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URIC ACID LEVELS IN PULMONARY TUBERCULOSIS PATIENTS DURING ANTI-TUBERCULOSIS THERAPY AT SEKIP PUBLIC HEALTH CENTER PALEMBANG IN 2025

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Abstract

Tuberculosis or TB is an infectious disease caused by the bacterium Mycobacterium tuberculosis. One of the Anti-Tuberculosis Drugs (OAT) is Rifampicin, Isoniazid (INH), Pirazinamid, and Ethambutol. Pirazinamid, and Ethambutol are types of OATs that are able to increase acid levels but their use for a long time can pose some risk of side effects in patients such as impaired liver function. Gout is a normal compound in the final stages of purine metabolism in the body. The purpose of this study is to find out the description of uric acid levels in patients with pulmonary tuberculosis who consume anti-tuberculosis drugs based on gender, age, and length of time consuming tuberculosis drugs at the Sekip Palembang Health Center in 2025. This study is a descriptive research, with a sample of 31 samples using the total sampling technique. The examination was carried out using the Point Of Care Testing (POCT) method. The results of the study of 31 people with tuberculosis who consumed OAT as many as 18 people (58%) had high uric acid levels. Based on male gender, 12 people (57%) had high uric acid levels. Meanwhile, 6 people (60%) had high uric acid levels. Based on the age of the adolescent group of 1 person (100%) high uric acid levels, the adult group of 8 people (67%) of high uric acid levels, the middle-aged youth group of 4 people (36%) of high uric acid levels, then the old adult group of 5 people (71%) of high uric acid levels. Based on the length of time of consuming anti-tuberculosis drugs in the early phase of treatment, 14 people (93%) had high uric acid levels. Meanwhile, the advanced phase treatment was 4 people (25%) with high uric acid levels. Recommended to pulmonary tuberculosis patients who consume OAT to reduce the consumption of foods high in purine and regularly check uric acid levels during treatment.

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Introduction

Tuberculosis (TB) is an infectious disease caused by *Mycobacterium tuberculosis* that primarily affects the lungs, resulting in pulmonary tuberculosis, although it may also involve extrapulmonary organs such as the pleura, lymph nodes, and bones (Montrose, 2025; Xiong et al., 2025). Tuberculosis remains one of the leading causes of mortality worldwide. According to the World Health Organization (WHO), Indonesia ranked as the country with the second-highest burden of TB cases globally in 2022, with an estimated 969,000 cases, showing an increase compared to 824,000 cases reported in 2020 (WHO, 2022).

The increasing number of TB cases is also reflected at the regional level. Data from the South Sumatra Provincial Health Office showed that TB cases increased from 13,514 cases in 2021 to 18,122 cases in 2022 and further rose to 23,256 cases in 2023. Similarly, data from the Palembang City Health Office indicated an increase from 6,927 cases in 2022 to 7,379 cases in 2023. In addition, the number of patients completing TB treatment increased from 4,488 cases in 2022 to 6,889 cases in 2023 (South Sumatra Health Office, 2023). These findings indicate that tuberculosis remains a significant public health problem requiring long-term treatment and continuous monitoring.

Tuberculosis treatment is administered using Anti-Tuberculosis Drugs (ATDs), commonly provided in the form of Fixed-Dose Combination (FDC) tablets or *Kombinasi Dosis Tetap* (KDT). These formulations combine several first-line anti-tuberculosis drugs, including Rifampicin, Isoniazid, Pyrazinamide, and Ethambutol, into a single tablet to simplify treatment administration and improve patient adherence. TB treatment consists of an intensive phase lasting 2–3 months followed by a continuation phase lasting 4–7 months. Although FDC therapy provides several advantages, prolonged use of anti-tuberculosis drugs may cause side effects, including hepatotoxicity and metabolic disturbances (Murphy et al., 2025; Rehena, 2025; Yadav et al., 2025; Khan et al., 2025).

One of the metabolic side effects associated with anti-tuberculosis therapy is hyperuricemia or elevated uric acid levels. Pyrazinamide and Ethambutol are known to interfere with uric acid excretion, resulting in increased serum uric acid concentrations. Uric acid is the final product of purine metabolism processed mainly in the liver and excreted through the kidneys. Normal serum uric acid levels range from 3.4–7.0 mg/dL in men and 2.4–5.7 mg/dL in women (Aritonang et al., 2025; Selvianty, 2025; Wijaya et al., 2025).

