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Association Between Hemoglobin Levels and Infection Outcomes During One-Year Follow- up in Women With Iron Deficiency Anemia

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Research Article

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Abstract

Background

Iron deficiency anemia (IDA) is associated with altered immune function and may influence susceptibility to infectious diseases in women. However, the relationship between anemia severity, hematologic recovery after iron replacement therapy, and infection-related outcomes in female patients with IDA remains incompletely understood. To investigate the association between hemoglobin levels, anemia severity, infection-related outcomes, and inflammatory burden during one-year follow-up in women with IDA receiving iron replacement therapy.

Methods

This retrospective observational study included women diagnosed with IDA who received first-time iron replacement therapy between September 1, 2021, and January 1, 2025. Infection-related outcomes during one-year follow-up included upper respiratory tract infection, lower respiratory tract infection, urinary tract infection, and vaginitis. Baseline and maximum follow-up hemoglobin, ferritin, and C-reactive protein (CRP) levels were assessed. Patients were categorized according to World Health Organization anemia severity criteria.

Results

A total of 1,260 female patients were included, comprising 453 anemic patients (36.0%) and 807 non-anemic group (64.0%). During follow-up, at least one infection episode occurred in 64.0% of patients. Overall infection frequency was significantly higher in the non-anemic group compared with the anemic group (67.0% vs. 58.5%, $p = 0.002$). Urinary tract infection was also more common in the non-anemic group (56.0% vs. 46.8%, $p = 0.001$). No significant differences were observed between groups regarding upper respiratory tract infection, lower respiratory tract infection, vaginitis, or maximum CRP levels. Anemia severity was not significantly associated with overall infection presence or infection-specific outcomes. Patients with at least one infection episode demonstrated slightly higher hemoglobin levels compared with those without infection (12.29 ± 1.36 vs. 11.99 ± 1.60, $p = 0.009$). Similarly, patients with lower respiratory tract infection and urinary tract infection had modestly higher hemoglobin levels.

Conclusions

In this real-world cohort of women receiving iron replacement therapy, infection-related outcomes were not associated with greater anemia severity. Unexpectedly, higher hemoglobin levels and non-anemic status were associated with higher frequencies of overall infection and urinary tract infection. These

findings highlight the complex relationship between iron metabolism, hematologic recovery, and infection susceptibility in women with treated IDA.

Background

Iron deficiency anemia (IDA) is one of the most common nutritional and hematologic disorders worldwide and remains a major public health concern, particularly among women of reproductive age [1, 2]. Iron deficiency may present either with or without anemia and is associated with fatigue, impaired physical performance, reduced quality of life, and multiple systemic consequences [1, 3]. In addition to its hematologic role, iron is essential for cellular metabolism, immune regulation, and inflammatory responses, making disturbances in iron homeostasis clinically important beyond erythropoiesis alone [4, 5].

Ferritin and hemoglobin measurements are central components of the diagnostic evaluation of IDA. Serum ferritin is widely accepted as a practical indicator of iron stores; however, its interpretation may become challenging in inflammatory conditions because ferritin also behaves as an acute-phase reactant [6, 7]. Current evidence suggests that both absolute and functional iron deficiency may influence immune system function and inflammatory pathways, potentially altering susceptibility to infectious diseases [3, 5].

The relationship between iron deficiency, anemia, and infection risk remains complex and incompletely understood. Iron is required not only for host immune cell activity but also for microbial proliferation, creating a biologically paradoxical interaction between iron metabolism and infection susceptibility [5, 8]. Experimental and clinical studies have suggested that iron deficiency and IDA may impair immune responses and increase vulnerability to infections, including respiratory and urinary tract infections [9, 10]. Conversely, inflammatory and infectious states may alter iron metabolism through hepcidin-mediated iron sequestration and suppression of erythropoiesis, further complicating the interpretation of anemia severity and iron biomarkers [4, 5].

Recent observational studies evaluating infection outcomes in iron-deficient populations have produced heterogeneous findings. While some studies reported increased susceptibility to infections and severe infectious events among iron-deficient individuals, others demonstrated inconsistent associations depending on patient population, baseline inflammatory status, and definitions of iron deficiency [9–11]. In addition, anemia severity has been associated with increased healthcare utilization and disease burden in chronic inflammatory conditions, suggesting that the clinical impact of anemia may extend beyond hemoglobin reduction alone [12].

Women are disproportionately affected by iron deficiency anemia because of menstrual blood loss, pregnancy-related iron demands, and increased susceptibility to chronic iron depletion during reproductive years. Consequently, women are more frequently exposed to both iron deficiency and iron replacement therapies throughout life. This repeated and prolonged interaction with altered iron metabolism may influence immune responses, inflammatory pathways, and susceptibility to infectious

diseases. Therefore, understanding the relationship between hemoglobin levels, iron replacement, and infection-related outcomes in female populations has particular clinical importance and may provide insights into the broader effects of iron metabolism beyond hematologic recovery alone.

