**Původní sdělení** | Original research article

# Determinants of Ineligibility for Intravenous Iron Therapy in Patients with Heart Failure and LVEF <45%: A Retrospective Cohort Study

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ARTICLE INFO

*Article history:*
Submitted: 17. 8. 2025
Accepted: 1. 9. 2025
Available online: 27. 11. 2025

*Klíčová slova:*
Guidelines ESC
Hemoglobin
Intravenózní podávání železa
Kritéria způsobilosti
Nedostatek železa
Srdeční selhání

SOUHRN

**Úvod:** Intravenózní suplementace železa zlepšuje symptomy a redukuje počet hospitalizací u pacientů se srdečním selháním (HF) a nedostatkem železa (ID). Přestože současné doporučené postupy Evropské kardiologické společnosti (ESC) nestanovují horní limit hemoglobinu (Hb) pro podání železa, klinická praxe se řídí limity převzatými z klinických studií. Cílem této retrospektivní kohortové studie bylo zhodnotit, jak různé prahové hodnoty Hb mohou ovlivňovat reálnou aplikovatelnost intravenózní terapie železem u pacientů se sníženou ejekční frakcí levé komory (EF LK ≤ 45 %).
**Metodika:** Analyzovali jsme 176 po sobě jdoucích pacientů sledovaných ve specializované ambulanci srdečního selhání v roce 2024. ID byl definován dle ESC (feritin < 100 µg/l nebo 100–299 µg/l při TSAT < 20 %). Simulovali jsme způsobilost k intravenózní aplikaci železa při třech prahových hodnotách Hb: ≤ 150 g/l, ≤ 155 g/l a ≤ 160 g/l. Následně jsme porovnali klinické charakteristiky způsobilých a nezpůsobilých pacientů.
**Výsledky:** Při standardním limitu Hb ≤ 150 g/l splňovalo kritéria k intravenózní terapii 29,5 % pacientů s ID. Při zvýšení limitu na 155 g/l by způsobilost vzrostla na 38,1 % a při 160 g/l na 46,7 %.
**Závěr:** Významná část pacientů s klinicky významným ID je v praxi vyloučena z intravenózní suplementace železem pouze na základě hodnoty Hb. Mírné zvýšení prahové hodnoty Hb by mohlo významně rozšířit dostupnost této léčby pro symptomatické pacienty. Výsledky podporují potřebu individualizovaného přístupu a prospektivního ověření bezpečnosti rozšířených kritérií.



*Keywords:*
Eligibility criteria
ESC guidelines
Heart failure
Hemoglobin threshold
Intravenous iron
Iron deficiency

ABSTRACT

**Background:** Intravenous iron therapy improves symptoms and reduces hospitalizations in patients with heart failure (HF) and iron deficiency (ID). Clinical trials evaluating this therapy have often excluded patients with higher hemoglobin (HGB) levels, although current European Society of Cardiology guidelines do not specify an upper HGB limit. This study aimed to assess how HGB thresholds influence eligibility for intravenous iron among real-world HF patients with left ventricular ejection fraction (LVEF) <45%.
**Methods:** We retrospectively analyzed consecutive patients attending a specialized HF outpatient clinic in 2024. ID was defined as ferritin <100 µg/L, or 100–299 µg/L with transferrin saturation (TSAT) <20%. Eligibility for intravenous iron was simulated using various HGB thresholds ranging from ≤150 g/L to ≤160 g/L. Clinical and laboratory characteristics of eligible and non-eligible patients were compared.
**Results:** Among 176 patients with LVEF <45%, 98 (55.7%) fulfilled ID criteria. Using an HGB threshold of ≤150 g/L, only 29.5% of patients were eligible for intravenous iron. Increasing the threshold to 155 g/L and 160 g/L would expand eligibility to 38.1% and 46.7%, respectively. Patients excluded based on higher HGB levels often exhibited functional ID and elevated NT-proBNP, indicating advanced HF. All patients who met the eligibility criteria during the study period received intravenous iron.
**Conclusion:** A substantial proportion of HF patients with LVEF <45% and clinically relevant ID may be excluded from intravenous iron therapy based on HGB levels, despite current guidelines not imposing a strict cutoff. A modest increase in the HGB threshold may allow more symptomatic patients to benefit from guideline-recommended treatment.

