RESEARCH PAPER

PATTERN OF ANEMIA IN PULMONARY TUBERCULOSIS PATIENTS IN TERTIARY CARE CENTER

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ABSTRACT

Background

Anaemia is one of the most common hematological abnormalities observed in patients with pulmonary tuberculosis (PTB). It results from a combination of chronic inflammation, altered iron metabolism, nutritional deficiencies, and impaired erythropoiesis. The present study was conducted to evaluate the prevalence and pattern of anaemia among pulmonary tuberculosis patients attending a tertiary care centre.

Methods

This cross-sectional study was conducted in the Department of Medicine, MMIMSR, Mullana, Ambala, from November 2024 to May 2026. A total of 100 clinically and microbiologically diagnosed pulmonary tuberculosis patients were enrolled. Detailed clinical evaluation, hematological investigations, iron profile assessment, vitamin B12 estimation, reticulocyte studies, and radiological investigations were performed. Data were analysed using SPSS version 20, and a p-value <0.05 was considered statistically significant.

Results

The study population comprised 73% males and 27% females, with a mean age of 46.5 ± 14.2 years. Anaemia was present in 72% of patients, with mild anaemia being the most common (35%), followed by moderate (29%) and severe anaemia (8%). Normocytic normochromic anaemia was the predominant morphological type (63.89%), followed by hypochromic microcytic anaemia (26.39%) and mixed morphology anaemia (9.72%). Mean serum ferritin was elevated (438.71 ± 377.43 ng/mL), while serum iron and transferrin saturation were relatively reduced, suggesting a mixed pattern of anaemia of chronic disease and iron deficiency anaemia. Sputum-positive patients had significantly lower BMI compared to sputum-negative patients, indicating an association between undernutrition and disease severity. Vitamin B12 levels were largely within the normal range, and the mean reticulocyte production index was low, suggesting inadequate marrow response.

Conclusion

Anaemia is highly prevalent among patients with pulmonary tuberculosis, with anaemia of chronic disease being the predominant pattern. Iron deficiency and poor nutritional status contribute substantially to the burden of anaemia. Routine evaluation of haematological parameters and nutritional status should be incorporated into the management of tuberculosis patients for early identification and appropriate treatment of anaemia.

Keywords: Pulmonary tuberculosis, Anaemia, Anaemia of chronic disease, Iron deficiency anaemia, Ferritin, Nutritional status, Body mass index.

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Introduction:

Tuberculosis (TB) remains one of the most significant infectious diseases worldwide and continues to be a major public health challenge. Evidence suggests that Mycobacterium tuberculosis has affected humans since ancient times, with genetic studies indicating its existence for thousands of years [1]. According to the World Health Organization (WHO), TB continues to be among the leading causes of death from a single infectious agent. Although substantial progress has been achieved in TB control, high-burden countries continue to account for the majority of global cases. India bears the highest burden of TB worldwide and has reported a notable decline in

incidence in recent years as part of its intensified disease control efforts [2].

The COVID-19 pandemic adversely affected TB detection and management globally, contributing to disruptions in healthcare services and delays in diagnosis and treatment [3,4]. Despite these challenges, pulmonary tuberculosis (PTB) remains the most common form of the disease and is responsible for significant morbidity and mortality, particularly in developing countries [5]. Comorbid conditions such as diabetes, HIV infection, and malnutrition further worsen treatment outcomes and represent important barriers to achieving the goals of the WHO End TB Strategy [6,7].

Malnutrition and tuberculosis are closely interrelated conditions that frequently coexist in low- and middle-income countries. Active TB can result in reduced appetite, malabsorption of nutrients, altered metabolism, and progressive wasting, while malnutrition impairs immune function and increases susceptibility to infection [8]. Consequently, malnourished TB patients often experience delayed recovery and higher mortality compared with well-nourished individuals [8].

Tuberculosis is associated with several hematological abnormalities, including anemia, lymphopenia, neutrophilia, monocytosis, thrombocytopenia, and, less commonly, thrombocytosis [9]. Among these, anemia is one of the most frequent findings and may significantly contribute to disease-related morbidity. According to WHO criteria, anemia is defined as hemoglobin levels below 13.0 g/dL in men and below 12.0 g/dL in women, and it can be classified as mild, moderate, or severe based on hemoglobin concentration [10].

