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ORIGINAL ARTICLE

ANALYSIS OF TUBERCULOSIS PATIENT CHARACTERISTICS OF GORONTALO CITY HOSPITAL USING K-MEANS CLUSTERING METHOD

Analisis Karakteristik Pasien Tuberkulosis Rumah Sakit Kota Gorontalo Menggunakan Metode K-Means Clustering

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ABSTRACT

Background: Tuberculosis (TBC) is a major health problem in Indonesia, especially in Gorontalo, with high spread due to poor ventilation, overcrowding, and unhealthy lifestyles. **Purpose:** To analyze the characteristics of TB patients in one of Gorontalo City's hospitals using K-Means Clustering. **Methods:** Data including age, gender, TBC history, HIV status, diabetes history, hypertension, drug resistance, drug side effects, and treatment results were analyzed for the number of clusters using the K-Means method because it is effective in grouping data based on similarity, easy to implement, and works well on large datasets. **Results:** The analysis resulted in three clusters. Cluster 0 (219 individuals): majority female (63.50%), mean age 45.37 years, low address score (0.49), low resistance and therapy (6.40%), no comorbidities, all experienced side effects (100%), and survival rate 4.10%. Cluster 1 (150 individuals): mean age 52.21 years, higher address score (0.77), resistance 7.30%, therapy 5.30%, comorbidities 100%, all experienced adverse events, and survival rate 4.70%. Cluster 2 (98 individuals): mean age 48.58 years, address score 0.65, very low resistance and therapy (2%), no side effects, 42.90% had comorbidities, and the highest survival rate (12.20%). **Conclusion:** Three clusters were obtained from the analysis using K-Means. Clustering supports specific

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interventions such as comorbidity management or intensive surveillance, improving TB control programs in Gorontalo.

ABSTRAK

Latar Belakang: *Tuberkulosis (TBC) adalah masalah kesehatan utama di Indonesia, terutama di Gorontalo, dengan penyebaran tinggi akibat ventilasi buruk, kepadatan, dan gaya hidup tidak sehat.* ***Tujuan****: Menganalisis karakteristik pasien TBC di salah satu rumah sakit kota gorontalo menggunakan K-Means Clustering.* ***Metode:*** *Data meliputi usia, jenis kelamin, riwayat TB, status HIV, riwayat diabetes, hipertensi, resistensi obat, efek samping obat, dan hasil pengobatan di analisis jumlah cluster dengan menguakan metode k-means karena efektif dalam mengelompokkan data berdasarkan kemiripan, mudah diterapkan, dan bekerja dengan baik pada dataset berukuran besar.* ***Hasil:*** *Analisis menghasilkan tiga klaster. Klaster 0 (219 individu): mayoritas perempuan (63,50%), usia rata-rata 45,37 tahun, skor alamat rendah (0,49), resistensi dan terapi rendah (6,40%), tanpa komorbid, semua mengalami efek samping (100%), dan survival rate 4,10%. Klaster 1 (150 individu): usia rata-rata 52,21 tahun, skor alamat lebih tinggi (0,77), resistensi 7,30%, terapi 5,30%, komorbid 100%, semua mengalami efek samping, dan survival rate 4,70%. Klaster 2 (98 individu): usia rata-rata 48,58 tahun, skor alamat 0,65, resistensi dan terapi sangat rendah (2%), tanpa efek samping, 42,90% memiliki komorbiditas, dan survival rate tertinggi (12,20%).* ***Simpulan:*** *Terdapat tiga cluster yang di dapatkan dari hasil analisis mengunakann K-Means. Clustering mendukung intervensi spesifik seperti pengelolaan komorbiditas atau pengawasan intensif, meningkatkan program pengendalian TB di Gorontalo.*

INTRODUCTION

Tuberculosis (TBC) is the leading cause of death from infectious diseases among adults worldwide (1). An estimated 10.6 million people worldwide fell ill with TB in 2021, an increase of 4.50% from the previous year (2). The disease is a chronic infection caused by Mycobacterium tuberculosis. Symptoms of TBC can include a severe cough lasting three weeks or more, chest pain, coughing up blood or phlegm, weakness or fatigue, weight loss, no appetite, chills, fever, and night sweats (3).