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**DOI:** 10.33678/cor.2025.093

**Please cite this article as:** Dodulík J, Podzemná K, Musiolová K, et al. Determinants of Ineligibility for Intravenous Iron Therapy in Patients with Heart Failure and LVEF <45%: A Retrospective Cohort Study. Cor Vasa 2025;67:671–676.

**Highlights:**
- Only 29.5% of HF patients with ID were eligible for IV iron at HGB ≤150 g/L.
- Raising HGB threshold to 155 and 160 g/L increased eligibility to 38.1% and 46.7%.
- Patients with functional ID and high HGB had elevated NT-proBNP levels.
- ESC guidelines do not define an upper HGB limit for IV iron therapy.
- HGB-based exclusions may limit access to beneficial iron treatment in real-world HF.

## Introduction

Iron deficiency (ID) is a common comorbidity in patients with heart failure (HF), with a reported prevalence of 30–50% in chronic HF and up to 80% in acute decompensation.[1] Importantly, ID in HF is associated with impaired functional capacity, reduced quality of life, and increased rates of hospitalization and mortality regardless of the presence of anemia.[2] Based on this evidence, intravenous iron therapy with ferric carboxymaltose has become an established treatment strategy in patients with symptomatic HF and reduced or mildly reduced left ventricular ejection fraction (LVEF).[3]

Current European Society of Cardiology (ESC) guidelines recommend that all symptomatic HF patients with LVEF <45% be screened for ID and considered for intravenous iron supplementation if ferritin is <100 µg/L or if ferritin is 100–299 µg/L with transferrin saturation (TSAT) <20%.[3]

Notably, these criteria do not define an upper limit for hemoglobin (HGB). However, all major randomized controlled trials that form the basis for this recommendation FAIR-HF, CONFIRM-HF, and AFFIRM-AHF applied specific HGB limits for patient selection.[2,4,5] For example, FAIR-HF included patients with HGB 95–135 g/L, CONFIRM-HF allowed up to 150 g/L, and IRONMAN excluded men with HGB >140 g/L and women with HGB >130 g/L.[2,4–6] Thus, while the ESC guidelines do not formally restrict treatment based on HGB, in clinical practice, these thresholds often inform eligibility decisions and drug reimbursement policies.

This creates a diagnostic and therapeutic paradox, patients with functional ID, often characterized by preserved or elevated HGB but impaired iron parameters, may be excluded from intravenous iron therapy.[7] Functional ID, typically associated with inflammation-driven hepcidin elevation, is common in HF and is clinically relevant even in the absence of anemia.[8] The prevalence and characteristics of these patients in routine outpatient practice remain underexplored.

In this retrospective cohort study, we evaluated the real-world impact of HGB thresholds on eligibility for intravenous iron therapy in patients with HF and LVEF <45%. We simulated different HGB cut-offs (150, 155, and 160 g/L) and analyzed the corresponding shifts in eligibility (**Fig. 1**). We also compared clinical and laboratory features of eligible versus non-eligible patients (**Table 1**) and explored whether excluded patients might still benefit from treatment based on markers of HF severity.

## Methods

### *Study design and setting*

This retrospective single-center cohort study was conducted at the Heart Failure Center of the Department of Internal Medicine and Cardiology, University Hospital Ostrava (the Czech Republic). The center provides specialized care to patients with chronic HF and serves as a tertiary referral facility for the Moravian-Silesian region.

### *Patient population*

We reviewed medical records of 176 consecutive outpatients with HF and LVEF <45% who were evaluated at the center between January and May 2024. All patients underwent comprehensive clinical and laboratory assessment, including standard transthoracic echocardiography (TTE) and iron metabolism profiling, during a routine follow-up visit.

### *Echocardiographic assessment*

LVEF was measured using two-dimensional TTE performed on a GE Vivid E95 ultrasound system. Examinations were conducted and interpreted by board-certified cardiologists with at least five years of echocardiography experience. LVEF was calculated using the biplane Simpson method in accordance with current recommendations.