Anemia in TB patients is multifactorial and may result from chronic inflammation, nutritional deficiencies, impaired iron metabolism, and reduced erythropoiesis [11,12]. Anemia of chronic disease and iron-deficiency anemia are the most commonly reported forms [11]. A recent systematic review and meta-analysis demonstrated a dose-dependent relationship between anemia severity and the risk of tuberculosis, while also reporting a high prevalence of anemia among TB patients [13,14]. Previous studies from India and other developing countries have documented anemia prevalence ranging from approximately 70% to 86% among patients with tuberculosis [15].

The clinical significance of anemia in tuberculosis extends beyond its high prevalence. Studies have linked anemia with delayed sputum conversion, severe forms of disease, increased risk of recurrence, and higher mortality [16,17]. Iron metabolism appears to play an important role in this relationship. Both iron deficiency and iron overload can adversely affect immune function and disease progression. Excess iron may promote mycobacterial growth and impair host defense mechanisms, whereas iron deficiency can compromise cellular immunity and increase susceptibility to infection [18].

Despite growing evidence regarding the impact of anemia on tuberculosis outcomes, routine screening for anemia is not currently emphasized in international guidelines or the National TB Elimination Programme (NTEP). Understanding the pattern and severity of anemia among patients with pulmonary tuberculosis may facilitate early identification and appropriate management of this potentially modifiable comorbidity. Therefore, the present study was undertaken to evaluate the pattern of anemia in patients with pulmonary tuberculosis attending a tertiary care centre.

Karyadiet al. (2000) [19] highlighted the bidirectional relationship between tuberculosis and malnutrition. The authors reported that malnutrition increases susceptibility to tuberculosis, while active TB leads to appetite loss, malabsorption, and wasting, thereby contributing to nutritional deficiencies and anemia.

Sei Won Lee et al. (2006) [20] evaluated 880 tuberculosis patients and reported anemia in 31.9% cases at diagnosis. Normocytic normochromic anemia was the predominant morphological type. The authors observed that anemia improved in the majority of patients following anti-tubercular therapy (ATT), suggesting an inflammatory basis for anemia.

ParasappaJoteppaYaranal et al. (2013) [21] studied the hematological profile of pulmonary tuberculosis patients and found normocytic normochromic anemia to be the most common morphological pattern. Microcytic and macrocytic anemia were less frequently observed.

Tumaini J. Nagu et al. (2014) [16] investigated the relationship between anemia and sputum conversion among pulmonary tuberculosis patients. The study demonstrated that baseline anemia was associated with delayed sputum smear conversion after two months of ATT, indicating its potential role as a marker of disease severity.

Marina Gribel Oliveira et al. (2014) [22] reported a high prevalence of anemia of chronic disease among hospitalized pulmonary tuberculosis patients. Anemia was significantly associated with malnutrition, low BMI, elevated ferritin levels, and increased ESR.

Minchella et al. (2015) [23] assessed iron biomarkers in tuberculosis patients and observed that anemia of inflammation was the most common type at diagnosis. The prevalence of anemia of inflammation decreased markedly after six months of ATT, whereas iron deficiency-related anemia showed less improvement.

Bashir A. Bashir et al. (2015) [24] reported that anemia of chronic disease was the most frequent form of anemia among pulmonary tuberculosis patients, followed by iron deficiency anemia. The

authors emphasized the contribution of altered iron metabolism in TB-associated anemia.

Christophe Mbombo Mulenga et al. (2017) [25] found anemia in 69% of newly diagnosed pulmonary tuberculosis patients. Moderate anemia was the most common presentation, and nearly half of the patients demonstrated an iron-deficient pattern.

Sandhya Mishra et al. (2018) [26] evaluated iron metabolism in pulmonary tuberculosis and observed significantly lower serum iron and transferrin levels, along with higher ferritin and CRP levels. These findings supported the role of inflammation-mediated iron sequestration in TB-associated anemia.