Despite growing interest in the interaction between iron metabolism and infection, real-world studies evaluating infection-related outcomes according to anemia severity and hematologic recovery after iron replacement therapy in women with IDA remain limited. Moreover, data regarding longitudinal infection patterns in routinely treated female IDA populations are scarce. Therefore, the present study aimed to investigate the association between baseline hemoglobin levels, anemia severity, infection-related outcomes, and inflammatory burden during one-year follow-up in women with iron deficiency anemia receiving iron replacement therapy.

Methods

Study Design and Patient Population

This retrospective observational study was conducted using electronic health records of female patients who attended the internal medicine outpatient clinic between September 1, 2021, and January 1, 2025. Women with a documented diagnosis of iron deficiency anemia (IDA) who received iron replacement therapy for the first time during the study period were considered eligible for inclusion. By restricting inclusion to patients with a first recorded iron prescription, the study aimed to evaluate incident cases of treated IDA in a female population.

The index date was defined as the date of the first iron prescription. Only patients with at least 12 months of available follow-up data in the electronic health record system were included in the analysis.

After application of exclusion criteria, a total of 1,260 female patients were included in the final cohort (Fig. 1). For comparative analyses, patients were categorized into anemic (n = 453) and non-anemic (n = 807) groups according to baseline hemoglobin levels measured at the index date. The non-anemic group consisted of women with previously documented IDA whose hemoglobin levels had normalized at the index evaluation despite ongoing iron deficiency-related follow-up.

Inclusion and Exclusion Criteria

Female patients were included if they had a documented diagnosis of IDA, available hemoglobin and ferritin measurements at the index visit, and at least one year of follow-up data.

Patients with malignancy were excluded because malignant diseases may independently alter infection susceptibility and inflammatory burden. In addition, records lacking hemoglobin measurements despite a documented diagnosis of iron deficiency anemia were excluded, as anemia severity based on

hemoglobin level represented the principal analytical grouping of the study. Patients without ferritin measurements were also excluded.

Classification of Iron Deficiency Anemia

To evaluate the association between anemia severity and infection-related outcomes, patients were categorized according to baseline anemia severity. The index date was defined as the first clinical encounter during which IDA was documented and laboratory measurements of hemoglobin and ferritin were available during the same visit.

Anemia severity was classified according to World Health Organization criteria. Hemoglobin levels of 11–11.9 g/dL were defined as mild anemia, levels of 8–10.9 g/dL as moderate anemia, and levels below 8 g/dL as severe anemia. Patients with hemoglobin levels ≥ 12 g/dL were categorized as the non-anemic group.

Laboratory Assessment

Baseline hemoglobin and ferritin measurements obtained at the index visit were recorded for all patients. In addition, maximum hemoglobin and ferritin levels observed during the one-year follow-up period were extracted from the database to evaluate hematologic recovery after iron replacement therapy.

This approach was considered important because patients with more severe anemia may require a longer period to achieve normalization of hemoglobin levels. Consequently, the relationship between baseline anemia severity and subsequent infection outcomes could be influenced by the degree of hematologic recovery achieved during follow-up. To better account for this potential effect, maximum hemoglobin levels during follow-up were additionally evaluated across study groups.

The maximum C-reactive protein (CRP) level recorded within one year after the index date was also analyzed as a surrogate marker of infection severity and systemic inflammatory burden.

Outcomes

The primary outcome was the occurrence of infections during the one-year follow-up period after the index date. Infection diagnoses were identified from diagnostic records documented in the electronic health record system. Evaluated infection categories included upper respiratory tract infection, lower respiratory tract infection, urinary tract infection, and vaginitis.

In addition to individual infection categories, a composite infection outcome was also created. Patients who developed at least one infection during the one-year follow-up period were classified as overall infection occurrence.

The secondary outcome was infection severity, assessed using the maximum CRP level recorded during the same follow-up period.

Data Completeness

As this study relied on retrospectively collected electronic health record data, certain variables may not have been consistently documented for all patients. Therefore, missing data may be attributable to incomplete data entry or variability in clinical documentation practices rather than the true absence of a clinical condition. No data imputation methods were applied, and all analyses were performed using available-case data.

Data Preprocessing

Data preprocessing and preparation were conducted using Wanalyzer v3.0 (WisdomEra Corp., Istanbul, Turkey), a python-based analytical environment integrating scientific computing libraries (https://analyzer.wisdomera.io, accessed on 12 May 2026). The platform is directly integrated with hospital information systems and laboratory information systems, enabling secure extraction, structured transformation, and standardized processing of routinely collected clinical data. The platform was used for data cleaning, normalization, transformation, feature structuring, and dataset harmonization prior to analysis.

Statistical Analysis

All statistical analyses were performed using Wistats v3.0 (WisdomEra Corp., Istanbul, Turkey), a Python-based analytical platform integrating the SciPy, scikit-learn, and statsmodels libraries (https://wistats.wisdomera.io).

Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as number and percentage. Data distribution characteristics were evaluated using skewness and kurtosis measures together with the Shapiro–Wilk test.Comparisons between anemic and non-anemic groups were performed using the independent samples t-test or Mann–Whitney U test for continuous variables, according to data distribution. Comparisons across anemia severity groups were conducted using one-way analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. Categorical variables were analyzed using the Chi-square test or Fisher’s exact test.

Associations between hemoglobin levels and infection-related variables were evaluated using correlation and comparative analyses according to variable type and distribution characteristics. A two-sided p value < 0.05 was considered statistically significant.