**Table 1 – Baseline characteristics of the study population stratified by intravenous iron eligibility at hemoglobin ≤150 g/L**

| | Eligible (HGB <150 g/L) | Non-eligible (HGB >150 g/L or no ID) |
|---|---|---|
| Age | 69.0 ± 12.0 | 62.2 ± 13.4 |
| Sex (N) | Male (59), female (23) | Male (83), female (11) |
| BMI | 28.1 ± 5.9 | 29.9 ± 6.0 |
| NYHA class (N) | I (7), II (43), III (27), IV (0) | I (21), II (51), III (20), IV (0) |
| LVEF | 30.0 ± 7.3 | 29.7 ± 7.5 |
| HGB | 133.59 ± 13.7 | 159.2 ± 13.4 |
| Ferritin | 120.0 ± 82.1 | 142.5 ± 131.3 |
| TSAT | 20.0% ± 10.0% | 30.0% ± 10.0% |
| NTproBNP | 1500.7 ± 825.6 | 970.0 ± 540.2 |

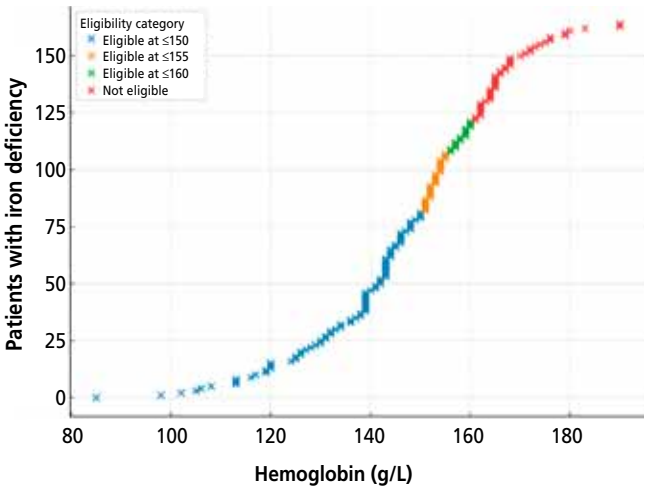


**Fig. 1 – Impact of hemoglobin threshold on eligibility for intravenous iron therapy.** Each dot represents one patient with iron deficiency (ID). The x-axis shows hemoglobin levels (g/L). Colors denote eligibility status under different thresholds: blue (eligible at ≤150 g/L), orange (newly eligible at ≤155 g/L), green (newly eligible at ≤160 g/L), and red (not eligible). This visualization highlights the incremental expansion of eligibility with increasing hemoglobin (HGB) thresholds.

### *Laboratory parameters and definitions*

Blood samples were collected on the same day as echocardiographic evaluation. Iron status was assessed using serum ferritin and TSAT. HGB concentration and NT-proBNP levels were also recorded. Functional ID was defined according to ESC 2021 guidelines as ferritin <100 µg/L, or ferritin 100–300 µg/L with TSAT <20%.[3]

Values for HGB, ferritin, and TSAT were used to evaluate eligibility for intravenous iron therapy. The distribution of HGB was analyzed in 5 g/L intervals from <100 g/L to >160 g/L (**Table 1**). Ferritin was categorized as <100, 100–299, or ≥300 µg/L, and TSAT as <20% or ≥20% (**Table 2**).

To evaluate the impact of HGB thresholds on intravenous iron eligibility, a simulation model was developed. Patients with ID (absolute or functional) were stratified according to three HGB cut-off values: ≤150 g/L, ≤155 g/L, and ≤160 g/L. For each cut-off, the number and proportion of patients deemed eligible for intravenous iron were calculated relative to both the entire cohort and the ID subgroup. A summary of eligibility rates across HGB thresholds is presented in **Figure 1**.

All patients who met the criteria for intravenous iron therapy during the analyzed period were treated with ferric carboxymaltose according to national reimbursement standards. This study did not include outcome assessment such as hospitalization or mortality due to its retrospective, exploratory design.