Barzegari et al. (2019) [27], in a systematic review and meta-analysis, reported an overall anemia prevalence of 61.53% among tuberculosis patients. Mild, moderate, and severe anemia were observed in 35.67%, 31.19%, and 11.61% patients respectively. Anemia of chronic disease was more common than iron deficiency anemia.

Mukherjee et al. (2019) [28] evaluated newly diagnosed pulmonary tuberculosis patients and concluded that normocytic normochromic anemia was the most frequent hematological abnormality, recommending routine screening for anemia in all TB patients.

Sandeep Chhabra et al. (2021) [29] reported anemia in more than 85% of tuberculosis patients. Anemia of chronic disease accounted for the majority of cases and was strongly associated with malnutrition and elevated inflammatory markers.

Edson Beyker de Mendonça et al. (2021) [30] observed anemia in 61.2% of tuberculosis patients. Normocytic normochromic anemia was the predominant pattern, and anemia was significantly associated with severe forms of tuberculosis, including disseminated and meningeal disease.

Joseph Baruch Baluku et al. (2022) [31] reported anemia in 58.7% of pulmonary tuberculosis patients. Low BMI, immune suppression, and microcytosis were identified as significant predictors of anemia.

Mengxing Luo et al. (2022) [32] demonstrated that tuberculosis patients with anemia had greater pulmonary damage and poorer radiological improvement during treatment, suggesting that anemia may serve as a prognostic indicator.

Yasmeen Batool et al. (2022) [33] reported anemia in 82.6% of newly diagnosed pulmonary tuberculosis patients, making it the most common hematological abnormality observed in the study population.

YeshewasAbaynew et al. (2023) [34], through a systematic review and meta-analysis, reported a pooled anemia prevalence of 69% among African tuberculosis patients. Normocytic normochromic anemia and anemia of chronic disease were identified as the predominant patterns.

Chandra et al. (2023) [35] observed that the prevalence of anemia decreased from 63% at baseline to 44% after completion of ATT. Female gender, undernutrition, poverty, and low dietary iron intake were associated with persistence of anemia after treatment.

Ramanna Nataraja Hithaish Kumar et al. (2023) [36] reported anemia in 76.1% of newly diagnosed tuberculosis patients. Most cases were mild to moderate in severity, and substantial improvement was observed following completion of ATT.

Maryam Farhadian et al. (2024) [37], in a meta-analysis of hematological abnormalities in tuberculosis, reported anemia in 61.6% of newly diagnosed TB patients, reaffirming anemia as the most common hematological manifestation of the disease.

Aim and Objective: The present study aimed to determine the prevalence of anemia and assess its morphological pattern and severity in patients with pulmonary tuberculosis attending a tertiary care centre.

Material and methodology: This observational cross-sectional study was conducted in the Department of Medicine, Maharishi Markandeshwar Institute of Medical Sciences and Research (MMIMSR), Mullana, Ambala, from November 2024 to May 2026. A total of 100 patients clinically and microbiologically diagnosed with pulmonary tuberculosis were enrolled after obtaining approval from the Institutional Ethics Committee and informed consent from participants.

Inclusion Criteria

Patients with clinically and microbiologically confirmed pulmonary tuberculosis who provided informed consent were included in the study.

Exclusion Criteria

Patients with extrapulmonary tuberculosis, carcinoma lung, pregnancy or lactation, hemolyticanemia, acute or chronic blood loss, and chronic disorders known to affect hematological parameters, including chronic liver disease, chronic kidney disease, hypothyroidism, rheumatoid arthritis, and systemic lupus erythematosus, were excluded.

Data Collection

A detailed clinical history and physical examination were performed for all participants. Demographic and clinical data were recorded at the time of diagnosis. Hematological evaluation included hemoglobin estimation, red blood cell indices (MCV, MCH, MCHC), peripheral blood smear examination, reticulocyte count, reticulocyte production index, serum ferritin, iron profile, and vitamin B12 levels. Radiological investigations included chest X-ray and ultrasonography of the abdomen. Additional investigations such as hemoglobin electrophoresis, bone marrow examination, and high-resolution computed

tomography (HRCT) of the chest were performed whenever indicated.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS version 20. Quantitative variables were expressed as mean ± standard deviation or median with interquartile range, while qualitative variables were presented as frequencies and percentages. The Chi-square test and Student's t-test were used for statistical analysis as appropriate. A p-value <0.05 was considered statistically significant.