Indonesia is one of the countries that have tuberculosis. Indonesia aims to eradicate tuberculosis by 2030, with the theme “Find Tuberculosis, Treat Until Cured” as the main message of TB control efforts (4). About 845,000 Indonesians had tuberculosis in 2019, and about 92,700 people died from it each year (5). About 17.30% of TBC patients in Indonesia are 45-54 years old, 16.80% are 25-34 years old, and 16.70% are 15-24 years old (6). Factors such as age, education, stress, depression, stigma, treatment adherence, and social support influence the high number of tuberculosis cases in Indonesia. This is also exacerbated by home environmental conditions such as poor ventilation, overcrowding, and inadequate lighting (7).

One of the provinces with the highest burden of tuberculosis in Indonesia is Gorontalo. Gorontalo province reported 2,873 TBC cases, of which Gorontalo City accounted for 643 cases (69.51% of the estimated 925 cases), with Kota Tengah Health Center recording the highest number of 92 cases, while Piloloda'a Health Center and Hulonthalangi Health Center recorded the lowest number of 29 and 36 cases, respectively (8). Similar to the factors affecting tuberculosis cases in Indonesia, age, education, economic status, smoking, and household contact are associated with the incidence of pulmonary tuberculosis in Gorontalo (9).

Precision medicine maximizes healthcare quality by individualizing the healthcare process based on each patient's unique health status, supporting evidence-based decision-making. Differences in patient characteristics can affect response to treatment, so clustering is necessary to

identify more effective and personalized treatment patterns. Precision medicine focuses on the individual patient based on their characteristics, genomic information, proteomics, and social environment, aiding in diagnosis and treatment (10). Precision medicine improves health by accounting for individual variability in genes, environment, and lifestyle (11). Patient clustering using clinical and digital data can improve clustering coherence and recommendation accuracy in healthcare (12). One of the clustering features that are often used is K-Means due to its advantages of being efficient in handling large datasets, having a fast computational process, being easy to implement, and producing clear clusters based on data similarity, making it suitable for pattern analysis in patient clustering. Grouping patients into different strata based on risk factors and clinical outcomes is essential for providing appropriate healthcare.

Through this analysis, it is expected to find groups of patients with similar characteristics, which can be used as a basis for designing more appropriate and effective precision medicine treatment strategies for TBC patients with comorbidities. The results of this study are expected to make a significant contribution to improving the treatment effectiveness and prognosis of patients with more complex conditions.

METHODS

This study was designed with an exploratory quantitative approach to analyze data on TBC patients with comorbidities in Gorontalo Provincial Hospital using the K-Means algorithm. The data used included gender variables divided into male and female, age categorized into less than or equal 50 years and more than 50 years, and classification based on treatment history, included new patients, those who had never undergone TBC therapy before; failed patients, those who had undergone treatment but showed no improvement or failed therapy; relapsed patients, those who had recovered or completed treatment but returned to active TBC; and treatment withdrawal patients, those who stopped treatment before completion. In addition, the drug resistance history variable was categorized into patients with a history of resistance, who had confirmed resistance to anti-TBC drugs previously, and patients without a history of resistance, who had never been diagnosed with resistance to TBC drugs.

The next stage is a data cleaning process to ensure the quality and consistency of the information used. Once the cleaning process is complete, the next step is the application of the K-Means algorithm to group patients based on similar characteristics. Determination of the optimal number of clusters is done by the Elbow or Silhouette Score method. This algorithm aims to divide patients into several groups that have similar treatment patterns and responses to therapy. To facilitate the visualization of clustering results, principal component analysis (PCA) is used to reduce the high dimensionality of data into two dimensions. PCA works by transforming the original variables into principal components (PCs) that represent the main patterns in the data. Its function in cluster analysis is to reduce data complexity, remove correlations between variables, and facilitate visualization in two-dimensional form (PC1 and PC2). PCA allows visualization of clustering results on a two-dimensional graph, where each point represents a patient and each cluster is assigned a different color. The platform used to analyze the data is Google Colab, which was chosen for its ease of access, support for Python libraries such as Scikit-learn for the K-Means (K-Means groups data by finding a cluster center (centroid) and updating it until the data in each cluster are most similar to each other) and PCA algorithms, and its ability to efficiently process large data using GPUs or TPUs. The formula for K-means is:

$$d_{ik}: \sqrt{\Sigma_j^m}(c_{ij} - c_{kj})$$

Information:
C_ij : Cluster center
C_{kj} : Data Figure

In addition, Google Colab supports real-time team collaboration, making it easier to jointly analyze and share research results. This research has obtained ethical permission from the Ahmad Dahlan University Ethics Committee with the number 012405106.