Results

Baseline Characteristics of the Study Cohort

After application of the exclusion criteria, a total of 1,260 female patients were included in the final analysis (Fig. 1). Among these, 453 patients (36.0%) were classified as anemic and 807 patients (64.0%) constituted the non-anemic group. The mean age of the overall cohort was 37.72 ± 9.17 years. Most patients were enrolled during 2022 (55.1%), followed by 2024 (24.5%), 2023 (11.3%), and 2021 (9.1%) (Table 1).

Table 1
Baseline Demographic and Clinical Characteristics of the Study Cohort

Cohort	**Cases (n = 1260)**
	Mean ± SD, N (%)
anemic	453 (36.0%)
normal	807 (64.0%)
Age	37.72 ± 9.17
Application Year	
2021	115 (9.1%)
2022	694 (55.1%)
2023	142 (11.3%)
2024	309 (24.5%)
Anemia Group	
mild	225 (49.7%)
moderate	212 (46.8%)
severe	16 (3.5%)
Infection Present	
no	454 (36.0%)
yes	806 (64.0%)
Upper respiratory tract infection within 1 year	
no	1171 (92.9%)
yes	89 (7.1%)
Lower respiratory tract infection within 1 year	
no	1126 (89.4%)
yes	134 (10.6%)
Urinary tract infection within 1 year	
no	596 (47.3%)
yes	664 (52.7%)

Cohort	Cases (n = 1260) Mean ± SD, N (%)
Vaginitis within 1 year	
no	1060 (84.1%)
yes	200 (15.9%)

Among anemic patients, mild anemia was observed in 49.7%, moderate anemia in 46.8%, and severe anemia in 3.5% of cases.

During the one-year follow-up period, at least one infection episode was recorded in 64.0% of the cohort. Upper respiratory tract infection was identified in 7.1% of patients, lower respiratory tract infection in 10.6%, urinary tract infection in 52.7%, and vaginitis in 15.9%.

Comparative Analysis Between Anemic and Non-Anemic Groups

Baseline ferritin levels were significantly lower in the anemic group compared with the non-anemic group (9.49 ± 16.27 vs. 17.40 ± 10.02, $p < 0.001$). Patients in the anemic group were also older and had significantly lower baseline hemoglobin levels (both $p < 0.001$) (Table 2).

Table 2
Comparative Outcomes Between Anemic and Control Groups

Ferritin	**Anemic (n = 453)**	**Normal (n = 807)**	**p**
	Mean ± SD, N (%)	**Mean ± SD, N (%)**	
	9.49 ± 16.27	**17.40 ± 10.02**	**< 0.001**
Age	38.96 ± 8.84	37.03 ± 9.28	**< 0.001**
Hgb level in first application	10.64 ± 1.16	13.05 ± 0.69	**< 0.001**
Infection Present			**0.002**
no	188 (41.5%)	266 (33.0%)	
yes	265 (58.5%)	541 (67.0%)	
Upper respiratory tract infection within 1 year			0.362
no	419 (92.5%)	752 (93.2%)	
yes	34 (7.5%)	55 (6.8%)	
Lower respiratory tract infection within 1 year			0.101
no	412 (90.9%)	714 (88.5%)	
yes	41 (9.1%)	93 (11.5%)	
Urinary tract infection within 1 year			**0.001**
no	241 (53.2%)	355 (44.0%)	
yes	212 (46.8%)	452 (56.0%)	
Vaginitis within 1 year			0.281
no	377 (83.2%)	683 (84.6%)	
yes	76 (16.8%)	124 (15.4%)	
Maximum Ferritin Level Within One Year	32.65 ± 78.20	33.11 ± 50.77	**< 0.001**
Maximum CRP Level Within One Year	12.94 ± 24.70	12.86 ± 25.79	0.935
Maximum Hgb Level Within One Year	11.85 ± 1.32	13.24 ± 0.86	**< 0.001**

At least one infection during follow-up was significantly more frequent in the non-anemic group compared with the anemic group (67.0% vs. 58.5%, p = 0.002).

Regarding specific infection categories, urinary tract infection was significantly more common in the non-anemic group compared with the anemic group (56.0% vs. 46.8%, p = 0.001) (Fig. 2). In contrast, no

statistically significant differences were observed between groups for upper respiratory tract infection, lower respiratory tract infection, or vaginitis during follow-up.

Maximum ferritin levels recorded within one year differed significantly between groups ($p < 0.001$). Similarly, maximum hemoglobin levels during follow-up remained significantly lower in the anemic group compared with the non-anemic group (11.85 ± 1.32 vs. 13.24 ± 0.86, $p < 0.001$) (Fig. 3). However, maximum CRP levels during follow-up were comparable between the groups ($p = 0.935$).

Outcomes According to Anemia Severity

Age differed significantly across anemia severity groups, with patients in the severe anemia group demonstrating the highest mean age ($p = 0.047$) (Table 3).