Results:

A total of 100 pulmonary tuberculosis patients were enrolled in the study. The majority of participants were male (73%), while females constituted 27% of the study population, demonstrating a male predominance as shown in Table 1.

Table 1: Gender distribution among patient study group

Gender	N	%
Female	27	27.0
Male	73	73.0
Total	100	100.0

Table 2 shows that the highest proportion of study participants belonged to the **>60 years age group (27%)**, followed by **41–50 years (19%)** and **51–60 years (18%)**. This indicates that pulmonary tuberculosis was more commonly observed among older adults in the present study population.

Table 2: Age distribution among patient study group

Age Group (in years)	N	%
≤30	19	19.0
31-40	17	17.0
41-50	19	19.0
51-60	18	18.0
>60	27	27.0
Total	100	100.0

As shown in Table 3, the most common presenting complaint among the study subjects was cough (79%), followed by breathlessness/shortness of breath (75%), fever (70%), and sputum production (35%).

Table 3: Chief complaints in patient Study group

Chief complaints	N=100	%
Cough	79	79.0
Breathlessness/SOB	75	75.0
Fever	70	70.0
Sputum Production	35	35.0

Our study also revealed that 41% of the study participants had no associated comorbidities. Among those with a positive past medical history, previous pulmonary tuberculosis was the most common condition, reported in 18% of subjects, followed by diabetes mellitus (7%) and hypertension (4%). A history of hepatitis C infection was noted in 1% of participants as shown in table 4. Patients with chronic kidney disease, chronic liver disease, hypothyroidism, rheumatoid arthritis, systemic lupus erythematosus, carcinoma lung, extrapulmonary tuberculosis, and hemolyticanemia were excluded as per the study criteria.

Table 4: Comorbidities associated in our study patient group

Past History	N=100	%
No history of any comorbidities	41	41.0
Tuberculosis (PTB)	18	18.0
Diabetes Mellitus	7	7.0
Hypertension	4	4.0
Multiple Comorbidities*	29	29.0
HCV	1	1.0

In our study we found that majority of patients (58%) were diagnosed on a clinico-radiological basis, using clinical presentation along with supportive imaging findings. The remaining 42% had microbiologically confirmed pulmonary tuberculosis based on sputum examination or other microbiological investigations as shown in table 5.

Table 5: Diagnostic Modality among study patient group

Diagnostic Modality	Basis	Number (n=100)	Percentage (%)
Microbiological Diagnosis	Sputum smear/ microbiological confirmation	42	42.0
Clinico-Radiological Diagnosis	Symptoms + clinical judgement +/- Chest X-ray / CT	58	58
Total	—	**100**	**100.0**

Our study revealed a high proportion of participants, 72%, were found to have anemia, while only 28% had normal hemoglobin levels. Mild anaemia was the most frequently observed category, affecting 35% of the study participants, followed by moderate anaemia in 29%. Severe anemia was comparatively less common and was present in 8% of the subjects as shown in table 6.

Table 6: Category wise distribution of Anemia in study patient group

Anemia	N	%
Mild Anemia	35	35.0

Moderate Anemia	29	29.0
Severe Anemia	8	8.0
Absent	28	28.0

The mean age of sputum-positive patients was 48.5 ± 13.0 years, compared to 46.2 ± 12.8 years among sputum-negative patients. Males constituted the majority in both groups, accounting for 31 of 42 sputum-positive cases and 42 of 58 sputum-negative cases. Additionally, sputum-positive patients had a lower mean BMI (19.2 ± 3.0 kg/m²) than sputum-negative patients (21.0 ± 3.2 kg/m²), indicating relatively poorer nutritional status among the former as shown in table 7.