RESULTS

Clustering using K-Means can improve the efficiency and precision of treatment by using clustering methods based on patient characteristics. Characteristics of patients (See Table 1), in the study consisted of female patients (62.75%), with most of them being over 50 years old (62.75%). Based on treatment history, most were new patients (61.66%), followed by relapse patients (30.40%), while treatment failure and dropout cases amounted to 1.92% and 5.99%, respectively. A total of 94.20% of patients had no history of resistance, and

96% received first-line therapy. Side effects were experienced by 79% of patients, while 41% had comorbidities. Survival rates were very high, with 94% of patients surviving, while 5.99% did not. These data reflect the predominant profile of patients and the pattern of treatment received.

Table 1
Description of the characteristics of TB patients in Hospital

Characteristics	n	%
Gender		
Male	293	62.75
Female	174	37.25
Age		
≤ 50 years old	174	37.25
>50 years old	293	62.75
Class Based on Treatment History		
New	288	61.66
Failed	9	1.92
Relapsed	142	30.40
Discontinued	28	5.99
Resistance History		
No	440	94.20
Yes	27	5.80
Comorbidities		
No Comorbidities	275	59
Had Comorbidities	192	41
Tuberculosis Therapy Received		
Line 1	443	96
Line 2	24	4
Side Effect		
No side effect	98	21
Had side effect	369	79
Survival		
Not survive	28	5.99
Survive	439	94

There are several characteristics that each cluster possesses. Cluster 0 consisted of 219 individuals with a female majority (63.50%), a mean age of 45.37 years, and a predominantly low address category (mean score 0.49). Classes based on drug use history were predominantly in the early category (mean 1.56), with a history of resistance and low therapy (6.40%), all experienced side effects (100%), no comorbidities, and a survival rate of 4.10%. Cluster 1 contained 150 individuals, with a higher mean age (52.21 years) and a greater address score (0.77). Resistance and therapy history remained low (7.30% and 5.30%), all experienced adverse events and comorbidities (100%), and the survival rate was 4.70%. Cluster 2, with 98 individuals, had a mean age of 48.58 years, an address score of 0.65, a very low history of resistance and therapy (2%), and no adverse events, but 42.90% had comorbidities, with the highest survival rate (12.20%).

The Figure 1 below is a visualization of the clustering results using K-Means, with PCA for dimension reduction, showing three clusters of patients with unique characteristics (see Figure 1). Cluster 0 (blue) has an average age of 45 years, predominantly female (63.50%), low drug resistance (6.40%), and no comorbidities, but all experience side effects with the lowest survival rate (4.10%). Cluster 1 (orange) contained older patients (mean 52 years), also predominantly female (62.00%), all had comorbidities and side effects, with drug resistance of 7.30% and a slightly higher survival rate (4.70%). Cluster 2 (green) showed the best results, with a mean age of 48 years, the lowest drug resistance (2%), 42.90% had comorbidities, no side effects, and the highest survival rate (12.20%). This analysis provides important insights for understanding patient needs and designing more effective therapies according to the characteristics of each cluster.

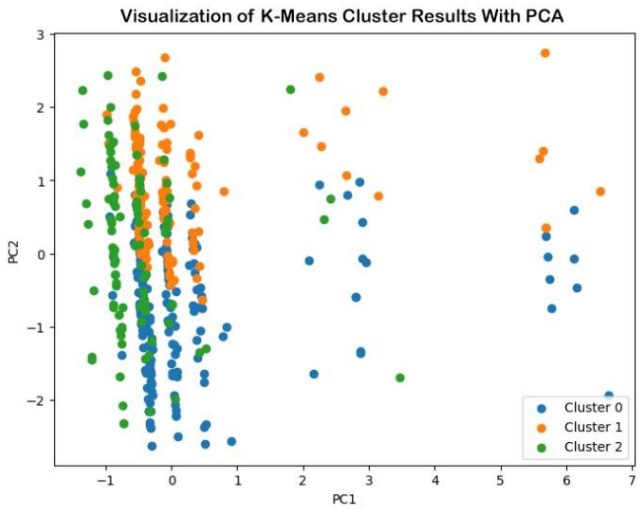

Figure 1. Visualization of Cluster Analysis Results

In the mean section, Gender can be categorized as majority male if the mean > 0.5, and majority female if ≤ 0.5. Age can be divided into young (<30), adult (30-50), and elderly (>50) categories. Address was classified as city-dominant if the mean was close to 0, and county-dominant if higher. History of Drug Use showed new patients if the mean ≤ 1, and patients with a history if more than 1. History of Resistance and Therapy Administered could be categorized as the majority did not experience resistance/therapy if the mean ≈ 0, and some experienced if the mean > 0. Side Effects and Comorbidities showed that if the mean = 1, all

patients experienced it, while if the mean = 0, patients did not experience it. Meanwhile, Survival is categorized as low if the mean is close to 0 if many survive and 1 if many do not survive (see Table 2).