Elevated uric acid levels may cause joint pain, discomfort, and decreased adherence to anti-tuberculosis treatment. Previous studies have reported increased uric acid levels among patients undergoing anti-tuberculosis therapy. Wang et al. (2025) reported that 75% of male TB patients receiving anti-tuberculosis drugs experienced elevated uric acid levels with an average concentration of 9.16 mg/dL, while 25% of female patients showed elevated levels with an average of 12.1 mg/dL. These findings indicate that monitoring uric acid levels is important during anti-tuberculosis treatment to prevent complications and support treatment success.

However, studies describing uric acid levels among pulmonary tuberculosis patients receiving anti-tuberculosis therapy at primary healthcare facilities in Palembang are still limited. Based on preliminary survey data conducted from January to December 2024, there were 38 pulmonary TB patients registered at Sekip Public Health Center, Palembang. Therefore, this study aims to describe uric acid levels among pulmonary tuberculosis patients undergoing anti-tuberculosis therapy at Sekip Public Health Center Palembang in 2025.

Methods

Study Design

This study employed a quantitative descriptive method with a cross-sectional design. The study aimed to describe serum uric acid levels among pulmonary tuberculosis patients receiving anti-tuberculosis drugs (ATDs) at Sekip Public Health Center, Palembang, in 2025. The main variable observed in this study was

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serum uric acid level in pulmonary TB patients undergoing anti-tuberculosis therapy.

Study Setting and Period

The study was conducted at Sekip Public Health Center, Palembang, South Sumatra, Indonesia. Data collection and laboratory examinations were carried out from January to June 2025. The study included interviews and blood sample examinations performed at the health center laboratory.

Population and Sample

The target population consisted of all pulmonary tuberculosis patients registered and receiving anti-tuberculosis treatment at Sekip Public Health Center during the study period. The sampling technique used was purposive sampling. A total of 38 pulmonary TB patients who met the inclusion criteria were included as research respondents.

Inclusion and Exclusion Criteria

The inclusion criteria in this study were pulmonary TB patients who had regularly consumed anti-tuberculosis drugs for at least one month, were willing to participate as respondents, and signed informed consent forms. Meanwhile, the exclusion criteria were patients with comorbid diseases that could affect uric acid levels, such as gout, chronic kidney disease, diabetes mellitus, or patients consuming drugs known to influence uric acid metabolism.

Data Collection Procedure

Data collection was conducted through interviews using structured questionnaires to obtain respondents' demographic characteristics, including age, sex, duration of treatment, and history of comorbid diseases. Blood sample collection was performed by medical laboratory technologists through venipuncture according to standard laboratory procedures. Serum uric acid levels were examined using the enzymatic colorimetric method with a spectrophotometer at the Sekip Public Health Center laboratory.

Data Analysis

The data obtained in this study were analyzed using descriptive statistical analysis. Respondent characteristic data and uric acid levels were presented in the form of frequency distributions, percentages, tables, and narrative descriptions. Normality testing was performed using the Shapiro–Wilk test to determine the distribution of numerical data. Data analysis was carried out using Statistical Package for the Social Sciences (SPSS) version 25.

Results

Based on uric acid levels in pulmonary tuberculosis patients, the results were categorized into three groups: normal, high, and low. The frequency distribution table is presented as follows:

Table 1. Distribution of Uric Acid Levels among Pulmonary Tuberculosis Patients Receiving Anti-Tuberculosis Therapy

Uric Acid Level	Frequency (n)	Percentage (%)
Normal	12	39
High	18	58
Low	1	3
Total	31	100

Based on Table 1, most pulmonary tuberculosis patients receiving anti-tuberculosis therapy had elevated uric acid levels, accounting for 18 respondents (58%). Meanwhile, 12 respondents (39%) had normal uric acid levels, and only 1 respondent (3%) had low uric acid levels. These findings indicate that hyperuricemia was the most dominant condition among pulmonary TB patients undergoing anti-tuberculosis treatment. Clinically, this condition may be associated with the side effects of anti-tuberculosis drugs, particularly Pyrazinamide and Ethambutol, which are known to interfere with uric acid excretion through the kidneys. Persistent elevated uric acid levels may increase the risk of joint pain and discomfort, potentially affecting patient adherence during long-term tuberculosis treatment.