Table 3
Comparison of Clinical, Laboratory, and Infection-Related Variables According to Anemia Severity

Ferritin	**mild**	**moderate**	**severe**	**p**
	mean ± sd, n (%)	**mean ± sd, n (%)**	**mean ± sd, n (%)**	
	13.19 ± 21.77	**5.95 ± 5.78**	**4.26 ± 4.41**	**< 0.001**
Age	38.06 ± 8.83	39.75 ± 8.72	41.19 ± 9.83	**0.047**
Hgb	11.49 ± 0.28	9.99 ± 0.77	7.10 ± 0.88	**< 0.001**
Infection Present				0.214
no	93 (41.3%)	85 (40.1%)	10 (62.5%)	
yes	132 (58.7%)	127 (59.9%)	6 (37.5%)	
Upper respiratory tract infection within 1 year				0.092
no	214 (95.1%)	190 (89.6%)	15 (93.8%)	
yes	11 (4.9%)	22 (10.4%)	1 (6.2%)	
Lower respiratory tract infection within 1 year				0.906
no	205 (91.1%)	192 (90.6%)	15 (93.8%)	
yes	20 (8.9%)	20 (9.4%)	1 (6.2%)	
Urinary tract infection within 1 year				0.108
no	112 (49.8%)	117 (55.2%)	12 (75.0%)	
yes	113 (50.2%)	95 (44.8%)	4 (25.0%)	
Vaginitis within 1 year				0.148
no	195 (86.7%)	169 (79.7%)	13 (81.2%)	
yes	30 (13.3%)	43 (20.3%)	3 (18.8%)	
Maximum Ferritin Level Within One Year	29.30 ± 44.86	36.92 ± 98.82	7.66 ± 3.59	**0.003**
Maximum CRP Level Within One Year	14.70 ± 28.52	11.67 ± 20.97	4.92 ± 6.77	0.306
Maximum Hgb Level Within One Year	12.17 ± 1.00	11.66 ± 1.39	10.21 ± 2.33	**< 0.001**

No statistically significant differences were observed among mild, moderate, and severe anemia groups regarding overall infection presence or specific infection categories, including upper respiratory tract infection, lower respiratory tract infection, urinary tract infection, and vaginitis during the one-year follow-up period (Fig. 4).

Maximum ferritin levels during follow-up differed significantly across anemia severity groups ($p = 0.003$). In addition, maximum hemoglobin levels achieved during follow-up progressively decreased with increasing baseline anemia severity ($p < 0.001$). In contrast, maximum CRP levels during follow-up did not significantly differ among anemia severity groups ($p = 0.306$).

Association Between Hemoglobin Levels and Infection-Related Variables

Hemoglobin levels demonstrated a weak but statistically significant negative correlation with age (coefficient: −0.12, $p < 0.001$) (Table 4).

Table 4
Association Between Hemoglobin Levels and Infection-Related and Inflammatory Variables

Age	**Hgb**	**p**
	Mean ± SD, Coefficient	
	Coefficient: -0.12	**< 0.001**
Infection Present		**0.009**
no	11.99 ± 1.60	
yes	12.29 ± 1.36	
Upper respiratory tract infection within 1 year		0.413
no	12.19 ± 1.45	
yes	12.03 ± 1.58	
Lower respiratory tract infection within 1 year		**0.037**
no	12.15 ± 1.47	
yes	12.40 ± 1.35	
Urinary tract infection within 1 year		**0.006**
no	12.03 ± 1.56	
yes	12.32 ± 1.34	
Vaginitis within 1 year		0.198
no	12.20 ± 1.46	
yes	12.07 ± 1.47	
Maximum CRP Level Within One Year After Treatment	Coefficient: 0.02	0.548

Patients with at least one infection episode during follow-up had slightly higher hemoglobin levels compared with patients without any recorded infection (12.29 ± 1.36 vs. 11.99 ± 1.60, p = 0.009) (Table 4).

Similarly, patients who developed lower respiratory tract infection during follow-up had higher hemoglobin levels compared with those without lower respiratory tract infection (12.40 ± 1.35 vs. 12.15 ± 1.47, p = 0.037). Patients with urinary tract infection also demonstrated higher hemoglobin levels than those without urinary tract infection (12.32 ± 1.34 vs. 12.03 ± 1.56, p = 0.006) (Table 4).

No significant associations were observed between hemoglobin levels and upper respiratory tract infection, vaginitis, or maximum CRP levels recorded during follow-up (Table 4).

Discussion

In this retrospective real-world study including 1,260 women, we investigated the association between baseline hemoglobin levels, anemia severity, infection-related outcomes, and inflammatory burden during one-year follow-up. Given that women are disproportionately affected by iron deficiency and are more frequently exposed to iron replacement therapies throughout reproductive life, understanding the interaction between iron metabolism and infection-related outcomes in female populations has particular clinical relevance. The principal findings of the study were that women in the non-anemic group demonstrated a higher frequency of overall infections compared with anemic patients (67.0% vs. 58.5%, p = 0.002), urinary tract infections were significantly more common in the non-anemic group (56.0% vs. 46.8%, p = 0.001), and patients with at least one infection episode had slightly higher hemoglobin levels than patients without infection (12.29 ± 1.36 vs. 11.99 ± 1.60, p = 0.009). Similarly, patients who developed lower respiratory tract infection and urinary tract infection during follow-up demonstrated modestly higher hemoglobin levels. In contrast, anemia severity was not significantly associated with infection frequency or maximum CRP levels during follow-up.