**Table 2 – Distribution of ferritin and transferrin saturation categories in the full cohort**

| Category | N (patients) | % of total |
|---|---|---|
| Ferritin <100 µg/L | 84 | 47.7% |
| Ferritin 100–299 µg/L | 81 | 46.0% |
| Ferritin ≥300 µg/L | 11 | 6.2% |
| TSAT <20% | 64 | 36.4% |
| TSAT >20% | 112 | 63.6% |

### *Outcomes and statistical analysis*

The primary outcome was the proportion of patients who met ESC criteria for IV iron therapy. The secondary outcome was the change in eligibility rates if the HGB threshold were relaxed > 150 g/L. Patient characteristics were compared between eligible and non-eligible groups using descriptive statistics. Continuous variables were presented as means with standard deviation (SD) or medians with interquartile ranges (IQR), depending on distribution. Group comparisons were performed using t-tests or Mann–Whitney U-tests as appropriate. A binary logistic regression model was constructed to identify predictors of ineligibility. The model included age, sex, body mass index (BMI), NT-proBNP, and HGB >150 g/L as covariates. Statistical analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY), and *p*-values <0.05 were considered statistically significant.

### *Ethics and data protection*

The study protocol was reviewed by the Institutional Ethics Committee of University Hospital Ostrava, which waived the requirement for individual informed consent due to the retrospective and anonymized nature of the analysis. All data were handled in accordance with the General Data Protection Regulation (GDPR, EU 2016/679). Patient records were fully anonymized prior to analysis, and no identifiable personal information was retained.

## Results

### *Baseline characteristics*

A total of 176 patients with LVEF <45% were included. The mean HGB level in the entire cohort was 142.5 ± 15.1 g/L. The majority of patients were male (80.68%) and in NYHA functional class II or III at the time of evaluation. The mean LVEF was 38.9 ± 5.2%. A detailed overview of baseline characteristics, including stratification by eligibility for intravenous iron at a HGB threshold of ≤150 g/L, is presented in **Table 1**.

Among all patients, 165 (93.8%) met the criteria for ID. Absolute ID (ferritin <100 µg/L) was present in 82 patients (46.6%), while functional ID (ferritin 100–299 µg/L and TSAT <20%) was identified in 83 patients (47.2%). Only 11 patients (6.2%) had no evidence of ID. The distribution of ferritin and TSAT across the cohort is shown in **Table 2** and **Figures 2** and **3**.

### *Eligibility for intravenous iron therapy*

Using the standard clinical threshold of HGB ≤150 g/L, only 82 out of 165 ID patients (49.7%) were eligible for intravenous iron therapy, representing 46.6% of the entire cohort. When the HGB cut-off was increased to 155 g/L, eligibility rose to 108 patients (65.5% of ID patients, 61.4% of the total cohort). At 160 g/L, eligibility increased to 122 patients (73.9% and 69.3%, respectively). These findings are illustrated in **Figure 1**.

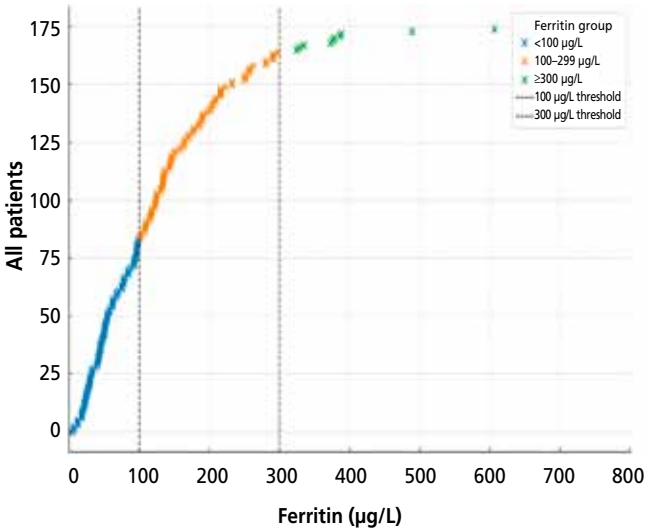


**Fig. 2 – Distribution of ferritin levels among all patients in the cohort.** Each cross represents one patient. Patients are color-coded according to ESC-relevant ferritin categories: <100 µg/L (absolute ID), 100–299 µg/L (functional ID), and ≥300 µg/L (no ID). Vertical dashed lines indicate ferritin thresholds at 100 and 300 µg/L.