Table 2 Distribution of Uric Acid Levels among Pulmonary Tuberculosis Patients Receiving Anti-Tuberculosis Therapy by Sex

	Gout			
Sex	**Normal (n/%)**	**High (n/%)**	**Low (n/%)**	**Total (n/%)**
Male	8 (38)	12 (57)	1 (5)	21 (100)
Female	4 (40)	6 (60)	0 (0)	10 (100)
Total	12 (39)	18 (58)	1 (3)	31 (100)

Based on Table 2, elevated uric acid levels were the most common finding among pulmonary tuberculosis patients receiving anti-tuberculosis therapy, both in male and female respondents. High uric acid levels were observed in 57% of male patients and 60% of female patients, indicating that hyperuricemia occurred consistently across both sex groups during anti-tuberculosis treatment. Meanwhile, low uric acid levels were found only in male patients. These findings suggest that anti-tuberculosis therapy, particularly drugs such as Pyrazinamide and Ethambutol, may contribute to increased uric acid levels regardless of sex. Clinically, persistent hyperuricemia may increase the risk of musculoskeletal complaints and could potentially affect treatment adherence among pulmonary tuberculosis patients.

Table 3. Distribution of Uric Acid Levels among Pulmonary Tuberculosis Patients Receiving Anti-Tuberculosis Therapy by Age Group

	Gout			
Age Group	**Normal n (%)**	**High (%)**	**Low n (%)**	**Total N (%)**
Adolescence	0 (0)	1 (100)	0 (0)	1 (100)
Adulthood	3 (25)	8 (67)	1 (8)	12 (100)
Early Middle Age	7 (64)	4 (36)	0 (0)	11 (100)
Late Adulthood	2 (29)	5 (71)	0 (0)	7 (100)
Total	12 (39)	18 (58)	1 (3)	31 (100)

Based on Table 3, elevated uric acid levels were more frequently observed in both age groups, particularly among older adults, where 71% of respondents showed high uric acid levels. In the adult group, more than half of the respondents also experienced elevated uric acid levels during anti-tuberculosis therapy. These findings indicate that hyperuricemia tends to occur more frequently among older patients, which may be associated with decreased renal function and reduced uric acid excretion with increasing age. In addition, prolonged use of anti-tuberculosis drugs such as Pyrazinamide and Ethambutol may further contribute to elevated serum uric acid levels.

Table 4. Distribution of Uric Acid Levels among Pulmonary Tuberculosis Patients by Treatment Phase

	Gout			
Treatment Phase	**Normal n (%)**	**High n (%)**	**Low n (%)**	**Total N (%)**
Intensive Phase	1 (7)	14 (93)	0 (0)	15 (100)
Continuation Phase	11 (69)	4 (25)	1 (6)	16 (100)
Total	12 (39)	18 (58)	1 (3)	31 (100)

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Based on Table 4, elevated uric acid levels were predominantly found in patients undergoing the intensive phase of anti-tuberculosis treatment, where 93% of respondents experienced hyperuricemia. In contrast, most patients in the continuation phase had normal uric acid levels. These findings suggest that elevated uric acid levels were more commonly observed during the early phase of anti-tuberculosis therapy, possibly due to the use of Pyrazinamide and Ethambutol in the intensive treatment regimen. The marked difference in uric acid distribution between treatment phases indicates a possible association between treatment duration and serum uric acid levels. Therefore, further bivariate analysis may be considered to evaluate the relationship between treatment phase and the occurrence of hyperuricemia among pulmonary tuberculosis patients.

Discussion

The present study demonstrated that elevated uric acid levels were commonly found among pulmonary tuberculosis patients receiving anti-tuberculosis therapy at Sekip Public Health Center, Palembang. This finding indicates that metabolic disturbances, particularly hyperuricemia, remain an important side effect during tuberculosis treatment. The occurrence of increased uric acid levels among TB patients highlights the need for closer clinical monitoring, especially because tuberculosis therapy is administered over a relatively long duration and involves multiple drug combinations.