IDA is traditionally considered a condition associated with impaired immune responses and increased susceptibility to infections because iron is essential for immune cell proliferation, cytokine signaling, and host defense mechanisms [5, 13]. Several previous studies have reported increased rates of respiratory and urinary tract infections in iron-deficient or anemic populations [9, 14, 15]. Moreover, epidemiological data suggest that severe anemia may predispose patients to invasive bacterial infections and worse infectious outcomes [16].

However, our findings demonstrated a unexpected pattern in which patients with higher hemoglobin levels experienced slightly more infection episodes. This observation may initially appear counterintuitive but is biologically plausible considering the complex interaction between iron metabolism, inflammation, and microbial growth. Iron is not only essential for host immunity but also a critical nutrient for many pathogens. Experimental and translational studies have shown that increased iron availability may facilitate bacterial proliferation and infection susceptibility under certain conditions [5, 17]. Mendelian randomization analyses by Butler-Laporte et al. suggested that higher iron stores may modestly increase the risk of bacterial infections, particularly urinary tract infections and sepsis [18]. Interestingly, in our cohort, urinary tract infection frequency was significantly higher in patients with relatively higher hemoglobin levels, which may be partially compatible with these observations.

Another potential explanation for our findings is the dynamic nature of iron replacement therapy and hematologic recovery. In our study, all included patients received iron replacement treatment, and maximum hemoglobin levels during follow-up increased substantially in many patients. Therefore, baseline anemia severity may not accurately reflect long-term iron exposure during the entire follow-up period. Patients with higher follow-up hemoglobin levels may represent individuals with more successful iron repletion, potentially altering host-pathogen iron availability. This possibility is supported by prior

studies suggesting that iron supplementation may influence infection patterns differently depending on the infectious agent, inflammatory status, and degree of iron exposure [17, 19].

Inflammation-driven iron sequestration also represents an important mechanistic consideration. Hepcidin-mediated blockade of iron absorption during inflammation is increasingly recognized as a central pathway linking infection, iron metabolism, and anemia of inflammation [4, 20, 21]. Respiratory infections and inflammatory cytokine activation may suppress iron utilization and contribute to functional iron deficiency despite apparently adequate iron stores [22, 23]. In our cohort, maximum CRP levels were comparable between anemia groups and were not significantly associated with baseline hemoglobin levels, suggesting that overt systemic inflammatory burden may not fully explain the observed differences in infection patterns.

Importantly, although overall infection frequency differed between groups, anemia severity itself was not significantly associated with infection occurrence. Mild, moderate, and severe anemia groups demonstrated similar rates of respiratory tract infection, urinary tract infection, vaginitis, and composite infection outcomes. These findings may indicate that baseline hemoglobin level alone is insufficient to predict subsequent infection burden in treated IDA populations. Instead, infection susceptibility may be influenced by multiple interacting factors including inflammatory status, iron supplementation dynamics, comorbid conditions, healthcare utilization patterns, and microbiological characteristics.

Our study has several strengths. First, the study included a relatively large real-world cohort of women with one-year longitudinal follow-up. Second, both composite and infection-specific outcomes were evaluated. Third, the study incorporated longitudinal laboratory recovery parameters including maximum hemoglobin, ferritin, and CRP levels, allowing assessment of hematologic recovery after treatment. Given that women are disproportionately affected by iron deficiency and frequently exposed to iron replacement therapies during reproductive life, evaluating these longitudinal infection-related outcomes in an exclusively female cohort represents an additional strength of the study. Finally, the use of integrated electronic health record systems enabled standardized extraction and harmonization of routinely collected clinical data.

Nevertheless, several limitations should be acknowledged. First, the retrospective observational design limits causal inference. Second, infection diagnoses were based on ICD-coded electronic health record data and may be subject to coding variability or underreporting. Third, detailed information regarding iron formulation, treatment adherence, cumulative iron exposure, microbiological confirmation, hospitalization status, and comorbid diseases was not consistently available. Fourth, CRP was used as a surrogate marker of infection severity, but more comprehensive inflammatory biomarkers such as procalcitonin, hepcidin, or cytokine profiles were unavailable. Fifth, because all patients received iron replacement therapy, the relationship between baseline anemia severity and infection risk may have been modified by subsequent hematologic correction during follow-up. In addition, information regarding menopausal status, menstrual blood loss, pregnancy history, and gynecological conditions was not consistently available in the electronic health record system.

Future prospective studies incorporating serial iron biomarkers, hepcidin measurements, microbiological data, and detailed iron replacement exposure are needed to better clarify the complex relationship between iron metabolism and infection susceptibility. In particular, studies distinguishing baseline iron deficiency from post-treatment iron repletion states may improve understanding of how dynamic iron status influences infectious outcomes in clinical practice.

These findings may suggest that infection susceptibility in treated IDA populations is influenced not only by anemia severity itself but also by dynamic alterations in iron availability during hematologic recovery.