Table 2
Description of Analysis Cluster

Cluster	Variable	Count	Mean	Std	Min	25%	50%	75%	Max
0	Gender	219	0.635	0.483	0	0	1	1	1
	Age	219	45.37	18.31	9	28	50	58	79
	Address	219	0.493	0.875	0	0	0	1	4
	Impression	219	0.0	0.0	0	0	0	0	0
	Grade Based on Drug Use History	219	1.566	0.834	0	1	1	2	4
	Resistance History	219	0.064	0.245	0	0	0	0	1
	Therapy Administered	219	0.064	0.245	0	0	0	0	1
	Side Effects	219	1.0	0.0	1	1	1	1	1
	Comorbidities	219	0.0	0.0	0	0	0	0	0
	Survival	219	0.041	0.199	0	0	0	0	1
1	Gender	150	0.620	0.487	0	0	1	1	1
	Age	150	52.21	13.02	18	44.25	53.5	62	78
	Address	150	0.773	1.216	0	0	0	2	5
	Impression	150	0.0	0.0	0	0	0	0	0
	Grade Based on Drug Use History	150	1.533	0.849	0	1	1	2	4
	Resistance History	150	0.073	0.262	0	0	0	0	1
	Therapy Administered	150	0.053	0.225	0	0	0	0	1
	Side Effects	150	1.0	0.0	1	1	1	1	1
	Comorbidities	150	1.0	0.0	1	1	1	1	1
	Survival	150	0.047	0.212	0	0	0	0	1
2	Gender	98	0.622	0.487	0	0	1	1	1
	Age	98	48.58	16.40	0	38.25	52	61	78
	Address	98	0.653	1.066	0	0	0	1.75	5
	Impression	98	0.0	0.0	0	0	0	0	0
	Grade Based on Drug Use History	98	1.520	0.911	0	1	1	2	4
	Resistance History	98	0.020	0.142	0	0	0	0	1
	Therapy Administered	98	0.020	0.142	0	0	0	0	1
	Side Effects	98	0.0	0.0	0	0	0	0	0
	Comorbidities	98	0.429	0.497	0	0	0	1	1
	Survival	98	0.122	0.329	0	0	0	0	1

DISCUSSION

Tuberculosis is a life-threatening infectious disease caused by Mycobacterium tuberculosis, and timely diagnosis and effective treatment are essential for its control (13). Treatment of tuberculosis requires adjustment in special circumstances, such as Crohn's disease and other circumstances (14). Grouping patients into subgroups can guide prioritization and determine the provision of intensive care (15). From the research conducted in the hospital, 467 patient data were obtained from the patient's medical record of 467 and processed using the K-Means algorithm.

In Cluster 0, which was dominated by younger patients (mean <45 years, including adolescents) without comorbidities but experiencing adverse effects of therapy, tuberculosis infection in children and adolescents is influenced by factors such as case characteristics, contact traits, and environmental determinants, and TBC preventive treatment is recommended to reduce the risk of disease progression (16). Individuals of productive age (ages 15-49) are particularly susceptible to tuberculosis, with 96% affected by the disease, and high school education is associated with higher risk (17). Children most commonly acquire TBC infection after exposure to adults with infectious TBC disease, with a high risk of disease progression and death (18). Children can contract TBC due to poor implementation of preventive therapy in those with latent infection, contacts, and people living with HIV and AIDS in most developing countries (19). Those with immunodeficiency have a higher risk of progression of TBC infection to TBC disease, and concurrent infections with viruses, bacteria, fungi, and protozoa can influence this risk (20). Prevention can focus on optimizing drug side effect monitoring through intensive patient education. Information on the early signs of serious side effects needs to be clearly communicated, followed by a rapid reporting system to healthcare professionals. In addition, early screening to adjust drug doses based on the patient's weight and clinical status can help reduce side effects.