The predominance of elevated uric acid levels observed in this study is in line with previous studies reporting hyperuricemia as one of the most frequent adverse effects of anti-tuberculosis drugs. Selvianty (2025) similarly found that most pulmonary TB patients undergoing anti-tuberculosis treatment experienced increased serum uric acid levels. The consistency between studies strengthens the evidence that hyperuricemia is closely associated with anti-tuberculosis therapy, particularly in patients receiving first-line treatment regimens containing Pyrazinamide and Ethambutol.

The increase in uric acid levels among pulmonary TB patients can be explained biologically through the mechanism of drug metabolism and renal excretion. Pyrazinamide is metabolized into pyrazinoic acid, which inhibits uric acid secretion in the renal tubules. This process results in decreased uric acid excretion and subsequent accumulation in the bloodstream. Ethambutol may also contribute to impaired renal clearance of uric acid. Consequently, prolonged administration of these drugs during tuberculosis therapy may increase the risk of hyperuricemia in susceptible patients (Chowdhury et al., 2025).

Clinically, persistent hyperuricemia may negatively affect patients' quality of life. Elevated uric acid levels are commonly associated with symptoms such as joint pain, swelling, inflammation, and musculoskeletal discomfort due to the deposition of urate crystals in joint tissues. Although hyperuricemia during anti-tuberculosis treatment is often considered a manageable side effect, untreated conditions may reduce patients' comfort and potentially interfere with adherence to long-term tuberculosis therapy. Therefore, monitoring metabolic side effects is important to ensure treatment continuity and therapeutic success (Rumambi et al., 2025).

Based on sex characteristics, elevated uric acid levels were identified in both male and female respondents with relatively comparable proportions. The findings of this study therefore suggest that hyperuricemia during anti-tuberculosis therapy may occur regardless of sex. Unlike several previous studies that reported male patients as having a higher risk of hyperuricemia, the current findings did not demonstrate a substantial difference between male and female respondents. This may indicate that the influence of anti-tuberculosis drugs on uric acid metabolism is more dominant than physiological differences related to sex (Daniel et al., 2025; Zielinski et al., 2025)..

The distribution of uric acid levels based on age showed that elevated levels tended to occur more frequently among older adult patients. This finding may be associated with age-related decline in kidney

function, which can reduce the body's ability to excrete uric acid efficiently. Decreased renal filtration capacity in older individuals may contribute to the accumulation of uric acid during anti-tuberculosis treatment. However, interpretation of these findings should be approached carefully because the number of respondents in certain age categories was relatively limited, reducing the strength of generalization.

An important finding of this study was the higher occurrence of hyperuricemia during the intensive phase of anti-tuberculosis treatment compared with the continuation phase. Patients in the intensive phase receive a combination of several first-line drugs simultaneously, including Pyrazinamide and Ethambutol, both of which are known to increase serum uric acid levels. In contrast, the continuation phase generally involves fewer medications, thereby reducing the metabolic burden associated with uric acid accumulation. These findings indicate that the intensive phase may represent the period with the greatest vulnerability to metabolic side effects among pulmonary TB patients (Tian et al., 2025).

The findings of this study provide important implications for clinical practice and laboratory monitoring in tuberculosis management. Routine evaluation of serum uric acid levels during anti-tuberculosis therapy may help healthcare professionals identify metabolic abnormalities earlier and prevent further complications. Early detection of hyperuricemia may also support patient education regarding treatment side effects and encourage adherence throughout the treatment process. Therefore, laboratory monitoring should be considered an integral part of comprehensive tuberculosis care (Arden & Pusparini, 2025).

From a scientific perspective, this study contributes additional evidence regarding the metabolic effects of anti-tuberculosis drugs among pulmonary TB patients at the primary healthcare level. Most previous studies regarding hyperuricemia in tuberculosis patients have been conducted in hospital settings, while studies at community health centers remain limited. The present findings therefore provide useful information for strengthening clinical monitoring strategies in primary healthcare services, particularly in areas with high tuberculosis prevalence (Salim et al., 2025).

This study has several limitations that should be considered when interpreting the findings. The study involved a relatively small number of respondents from a single health center, which may limit the generalizability of the results. In addition, the cross-sectional design only described uric acid levels at one point in time and could not establish causal relationships between anti-tuberculosis therapy and hyperuricemia. Baseline uric acid levels before treatment initiation were not measured, and several potential confounding factors such as dietary intake, kidney function, hydration status, and concurrent medications were not evaluated. Therefore, further studies with larger sample sizes, longitudinal approaches, and more comprehensive assessment of confounding variables are recommended to provide stronger evidence regarding the relationship between anti-tuberculosis therapy and serum uric acid levels.