Conclusions

In this real-world retrospective cohort of women with IDA receiving iron replacement therapy, overall infection frequency and urinary tract infection were paradoxically more common among patients with higher hemoglobin levels and in the non-anemic group. In contrast, anemia severity itself was not significantly associated with infection occurrence or inflammatory burden during follow-up. Given the high lifetime burden of iron deficiency and repeated exposure to iron replacement therapies among women, these findings highlight the complex and bidirectional relationship between iron metabolism, hematologic recovery, and infection susceptibility, emphasizing that hemoglobin level alone may not adequately reflect infection risk in treated female IDA populations.

Abbreviations

IDA
Iron Deficiency Anemia
Hgb
Hemoglobin
CRP
C-Reactive Protein
URTI
Upper Respiratory Tract Infection
LRTI
Lower Respiratory Tract Infection
UTI
Urinary Tract Infection
ICD
International Classification of Diseases
ATC
Anatomical Therapeutic Chemical
ANOVA
Analysis of Variance
EHR

Electronic Health Record
SD
Standard Deviation

Declarations

Ethics approval and consent to participate

The research was conducted in compliance with the principles of the Declaration of Helsinki. Ethical clearance was obtained from the Ethics Committee of Istanbul Kent University prior to data analysis. The study was reviewed at the committee meeting held on January 20, 2026 and was approved (Protocol No: 2026-03).

This study utilized a retrospective design based on previously collected clinical records. Prior to analysis, all patient data were irreversibly anonymized. In view of the retrospective framework and the absence of identifiable personal information, the institutional ethics committee granted a waiver of informed consent.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the Dataset Sharing Platform of Istinye University repository, [https://dataset.istinye.edu.tr/dataset?did=97]

Competing interests

The authors declare no conflicts of interest.

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Authors' contributions

Conceptualization: N.A.; Methodology: N.A.; Investigation: N.A.; Resources: N.A.; Data Curation: N.A.; Writing – Original Draft Preparation: N.A.; Writing – Review & Editing: N.A.; Supervision: N.A.; Formal Analysis: N.A.

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Figures

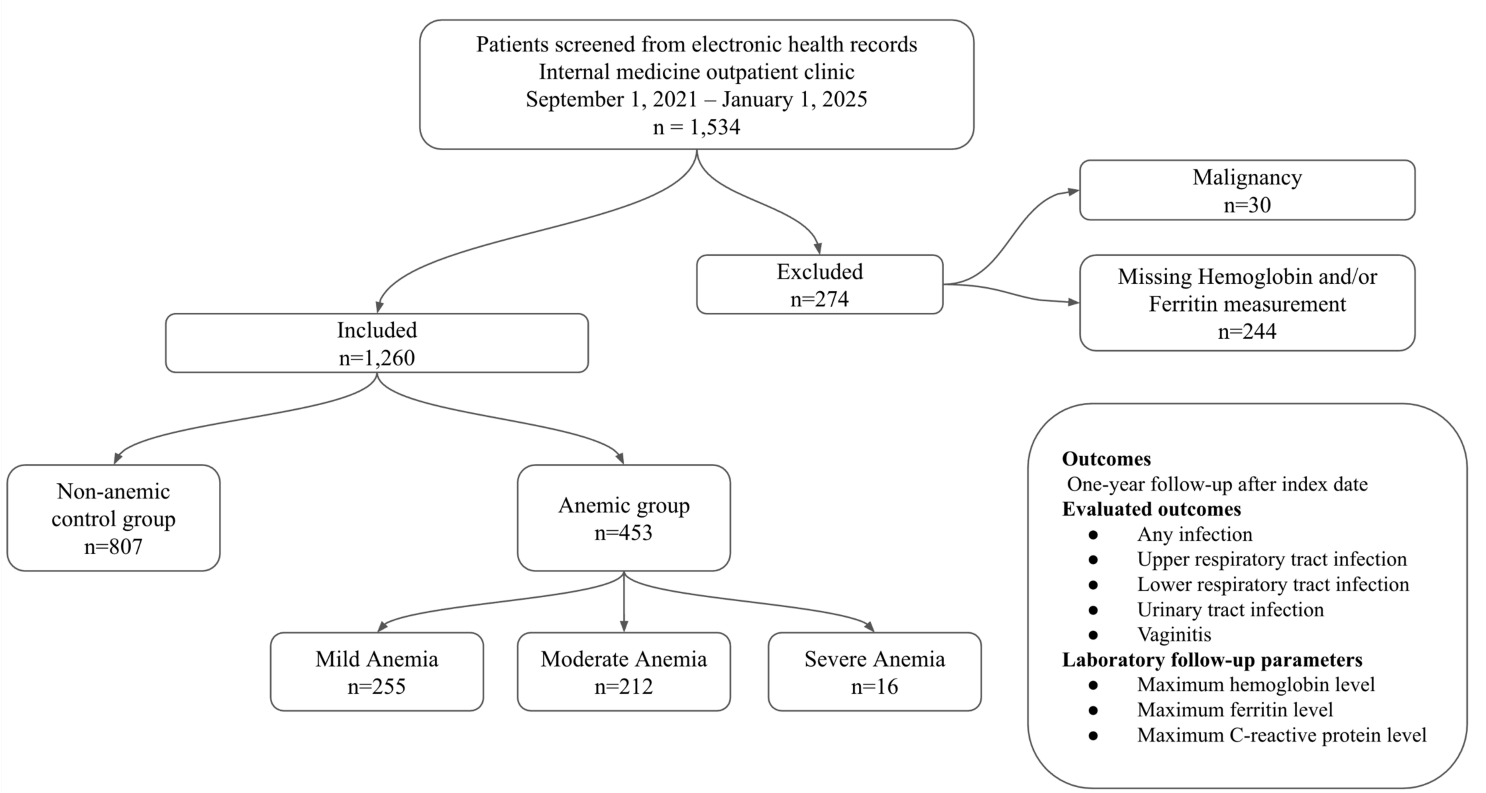


Figure 1

Study flow diagram of patient selection and follow-up process.

