuberculosis (TB) patients in Banyumas Regency using the Kaplan-Meier method, a non-parametric approach in survival analysis. Data were obtained from the Banyumas Health Office between March and November 2023, covering 25 patients. The variables analyzed included gender, age, and treatment completion status. Kaplan-Meier estimation indicated a median treatment time of six months. Incomplete treatment occurred in 8.3% of male patients (1 of 12) and 15.4% of female patients (2 of 13). Similarly, patients over 40 years of age had a higher non-completion rate (15.4%) compared to those aged 40 years or younger (8.3%). These findings highlight disparities in treatment adherence across demographic groups. Although limited by the small sample size, this study provides local evidence that can guide policymakers in developing age- and gender-sensitive strategies to improve TB control in Banyumas Regency.

*Keywords:* Survival analysis, Banyumas, Hazard function, Survival function, Tuberculosis.

## 1. Introduction

Tuberculosis (TB) remains one of the leading causes of death worldwide and continues to be a major public health problem in Indonesia (WHO, 2023; Nurjana, 2015). Despite continuous prevention and treatment efforts, the incidence and mortality rates remain high (Khariri & Saraswati, 2021). In Banyumas Regency, TB poses a persistent health challenge that affects both individual well-being and community productivity.

Survival analysis is a statistical method used to model the time until a specific event occurs, while accounting for incomplete or censored data (Etikan et al., 2017). This method has been widely applied in health research, including studies of cancer, kidney failure, and infectious diseases, to estimate survival time and identify factors associated with treatment outcomes (Ilahi et al., 2024). The Kaplan-Meier method, introduced by Kaplan and Meier (1958), is one of the most widely used non-parametric techniques for estimating survival functions and comparing groups. It is particularly useful for studies with relatively small sample sizes and censored observations (Ramadhani et al., 2023).

Previous studies have examined TB treatment success factors, such as adherence and regularity of treatment schedules (Scientific, 2015; Audina & Fatekurohman, 2020). However, local-level studies in Indonesia remain limited, especially in Banyumas Regency, where demographic characteristics such as gender and age may influence treatment adherence. Understanding these local dynamics is essential for designing more effective TB control strategies.

This study aims to analyze the treatment duration of TB patients in Banyumas Regency using the Kaplan-Meier method, with a focus on gender and age as potential determinants of treatment completion. By providing quantitative evidence through survival analysis, this research seeks to contribute to the development of targeted interventions that address demographic disparities in TB treatment outcomes.

## 2. Literature Review

### 2.1. Survival Analysis

Survival analysis is a statistical approach used to model the time until an event of interest occurs, considering the possibility of incomplete (censored) observations (Etikan et al., 2017). Events in survival analysis may include death, recovery, relapse, or treatment completion, depending on the study context (Ilahi et al., 2024). Survival time is defined by two components: the starting point of observation and the endpoint marked by the occurrence of the event.

In survival analysis, three types of censoring are recognized:

1. Right-censored, when the event has not yet occurred at the end of the observation period.
2. Left-censored, when the event occurs before the start of observation.
3. Interval-censored, when the event occurs within a certain time interval but the exact timing is unknown.

## 2.2. Survival Time Distribution of Continuous and Discrete Models

The survival function represents the probability that a random variable $T$ will be greater than a certain time $t$. If $T$ is a non-negative random variable in the time range $[0, \infty)$ that indicates the time until an individual experiences an event in the population, then $f(t)$ is the probability density function of $t$. Thus, the probability that an individual has not experienced an event until time $t$ is expressed through the survival function $K(t)$ (Ilahi et al., 2024).

$$K(t) = Pr(T \geq t) = \int_t^\infty f(x)dx \tag{1}$$

Based on the definition of the survival function in Equation (1) which comes from the cumulative distribution of random variables $T$, the survival function $K(t)$ can be formulated in Equation (2) and as a result Equation (3) is obtained, namely the cumulative distribution function:

$$K(t) = Pr(T \geq t) = 1 - Pr(T \leq t) = 1 - F(t) \tag{2}$$

$$F(t) = 1 - K(t) \tag{3}$$

Where:

$K(t)$ : survival function

$T$ : random variable represents the remaining life

$t$ : age

Meanwhile, the survival time distribution of the discrete model is defined as follows:

$$K(t) = Pr(T \geq t) = \sum_{t_i \geq t} f(t_i) \tag{4}$$

## 2.3. Kaplan-Meier method

The Kaplan-Meier method, introduced by Kaplan and Meier (1958), is one of the most widely applied non-parametric techniques in survival analysis. It estimates the survival function by calculating the probability of surviving past certain time points, accommodating censored data. This method is particularly effective for studies with small sample sizes, making it suitable for health research in local settings (Ramadhani et al., 2023).