In Cluster 1, patients tend to be older (mean age >52 years) with a high prevalence of comorbidities and continue to experience adverse effects of therapy. Elderly patients with pulmonary tuberculosis are vulnerable, with high mortality and challenging diagnosis, and tertiary referral hospitals with expertise in TBC management can improve treatment outcomes (21). Elderly people are more susceptible to TB due to factors such as decreased lung function, premature aging, inflammation, drug side effects, low tolerance to anti-TBC drugs, and age-related comorbidities (22). Elderly patients with pulmonary tuberculosis experience increased mortality during treatment and more frequent adverse effects, even when pyrazinamide was often avoided (23). This is compounded by the presence of comorbidities such as diabetes, hypertension, and HIV in patients. Comorbidities, especially diabetes and chronic respiratory diseases, may delay treatment response and require continued treatment for a successful outcome in TBC patients (24). In addition, multimorbidity is common among TBC patients (25). Early detection of comorbidities of diabetes, hypertension, and HIV in TBC patients is important, as the prevalence of these conditions is high and their associated risk factors are significant. TB patients with diabetes mellitus or depression have a higher risk of death, relapse, and recurrence, and their comorbidities may negatively accrue in a synergistic manner (26). In addition, high blood pressure in TB patients leads to increased mortality. People with TB and HIV need to be vigilant because HIV increases the risk of TB infection and disease progression, and TB slows CD4 recovery and increases progression to AIDS and death among the HIV-infected (27). Preventive measures include comprehensive comorbidity management, such as control of chronic diseases (hypertension or diabetes) to reduce complications. Drug therapy should be selected with consideration of drug interactions, and a multidisciplinary approach involving internal medicine specialists or clinical pharmacologists is required. Patient education regarding the importance of medication adherence also needs to be strengthened to prevent drug resistance.

In Cluster 2, which includes patients with a mean age of 48 years with moderate comorbidities and low risk of drug resistance, prevention can focus on early detection of comorbidities through routine screening programs. TBC screening can improve diagnosis, treatment outcomes (28). Pharmacist intervention in screening tests for comorbidities in at-risk patients allows early detection and prompt treatment, preventing serious health consequences (29). Education on healthy lifestyles, such as a balanced diet, exercise, and cessation of bad habits such as smoking, can reduce the burden of future comorbidities. In addition, supervision of appropriate drug use should be strengthened to prevent the emergence of resistance in the future. Multilevel interventions are needed to address the unique challenges of TBC treatment adherence among children and adolescents/young adults, which are influenced by structural, community, health system, household, and individual factors (30).

Based on the analysis of the three patient clusters, the recommendations for health workers, especially pharmacists, involve a specific approach for each group. In Cluster 0, focus should be on intensive education on monitoring drug side effects and early detection of serious signs to prevent complications. In Cluster 1, priority is given to comorbidity management through multidisciplinary collaboration, such as diabetes, hypertension, and HIV control, and therapy selection that considers drug interactions. For Cluster 2, prevention through routine screening programs and healthy lifestyle

education needs to be enhanced to reduce the risk of future comorbidities and resistance. This approach aims to improve patients' quality of life and overall therapeutic success.

Intervention strategies obtained can be carried out with an approach to each cluster. In Cluster 1, which includes older patients with high comorbidities, chronic disease management is a priority with regular comorbidity checks by doctors, close monitoring of treatment by nurses, and pharmacist consultations on potential drug interactions. Meanwhile, Cluster 2, which has the highest mortality rate and moderate comorbidity levels, requires an intensive risk-based approach, such as closer supervision of therapy by doctors, monitoring of side effects and clinical conditions by nurses, and special education by pharmacists to ensure patients understand the importance of adherence. This multidisciplinary collaboration can improve the effectiveness of treatment and optimize care outcomes in each cluster.

In the future, researchers may look into ways to lower the side effects of TB drugs in young patients using pharmacogenetic approaches and non-drug interventions. They may also look into how to manage TB and other health problems in older patients. In addition, exploration of socioeconomic influences, digital monitoring technologies, and predictive biomarkers may provide new insights to improve the success of TB therapy in a holistic manner.

CONCLUSION

K-Means clustering analysis shows that TB patients with comorbidities in Gorontalo city hospital have diverse characteristics, requiring a customized approach for each group. Cluster 0 requires attention to side effect monitoring and intensive education, Cluster 1 requires comprehensive comorbidity management and strengthening of treatment adherence, while Cluster 2 focuses on prevention through routine screening and promotion of healthy lifestyles. These recommendations highlight the importance of a multidisciplinary role, including pharmacists, in supporting more effective therapy and improving TB patient outcomes.

CONFLICT OF INTEREST

All authors declare there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The contributions of each author are as follows: MHW was responsible for conceptualization, methodology, software, and writing; SNA contributed to data curation and writing; AFH handled visualization; ED focused on reviewing and editing; WS contributed to reviewing; and SS was involved in reviewing and editing.

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