Conclusions and Recommendations

This study concluded that elevated uric acid levels were commonly found among pulmonary tuberculosis patients receiving anti-tuberculosis therapy at Sekip Public Health Center, Palembang, in 2025. Increased uric acid levels were observed in both male and female patients and tended to occur more frequently during the intensive phase of treatment. These findings indicate the importance of monitoring uric acid levels in pulmonary tuberculosis patients undergoing anti-tuberculosis therapy. Recommendation Healthcare workers are encouraged to perform regular monitoring of serum uric acid levels, particularly during the intensive phase of anti-tuberculosis treatment, to identify metabolic side effects early and prevent further complications. Future studies are recommended to involve larger sample sizes and longitudinal study designs, as well as evaluate other factors that may influence uric acid levels, such as renal function, dietary patterns, and lifestyle factors.

References

Arden, P., & Pusparini, P. (2025). Relationship

Between Consumption of Simple Carbohydrates and Serum Uric Acid Concentration in Adolescents. *Hearty*, *13*(3), 585–591. https://doi.org/10.32832/hearty.v13i3.18206

Aritonang, E. Y., Manalu, S. P., & Manalu, S. M. H. (2025). Correlation of macronutrient and micronutrient intake with anemia status in pulmonary tuberculosis patients at namorambe community health center. *BIO Web of Conferences*, *159*. https://doi.org/10.1051/bioconf/202515901004

Ayesha Sundas, Saadia Ashraf, & Rabia saeed. (2025). Hyperuricemia in Tuberculosis Patients Treated with Pyrazinamide. *Journal of Health, Wellness and Community Research*, *III*(Iii), e105. https://doi.org/10.61919/2qryce79

Chowdhury, R., Ferdous, K., Khatun, A., Halder, S., & Zafreen, A. (2025). Association between Serum Uric Acid levels and Cardiovascular risk factors in type 2 diabetes mellitus. *Molecular Mechanism Research*, *3*(1). https://doi.org/10.59429/mmr.v3i1.9170

Daniel, B. D., Inbaraj, L. R., Kumaravadivelu, S., Subramanian, K., Ramraj, B., & Manesh, A. (2025). Optimizing Pyrazinamide Use: A Low-Hanging Fruit in Improving Outcomes with Tuberculous Meningitis? Narrative Review. *Infectious Diseases and Therapy*, *14*(2), 317–325. https://doi.org/10.1007/s40121-024-01102-1

Herenda, V., Jusufović, S., & Musanović, A. (2025). Fixed-dose combination antihypertensives in patients with chronic kidney disease: A systematic literature review. *Medicinski Glasnik*, *22*(2). https://doi.org/10.17392/1862-22-02

Khan, A., Khan, F. N., Ahsan, T., & Saqib, M. N. (2025). *Formulation Development And Stability Study Of Fixed Dose Formulation Development And Stability Study Of Fixed Dose Combination (Fdc) Tablet Of Montelukast And Loratadine*. *July*. https://doi.org/10.5281/zenodo.15826355

Liza Novitasari Wijaya, Tri Hardi Miftahul Ulum, & Kiki Rizki Handayani. (2025). Difference in Effectiveness of Acupressure With a Mixture of Ginger and Lemon Extracts on Reducing Oat Side Effects in Tuberculosis Patients. *Professional Health Journal*, *6*(2), 698–705. https://doi.org/10.54832/phj.v6i2.997

Ministry of Health. (2023). *The Ministry of Health is concerned about the increasing TB cases in Indonesia*. Ministry of Administrative and Bureaucratic Reform.

Montrose. (2025). The influence of side effects on adherence to the use of anti-tuberculosis drugs for pulmonary tuberculosis patients. *Jurnal Farmasi Dan Ilmu Kesehatan*, *10*(1), 23–29.