A total of 1,534 patients screened from electronic health records between September 1, 2021 and January 1, 2025 were evaluated for eligibility. Patients with malignancy, missing hemoglobin measurements, or missing ferritin data were excluded. The final cohort consisted of 1,260 women, including anemic and non-anemic groups. Patients were followed for one year after the index date for assessment of infection-related outcomes and longitudinal laboratory parameters.

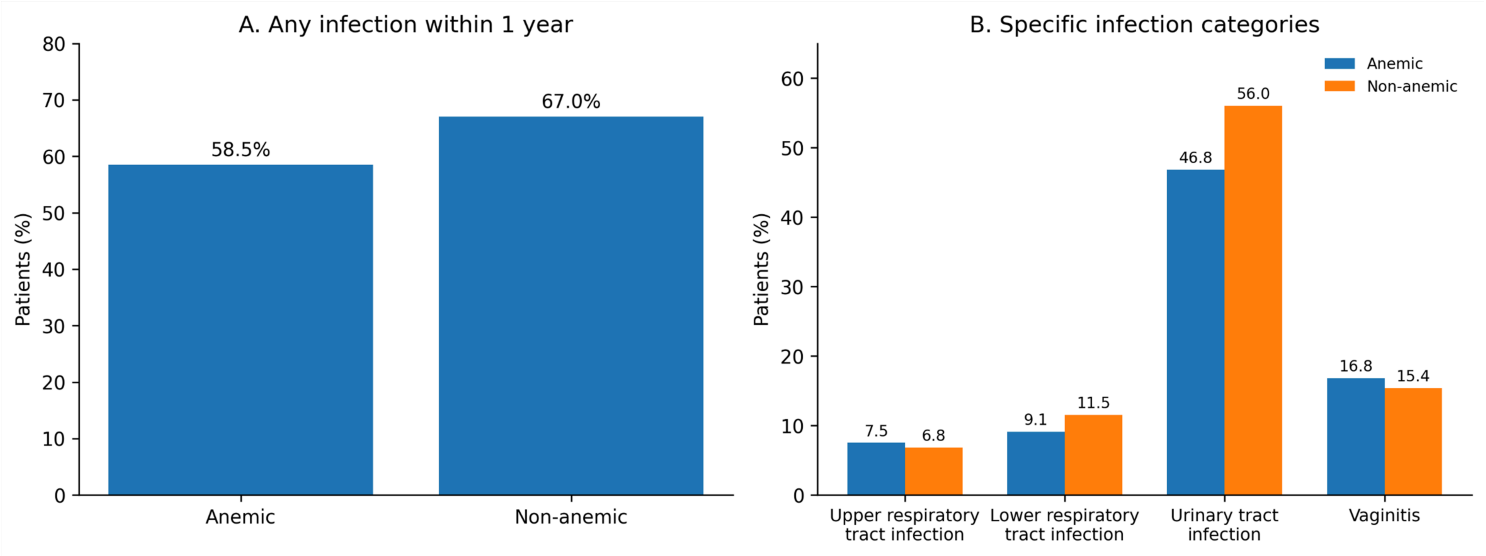


Figure 2

Infection outcomes according to anemia status.

(A) Comparison of overall infection occurrence within one year between anemic and non-anemic patients.

(B) Comparison of specific infection categories, including upper respiratory tract infection, lower respiratory tract infection, urinary tract infection, and vaginitis, according to anemia status.

Abbreviations: URTI, upper respiratory tract infection; LRTI, lower respiratory tract infection; UTI, urinary tract infection.