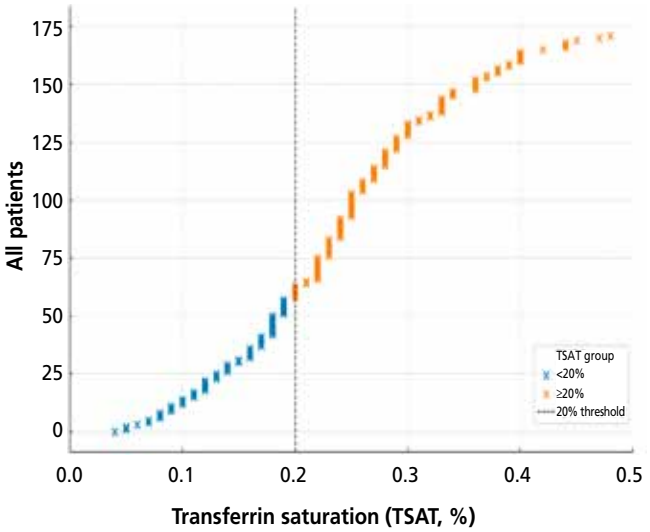


**Fig. 3 – Distribution of transferrin saturation (TSAT) levels among patients with iron deficiency.** Each dot represents one patient with iron deficiency. TSAT values (%) are plotted along the x-axis. Color-coding distinguishes patients below (<20%) and above (≥20%) the ESC diagnostic threshold. This figure demonstrates that the majority of patients with iron deficiency fall below the TSAT cut-off of 20%.

A detailed breakdown of patient distribution across 5 g/L HGB intervals revealed that patients with preserved or elevated HGB (≥151 g/L) made up a substantial subgroup with ID (**Table 3**). Specifically, 43.6% of ID patients had HGB between 151–160 g/L.

### *Clinical and laboratory profile of eligible vs. non-eligible patients*

**Table 1** compares key clinical and laboratory parameters between ID patients eligible vs. ineligible for intravenous iron therapy using the standard HGB threshold of ≤150 g/L. Eligible patients had significantly lower TSAT (17.6 ± 9.3% vs. 25.8 ± 11.5%, $p$ <0.01), ferritin (92.4 ± 45.2 µg/L vs. 182.6 ± 70.1 µg/L, $p$ <0.001), and HGB (132.4 ± 10.2 g/L vs. 155.1 ± 9.4 g/L, $p$ <0.001), and had higher NT-proBNP levels (1500.7 ± 825.6 ng/L vs. 970.0 ± 540.2 ng/L, $p$ = 0.027).

These findings suggest that excluded patients despite having elevated HGB frequently exhibit functional ID and moderately elevated markers of HF severity.

### *Sensitivity analysis across simulated thresholds*

A sensitivity analysis exploring the shift in eligibility across increasing HGB thresholds is presented in **Table 4**. The proportion of ID patients classified as eligible increased incrementally by 8–9% per 5 g/L increase in the HGB cut-off between 150 and 160 g/L. This stepwise progression suggests that HGB is a key modifier of access to intravenous iron in clinical practice, even in the absence of formal guideline constraints.

## Discussion

This retrospective cohort study included 176 patients with HF and LVEF <45%. ID was present in 93.8% of patients. However, only 49.7% of ID individuals met the eligibility criteria for intravenous iron therapy when applying a HGB cut-off of ≤150 g/L.

Increasing the HGB threshold to 155 and 160 g/L expanded eligibility to 65.5% and 73.9% of ID patients, respectively. Notably, patients ineligible due to higher HGB frequently exhibited laboratory and clinical signs of functional ID, including lower TSAT and higher NT-proBNP levels, suggesting they may still derive therapeutic benefit (**Fig. 1**, **Tables 1, 3, 4**).

These findings align with the known high prevalence of ID in HF, observed in up to 50% of chronic and 80% of acutely decompensated patients.[1] ID in HF is an independent predictor of reduced exercise capacity, poorer quality of life, and higher hospitalization and mortality risk even in the absence of anemia.[4] Clinical trials such as FAIR-HF,[2] CONFIRM-HF,[5] and AFFIRM-AHF[3] established the efficacy and safety of ferric carboxymaltose in this setting, which led to the 2021 ESC guideline recommendation to screen for and treat ID in all symptomatic HF patients with LVEF <45%.[6]