The Kaplan-Meier estimator has been used in various medical studies. For example, Audina and Fatekurohman (2020) applied the method to analyze COVID-19 patient recovery in Jember Regency, while Ilahi (2022) employed it to study kidney failure patients. These studies highlight the flexibility of the Kaplan-Meier approach in analyzing treatment outcomes across diverse diseases. The empirical survival function for all data is defined as: (Ramadhani et al., 2023)

$$\widehat{K}(t) = \frac{number\ of\ observations \geq t}{n}, \qquad t \geq 0 \tag{5}$$

Where:

$\widehat{K}(t)$ : empirical survival function

If there is incomplete data in Equation (2.6), it will be converted into a limit product estimate known as the Kaplan-Meier estimate. In the Kaplan-Meier method, the observation time $t_i$ with $i = 1,2, \dots, k$ is first sorted from the smallest to the largest, so that a certain time sequence is obtained $0 < t_1 < t_2 < \cdots < t_k$. Thus, the survival function estimate can be calculated as follows:

$$\widehat{K}(t) = \prod_{t_i \geq t} \left(1 - \frac{d_i}{n_i}\right) \tag{6}$$

where the number of individuals with observation time $t_i$ is $d_i$ and $n_i$ indicates the number of individuals experiencing the event at time $t_i$ or later.

Assuming that in $k$ trials $n_i$ events occur and $d_i$ is the number of deaths at time $t_i$, and the probability of death is $h(t_i)$. To obtain an estimate of the hazard function, the first derivative of $L(t_i, h(t_i))$ is taken with respect to $h(t_i)$ and then equalized to zero. The equation is solved for $h(t_i)$ as follows:

$$\ln L(t_i, h(t_i)) = \prod \left(h(t_i)\right)^{t_i} (1 - h(t_i)^{n_i - d_i} \tag{7}$$

$$= \sum_I \left( d_i \ln h + (n_i - d_i) \ln\left(1 - h(t_i)\right) \right)$$

### 2.4. Tuberculosis

Tuberculosis (TB) is caused by Mycobacterium tuberculosis, which primarily affects the lungs but can also spread to other organs such as bones, lymph nodes, and the central nervous system (Kaban et al., 2023). TB transmission occurs through airborne droplets released by infected individuals when coughing or sneezing.

In Indonesia, TB remains a major public health concern. The Household Health Survey (1995) reported TB as the leading cause of death among infectious diseases, and WHO (1999) estimated 583,000 new TB cases annually, with around 140,000 related deaths. Most TB patients are within the productive age group (15–50 years), which impacts both economic productivity and public health (Putra, 2018).

Studies have emphasized that regularity and adherence to treatment are critical for TB recovery (Scientific, 2015). However, adherence is often influenced by demographic and socio-economic factors, including gender, age, and education level (Kaban et al., 2023). This highlights the importance of analyzing TB treatment outcomes within specific local contexts.

## 3. Methodology

### 3.1. Data Source

This study used secondary data from the Banyumas Regency Health Office, covering TB patients treated between March and November 2023. A total of 25 patients were included in the analysis.

### 3.2. Variables

The dependent variable was treatment duration until completion (in months). Independent variables included:

1. Gender: male or female.
2. Age group: ≤40 years and >40 years.
3. Treatment status: completed (event occurred) or censored (treatment incomplete).

### 3.3. Kaplan-Meier Analysis

The Kaplan-Meier method was applied to estimate the survival function, hazard function, and probability of treatment completion. Censored data were incorporated into the analysis to ensure accurate estimation.

### 3.4. Statistical Test

The Log-Rank test was employed to compare survival distributions between groups (male vs female, ≤40 vs >40 years). Statistical significance was determined at a 5% level (p<0.05p < 0.05p<0.05).

## 4. Results and Discussion

### 4.1. Descriptive Data

Medical record data from the Banyumas Regency Health Office between March and November 2023 included 25 TB patients, with a maximum treatment duration of eight months. Table 1 summarizes the patient data.

**Table** 1: Tuberculosis Patient Data (March–November 2023)

| $i$ | Treatment Time ($t_i$) | *n. risk* ($n_i$) | Status | | Gender | | | | Age | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | L | | P | | $\leq 40$ | | $> 40$ | |
| | | | PS | S | PS | S | PS | S | PS | S | PS | S |
| 1 | 0 | 25 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 2 | 1 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2 | 23 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 4 | 3 | 22 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 5 | 4 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 5 | 21 | 15 | 0 | 8 | 0 | 7 | 0 | 8 | 0 | 7 | 0 |
| 7 | 6 | 6 | 3 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 0 |
| 8 | 7 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 9 | 8 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |

Source: Banyumas Regency Health Office, 2024
Description: PS=Treatment Completed, S=Censored.

### 4.2. Descriptive Statistics

As shown in Table 2, 22 patients (88%) completed treatment, while 3 patients (12%) were censored.

**Table 2**: Descriptive Statistics of Tuberculosis Patient Data

| Variables | Amount |
|---|---|
| Tuberculosis Treatment Patients Completed | 22 |
| Censored Treatment Patients | 3 |
| Number of Tuberculosis Patients | 25 |

Source: Secondary data processing, 2024

These results indicate that most patients adhered to the full treatment regimen, though a small proportion did not.

### 4.3. Survival Analysis by Gender

Table 3 Table 3 presents TB treatment outcomes by gender. Among 12 male patients, 11 completed treatment and 1 was censored (8.3%). Among 13 female patients, 11 completed treatment and 2 were censored (15.4%).