Table 7: Diagnostic status (Sputum positive/ Sputum Negative) among study patient group

Diagnostic Status	Number of Subjects, N (%)	Mean Age (years) ± SD	Gender (Male/Female)	Mean BMI ± SD
Sputum Positive (Microbiological)	42 (42.0 %)	48.5 ± 13.0	31/11	19.2 ± 3.0
Sputum Negative (Clinico-radiological)	58 (58.0 %)	46.2 ± 12.8	42/16	21.0 ± 3.2
p value	100 (100.0 %)	0.08	0.06	0.04

Our study also revealed that the mean hemoglobin level of the study participants was 9.74 ± 1.63 g/dL (range: 5.40–12.10 g/dL), indicating a high burden of anemia. The mean MCV was 80.21 ± 11.41 fL (range: 56.90–96.20 fL), suggesting the presence of both microcytic and normocytic red cell patterns. The mean MCH and MCHC were 27.20 ± 6.31 pg (range: 18.70–64.20 pg) and 32.35 ± 2.40 g/dL (range: 20.70–37.30 g/dL), respectively, reflecting variability in hemoglobin content and concentration within red blood cells as shown in table 8.

Table 8: Biochemical parameters in our study patient group.

Variables	Minimum	Maximum	Mean	SD
Hb (gm/dl)	5.40	12.10	9.74	1.63
MCV	56.90	96.20	80.21	11.41
MCH	18.70	64.20	27.20	6.31
MCHC	20.70	37.30	32.35	2.40

Our study also found that the mean serum ferritin level was 438.71 ± 377.43 ng/mL (range: 32.30–2140.20 ng/mL), indicating markedly elevated ferritin levels in many patients, consistent with the inflammatory milieu associated with pulmonary tuberculosis. The mean serum iron level was 66.12 ± 31.49 mcg/dL (range: 8.94–131.90 mcg/dL), suggesting reduced circulating iron levels in a substantial proportion of subjects. Mean TIBC was 329.43 ± 116.33 mcg/dL (range: 92.00–496.50 mcg/dL), while mean transferrin saturation was 20.46 ± 9.19% (range: 4.75–40.70%). Overall, the iron profile demonstrated features of both anemia of chronic disease and iron deficiency anemia, reflecting the multifactorial nature of anemia among patients with pulmonary tuberculosis shown in table 9.

Table 9: Iron profile among study patient group

Variables	Minimum	Maximum	Mean	SD
S. Ferritin (ng/ml)	32.30	2140.20	438.71	377.43
S. Iron (mcg/dl)	8.94	131.90	66.12	31.49
TIBC (mcg/dl)	92.00	496.50	329.43	116.33
Transferrin sat. (%)	4.75	40.70	20.46	9.19

The mean vitamin B12 level was 428.75 ± 269.77 pg/mL (range: 120–1401.20 pg/mL), with the overall mean falling within the normal range. The mean reticulocyte count was 2.29 ± 0.55% (range: 0.80–3.11%). The mean reticulocyte production index (RPI) was 0.73 ± 0.24 (range: 0.17–1.22). All patients had an RPI <2.5, indicating an inadequate bone marrow response to anemia, while no evidence of a hyperproliferative marrow response was observed as depicted in table 10.

Table 10: Descriptive analysis of Vit B12 (pg/ml), Reticulocyte count (%) and RPI

Variables	Minimum	Maximum	Mean	SD
Vit B12 (pg/ml)	120	1401.20	428.75	269.77
Reticulocyte count (%)	0.80	3.11	2.29	0.55
RPI	0.17	1.22	0.73	0.24

Normocytic normochromic anemia was the most common morphological pattern, observed in **63.89%** of anemic patients, followed by **hypochromic microcytic anemia (26.39%)** and **hypochromic normocytic/microcytic anemia (9.72%)**. No cases of macrocytic anemia were identified. Overall, **anemia of chronic disease (63.89%)** was the predominant type, followed by iron deficiency-related anemia, suggesting that chronic inflammation and iron deficiency were the major contributors to anemia in pulmonary tuberculosis patients as shown in Table 11.