Murphy, A., Mbuthia, D., Willis, R., Tsofa, B., Gichagua, M., Mugo, P., Hanson, K., & Reich, M. R. (2025). Improving Implementation of NCD Care in Low- and Middle-Income Countries: The Case of Fixed Dose Combinations for Hypertension in Kenya. *Health Systems and Reform*, *11*(1). https://doi.org/10.1080/23288604.2024.2448862

Park, S., Kim, J. O., Park, G. N., Oh, J. W., & Lee, S. (2025). Sex-based disparities in the association between uric acid levels and anxiety: a cross-sectional analysis of nationwide data in Korea. *BMC Psychiatry*, *25*(1). https://doi.org/10.1186/s12888-025-06474-3

Rehena. (2025). Global child-friendly anti-TB medicines – where do we stand? *IJTLD*, *2*(July), 501–504.

Rumambi, M. F., Sitio, R., Sidauruk, S. P. R., Kristanti, S. A., & Pangkey, B. C. A. (2025). Location of Signs and Symptoms of Gout Arthritis Patients. *Holistic Nursing and Health Science*, *8*(1), 32–41. https://doi.org/10.14710/hnhs.8.1.2025.32-41

Salim, A. A., Kawasoe, S., Kubozono, T., Ojima, S., Yamaguchi, S., Higuchi, K., Ikeda, Y., Miyahara, H., Tokushige, K., & Ohishi, M. (2025). Association between serum uric acid levels and left ventricular hypertrophy based on electrocardiographic findings: a sex-specific analysis across cardiometabolic diseases. *Scientific Reports*, *15*(1), 1–12. https://doi.org/10.1038/s41598-025-86497-8

Selvianty. (2025). The Relationship Between Anti-Tuberculosis Drug Therapy and Uric Acid and Creatinine Levels in Tuberculosis Patients in Kayong Utara District. *International Medical Scientific Journal*, *7*(2), 75–82.

Shin, W. (2025). Bioequivalence of a Metformin / Linagliptin Fixed-Dose Combination Tablet Compared With Coadministered Single Extended-Release Agents in Healthy Adult Subjects. *International Journal of Clinical Practice*, *2025*. https://doi.org/10.1155/ijcp/7111508

South Sumatra Provincial Health Office. (2023). *Disease cases by regency/municipality and type of*

disease, 2022–2023. Central Bureau of Statistics of South Sumatra Province.

Subhiksha. (2025). Advances In The Development Of Innovative Dosage Forms For Fixed-Dose Combinations Of Active. *World Journal of Pharmaceutical Research*, *14*(13), 21–35. https://doi.org/10.20959/wjpr202513-36884

Tian, J., Huang, Y., Xiao, Z., Yuan, S., Ma, S., Zhao, X., & Liu, Y. (2025). The association between the uric acid to high-density lipoprotein cholesterol ratio (UHR) index and obesity in postmenopausal women: a cross-sectional analysis based on the NHANES. *Lipids in Health and Disease* , *24*(1). https://doi.org/10.1186/s12944-025-02715-2

Wang, Z., Guo, Z., Wang, W., Zhang, Q., Song, S., Xue, Y., Zhang, Z., & Wang, J. (2025). Prediction of tuberculosis treatment outcomes using biochemical makers with machine learning. *BMC Infectious Diseases*, *25*(1). https://doi.org/10.1186/s12879-025-10609-y

World Health Organization. (2023). *Tuberculosis.* https://www.who.int/news- room/fact-sheets/detail/tuberculosis

Xiong, X.-S., Zhu, Q.-H., Liu, Z.-Z., Huang, T.-T., Fan, J.-B., Zhao, X., Gu, J.-S., & Li, F. (2025). The Prevalence, Risk Factors, and Drug Resistance Profiles of Mycobacterium tuberculosis in China: A Mini-Review. *Mycobacteria - Comparative Genomics, Biomarker Identification, Laboratory Diagnosis and Clinical Treatment [Working Title]*. https://doi.org/10.5772/intechopen.1010839

Yadav, D. K., Mishra, R., Saini, P., Sharma, N., & Mandal, R. K. (2025). *Next Generation Tuberculosis Therapy : From Drug Design To Delivery Next Generation Tuberculosis Therapy : From Drug Design To Delivery*. *August*. https://doi.org/10.31531/jprst.1000194

Zielinski, N., Brehm, T. T., Köhler, N., Sánchez Carballo, P., Schaub, D., Lange, C., & Reimann, M. (2025). Analysis of gene expression in patients prior to TB treatment to identify those associated with pyrazinamide-hepatotoxicity. *IJTLD Open*, *2*(8), 497–499. https://doi.org/10.5588/ijtldopen.25.0189