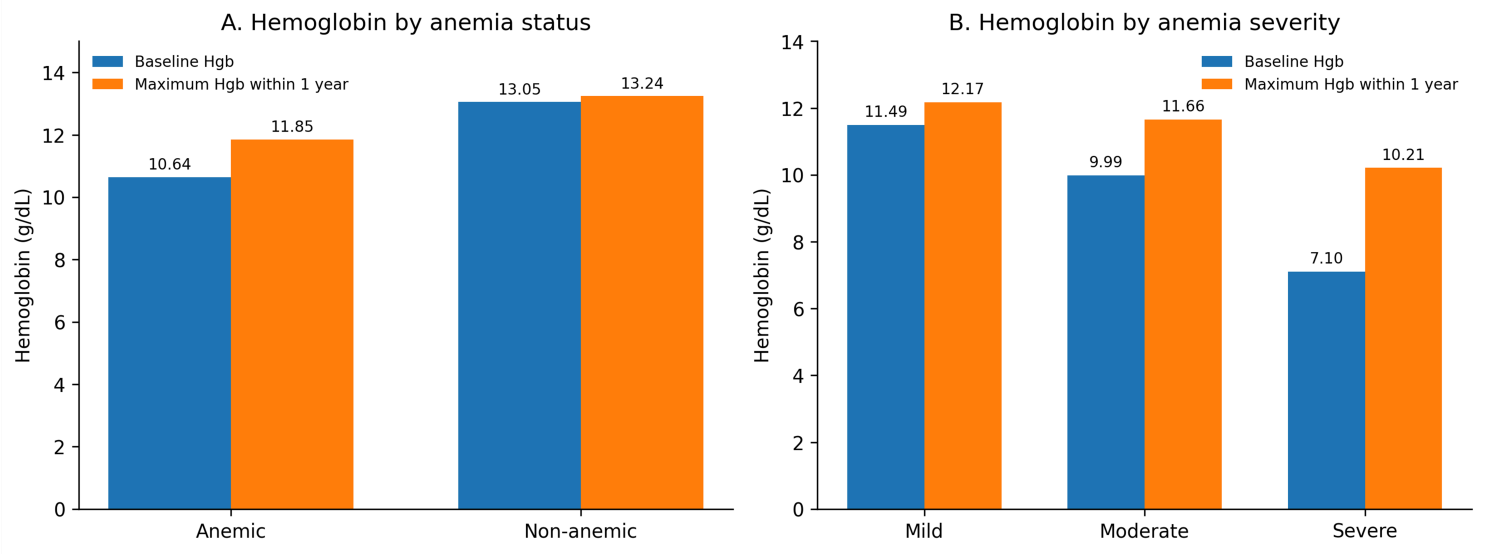


Figure 3

Hemoglobin levels at baseline and during follow-up.

(A) Comparison of baseline hemoglobin levels and maximum hemoglobin levels achieved during one-year follow-up between anemic and non-anemic groups.

(B) Baseline and maximum hemoglobin levels according to anemia severity categories (mild, moderate, and severe anemia).

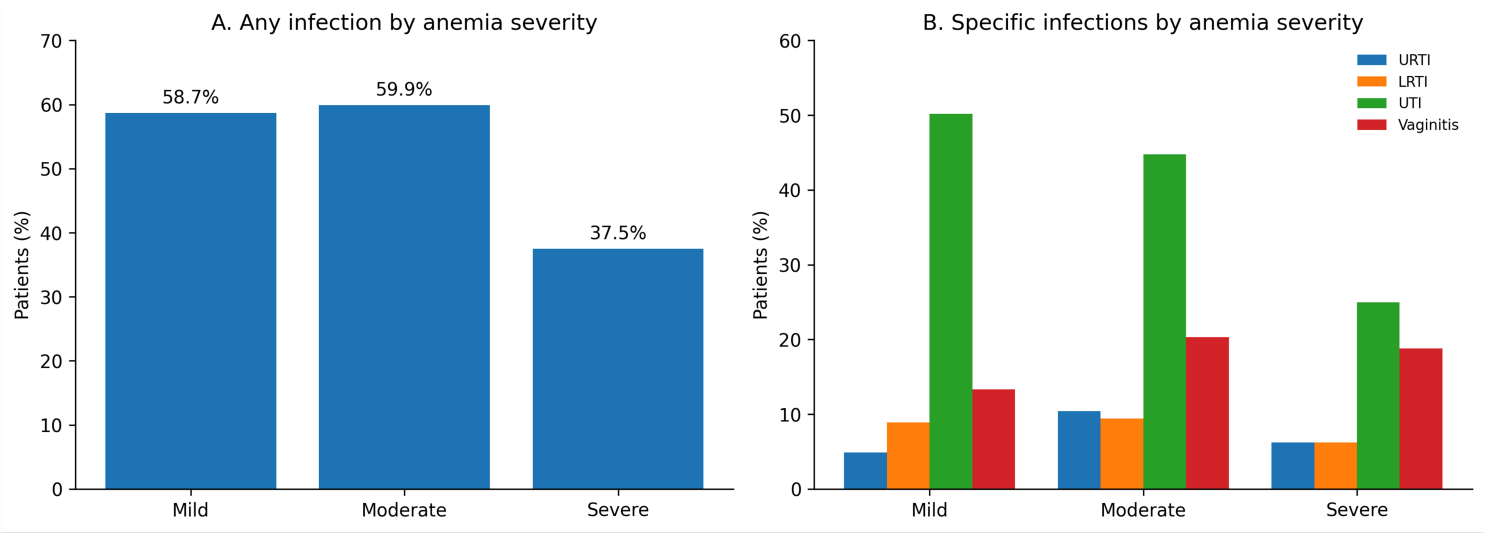


Figure 4

Infection outcomes according to anemia severity.

(A) Comparison of overall infection occurrence according to anemia severity.

(B) Distribution of specific infection categories, including upper respiratory tract infection, lower respiratory tract infection, urinary tract infection, and vaginitis, across anemia severity groups.

Abbreviations: URTI, upper respiratory tract infection; LRTI, lower respiratory tract infection; UTI, urinary tract infection.