Table 11: Distribution of study subjects according to morphology

Anemia	N=72	%
Normocytic Normochromic Anemia	46	63.89
Hypochromic Microcytic Anemia	19	26.39
Hypochromic Normocytic/Microcytic Anemia	7	9.72
Macrocytic Anemia	0	0.00

Among patients with **normocytic normochromic anemia**, **78.26%** had raised ferritin levels, supporting anemia of chronic disease. In contrast, only **26.32%** of patients with **hypochromic microcytic anemia** had elevated ferritin, consistent with iron deficiency anemia. Among those with **mixed morphology**, **71.43%** showed raised ferritin levels, suggesting overlapping features of anemia of chronic disease and iron deficiency anemia. No cases of macrocytic anemia were observed.

Our study also revealed that Normocytic normochromic anemia (ACD) was the most common type, followed by **hypochromic microcytic anemia (IDA)** and mixed morphology anemia. Significant differences were observed in **BMI, hemoglobin levels, red cell indices (MCV, MCHC), serum ferritin, serum iron, TIBC, and transferrin saturation** ($p<0.05$). Patients with hypochromic microcytic anemia had the **lowest BMI, hemoglobin, serum iron, and transferrin saturation, but the highest TIBC**, consistent with iron deficiency anemia. In contrast, normocytic normochromic anemia showed **higher ferritin levels and lower TIBC**, supporting anemia of chronic disease. **Age, gender, reticulocyte count, and vitamin B12 levels did not differ significantly** among the anemia subtypes as shown in table 12.

Table 12: Clinico-Hematological Correlation across Different Morphologies of Anemia

Parameters	Normocytic Normochromic (n=46)	Hypochromic Microcytic (n=19)	Mixed Morphology (n=7)	p-value
Etiology (Major Type)	Anemia of Chronic Disease (ACD)	Iron Deficiency Anemia (IDA)	Mixed anemia	-
Gender Distribution (Male/Female)	35 Male / 11 Female	10 Male / 9 Female	5 Male / 2 Female	0.06
Mean Age (years) ± SD	49.6 ± 13.2	42.8 ± 12.6	51.2 ± 11.9	0.08
Mean BMI ± SD	20.3 ± 3.1	18.9 ± 2.8	19.5 ± 2.6	0.04*
Mean Hb (gm/dl) ± SD	9.8 ± 1.2	8.5 ± 1.4	9.0 ± 1.1	0.03*
Mean MCV (fl) ± SD	86.5 ± 5.2	68.4 ± 6.1	76.2 ± 8.0	<0.001*
Mean MCHC (g/dl) ± SD	33.1 ± 1.5	28.5 ± 2.1	31.0 ± 1.8	<0.001*
Mean Reticulocyte Count (%) ± SD	2.10 ± 0.42	2.45 ± 0.51	2.60 ± 0.60	0.12
Mean Ferritin (ng/ml) ± SD	612.5 ± 380.2	112.4 ± 90.3	455.3 ± 310.1	<0.01*
Mean Vit B12 (pg/ml) ± SD	410.2 ± 250.4	395.6 ± 210.2	350.4 ± 190.7	0.31
Mean Serum Iron (mcg/dl) ± SD	58.4 ± 28.1	38.6 ± 18.5	52.3 ± 25.6	0.002*
Mean TIBC (mcg/dl) ± SD	290.2 ± 102.4	410.6 ± 120.3	330.5 ± 110.2	<0.01*
Mean Transferrin Sat. (%) ± SD	18.2 ± 8.6	9.5 ± 4.2	15.6 ± 7.1	0.001*

Discussion:

Anaemia is a common hematological manifestation of pulmonary tuberculosis (PTB) and is primarily attributed to chronic inflammation, impaired erythropoiesis, nutritional deficiencies, and altered iron metabolism [38–40]. In the present study, anaemia was observed in 72% of PTB patients, highlighting its substantial burden among tuberculosis patients.

A male predominance of 73% was observed in our cohort, which is consistent with findings reported by Baruch Baluku J et al. [31], Dileepan et al. [41], and de Mendonca EB et al. [30]. The mean age of participants was 46.5 ± 14.2 years, comparable to studies by Chhabra et al. [29], although Bashir et al. [24] reported a relatively younger population.