**Table 3**: Survival Analysis of TB Patients by Gender

| Gender | Completed | Censored | Completion Rate | Log-Rank p-value |
|---|---|---|---|---|
| Male | 11 | 1 | 91.7% | 0.421 |
| Female | 11 | 2 | 84.6% | |

Kaplan-Meier curves (Figure 1) show that male patients had a slightly higher probability of incomplete treatment compared to females. However, the Log-Rank test indicated that this difference was not statistically significant ($p$ = 0.421).

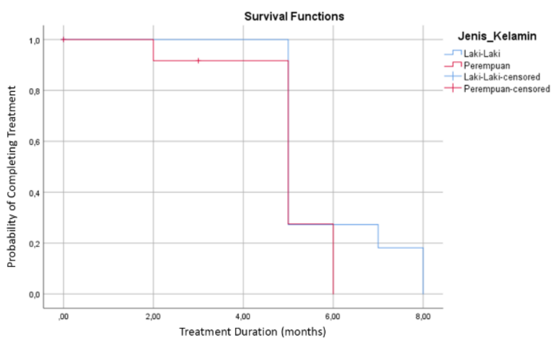


**Figure 1**: Kaplan–Meier Survival Curves of TB Patients by Gender

This finding is consistent with previous studies (Audina & Fatekurohman, 2020), which observed gender-related differences in treatment adherence but emphasized that significance often depends on larger sample sizes.

### 4.4. Survival Analysis by Age Group

Table 4 summarizes treatment outcomes by age. Patients aged ≤40 years had 11 completed and 1 censored case (8.3%), while those aged >40 years had 11 completed and 2 censored cases (15.4%).

**Table 4**: Survival Analysis of TB Patients by Age Group

| Age group | Completed | Censored | Completion Rate | Log-Rank p-value |
|---|---|---|---|---|
| ≤ 40 | 11 | 1 | 91.7% | 0.387 |
| > 40 | 11 | 2 | 84.6% | |

Kaplan-Meier curves (Figure 2) show that older patients (>40 years) tended to have a higher probability of non-completion and longer treatment duration. However, the Log-Rank test revealed no statistically significant difference between the two age groups ($p$ = 0.387).

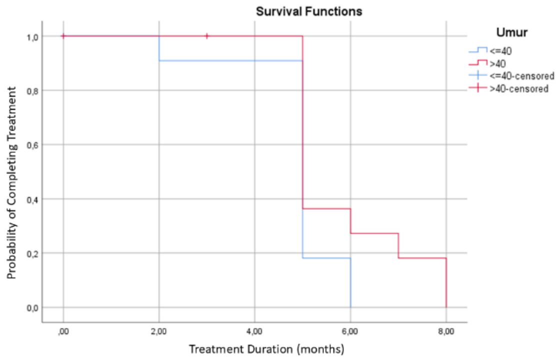


**Figure 2**: Kaplan–Meier Survival Curves of TB Patients by Age Group

This pattern is consistent with findings in other TB studies, which reported that older patients often face greater challenges in treatment adherence due to comorbidities and longer recovery times (Kaban et al., 2023).

### 4.5. Discussion

The Kaplan-Meier analysis provides insight into TB treatment completion in Banyumas Regency. While descriptive differences were observed across gender and age groups, the Log-Rank tests showed no statistically significant variations. This is likely due to the limited sample size (n = 25), which reduces statistical power.

Despite this limitation, the analysis suggests that: (1) Male patients have a slightly higher probability of non-completion than female patients. (2) Older patients (>40 years) show a higher tendency to discontinue treatment compared to younger patients.

These results align with earlier findings that demographic factors, particularly age and gender, can influence TB treatment adherence (Scientific, 2015; Audina & Fatekurohman, 2020).

From a policy perspective, the findings highlight the importance of targeted interventions: (1) Health promotion campaigns aimed specifically at men. (2) Counseling and support programs for older patients. (3) Strengthening community health monitoring to reduce treatment dropout.

Finally, the limitations of this study include the small sample size and the limited variables analyzed (only gender and age). Future research should involve larger cohorts and incorporate additional variables such as socioeconomic status, education, comorbidities, and access to healthcare facilities to provide a more comprehensive understanding of TB treatment adherence.

## 5. Conclusion

This study analyzed the treatment duration of tuberculosis (TB) patients in Banyumas Regency using the Kaplan–Meier survival method. The results showed that male patients and those aged over 40 years tended to have a lower probability of completing treatment compared to female patients and younger patients. However, Log-Rank tests indicated that these differences were not statistically significant, which may be influenced by the relatively small sample size.

Despite this limitation, the findings highlight important trends in treatment adherence that can inform local TB control strategies. Health authorities should pay particular attention to male patients and older age groups, who may require targeted interventions such as personalized counseling, family support, or community-based monitoring to improve treatment completion rates.

Future research should involve larger and more diverse samples, include additional variables such as socioeconomic status, comorbidities, and access to healthcare services, and employ complementary statistical approaches to strengthen the robustness of the analysis. By addressing these factors, subsequent studies can provide stronger evidence to support policy development and program implementation for TB control in Indonesia.

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