Cough, breathlessness, and fever were the most common presenting symptoms, similar to observations by Dileepan et al. [41] and Chhabra et al. [29], reflecting the typical clinical profile of pulmonary tuberculosis.

The prevalence of anaemia in the present study (72%) is comparable to reports by Dileepan et al. [41], de Mendonca et al. [6], Nagu et al. [16], Minchella et al. [23], Oliveira et al. [22], Isanaka et al. [17], and Baruch Baluku J et al. [31], all of whom demonstrated a high burden of anaemia among tuberculosis patients. The lower prevalence reported by Lee et al. [20] may be attributable to differences in study design and exclusion criteria.

Most anaemic patients had mild (35%) or moderate (29%) anaemia, whereas severe anaemia was less frequent (8%). Similar severity distributions have been reported by Baruch Baluku J et al. [31], Dileepan et al. [92], and de Mendonca et al. [30].

Regarding morphological patterns, normocytic normochromic anaemia was the predominant type (63.89%), followed by hypochromic microcytic anaemia (26.39%). These findings are in agreement with studies by de Mendonca et al. [30], Dileepan et al. [41], Yarnal et al. [21], Thatoi et al. [43], Lee et al. [20], and Kumar et al. [44], which also identified anaemia of chronic disease (ACD) as the predominant pattern in tuberculosis patients. The predominance of normocytic normochromic morphology supports the role of chronic inflammation in the pathogenesis of anaemia among PTB patients.

Iron profile analysis demonstrated elevated serum ferritin with relatively low serum iron and transferrin saturation, suggesting a mixed pattern of anaemia of chronic disease and iron deficiency anaemia. Among normocytic normochromic anaemia cases, raised ferritin levels were common, further supporting an inflammatory aetiology. Conversely, hypochromic microcytic anaemia was associated with lower ferritin and iron levels, indicating iron deficiency. These findings emphasize the multifactorial nature of anaemia in tuberculosis and are consistent with previous reports highlighting altered iron metabolism in chronic infections [45].

Vitamin B12 levels were largely within the normal range, suggesting a minimal contribution of vitamin B12 deficiency to anaemia in this population. Furthermore, the mean reticulocyte production index was below 2, indicating an inadequate bone marrow response and supporting the hypothesis of suppressed erythropoiesis secondary to chronic inflammation.

Lower BMI was significantly associated with sputum positivity and iron deficiency-related anaemia. Similar observations have been reported by Chhabra et al. [29], Tungdim et al. [12], and de Mendonca et al. [30]. Malnutrition likely contributes to both the severity of tuberculosis and the development of anaemia through impaired nutritional intake and dysregulated inflammatory pathways.

No significant association was observed between anaemia and age or gender, consistent with findings by de Mendonca et al. [30] and Baruch Baluku J et al. [31]. However, significant associations were found between anaemia morphology and BMI, haemoglobin concentration, red cell indices, ferritin, serum iron, TIBC, and transferrin saturation, indicating that iron metabolism plays a central role in determining the pattern of anaemia in PTB patients

Conclusion:

Anaemia was highly prevalent among patients with pulmonary tuberculosis, affecting nearly three-fourths of the study population. The predominant morphological pattern was normocytic normochromic anaemia, indicating that anaemia of chronic disease is the major underlying mechanism. However, a considerable proportion of patients also exhibited hypochromic microcytic anaemia, suggesting coexisting iron deficiency and highlighting the multifactorial nature of anaemia in pulmonary tuberculosis.

Iron profile findings, characterized by elevated serum ferritin with reduced serum iron and transferrin saturation, further support the contribution of chronic inflammation and altered iron metabolism. Lower BMI was significantly associated with iron deficiency-related anaemia and sputum positivity, emphasizing the role of undernutrition in the development and severity of anaemia. In contrast, vitamin B12 deficiency appeared to have a minimal role in the pathogenesis of anaemia in this cohort.

Overall, anaemia in pulmonary tuberculosis is primarily driven by chronic inflammation, often compounded by nutritional deficiencies. Routine haematological assessment, including evaluation of iron parameters and nutritional status, should be integrated into the management of tuberculosis patients to facilitate early identification and appropriate treatment of anaemia, thereby improving patient outcomes.

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