Importantly, ESC guidelines do not specify any upper limit of HGB for treatment indication.[6] However, all landmark trials informing this recommendation used HGB-based exclusion criteria: FAIR-HF enrolled patients with HGB 95–135 g/L,[2] CONFIRM-HF allowed up to 150 g/L,[5] and IRONMAN excluded men with HGB >140 g/L and women with HGB >130 g/L.[9] These criteria, although not formalized in ESC guidelines, are routinely used in clinical practice and embedded in national reimbursement rules. In the Czech Republic, for example, intravenous iron is reimbursed only for patients fitting the studied population of pivotal trials, typically with HGB ≤150 g/L. Moreover, the Summary of Product Characteristics (SmPC) for ferric carboxymaltose refers to these same inclusion parameters.[7]

**Table 3 – Distribution of patients by hemoglobin intervals (in 5 g/L steps)**

| HGB interval (g/L) | N (patients) | % of total |
|---|---|---|
| 80–84 | 1 | 0.6% |
| 85–89 | 0 | 0% |
| 90–94 | 0 | 0% |
| 95–99 | 2 | 1.1% |
| 100–104 | 2 | 1.1% |
| 105–109 | 2 | 1.1% |
| 110–114 | 3 | 1.7% |
| 115–119 | 8 | 4.5% |
| 120–124 | 4 | 2.3% |
| 125–129 | 8 | 4.5% |
| 130–134 | 7 | 4.0% |
| 135–139 | 16 | 9.1% |
| 140–144 | 22 | 12.5% |
| 145–149 | 15 | 8.5% |
| 150–154 | 26 | 14.8% |
| 155–159 | 16 | 9.1% |
| 160–164 | 21 | 11.9% |
| 165–169 | 9 | 5.1% |
| 170–174 | 6 | 3.4% |
| 175–179 | 5 | 2.8% |
| 180–184 | 1 | 0.6% |
| 185–189 | 2 | 1.1% |
| >190 | 0 | 0% |

This discrepancy between evidence-based recommendations and practice-driven constraints may lead to under-treatment. Our results indicate that patients with preserved or even elevated HGB can still exhibit significant functional ID and clinical instability, as reflected by high NT-proBNP values. This supports previous observations that anemia represents a late consequence of ID, and that earlier identification and intervention are warranted.[8] A rigid interpretation of HGB thresholds may thus prevent eligible patients from receiving potentially beneficial therapy.

Expanding the HGB cut-off to 155 or 160 g/L would modestly but meaningfully increase treatment access, potentially by 8–9% per 5 g/L step. Given the high prevalence of functional ID and its established prognostic value,[10] these patients may benefit from IV iron, even in the absence of anemia. We propose that eligibility criteria should reflect a more individualized and pathophysiologically guided approach.

However, this suggestion must be balanced with caution. Elevated HGB levels have been associated with increased thrombotic risk in other settings, and concerns regarding iron overload and free radical generation persist.[11] Although ferric carboxymaltose has demonstrated a favorable safety profile in the studied populations,[2,3,5] the safety of expanding therapy to patients with higher baseline HGB has not been prospectively validated. Moreover, the risk of subclinical hemochromatosis, particularly in individuals with *HFE* mutations, cannot be excluded in the absence of genetic screening.

This study has several limitations. First, its retrospective and single-center nature limits generalizability. Second, we did not include follow-up outcomes such as hospitalization or mortality, which would be necessary to support clinical benefit. Third, the simulation of HGB thresholds is hypothetical, and cannot be interpreted as evidence for guideline revision. Lastly, markers of inflammation and iron homeostasis such as CRP, hepcidin, and soluble transferrin receptor were not systematically measured.

Nevertheless, our results generate a clinically relevant hypothesis, that expanding HGB-based eligibility criteria may uncover a symptomatic subgroup of HF patients with functional ID who are currently undertreated. This concept warrants prospective investigation in larger multicenter studies.

## Future directions

The present study identified HGB concentration above 150 g/L as the most frequent reason for ineligibility for IV iron therapy among patients with HF and a LVEF below 45%. While our simulation suggests that modest adjustment of this threshold could expand access to treatment, these findings remain exploratory and require prospective validation.

To address these limitations, a multicenter observational study is currently being initiated. This study will enroll 400 patients with LVEF <45% and evaluate not only classical markers of iron status (ferritin, TSAT, HGB), but also key confounders known to influence iron metabolism. These include renal function, systemic inflammation (C-reactive protein, interleukin-6), nutritional markers (albumin, vitamin C levels), and pharmacological agents such as proton pump inhibitors, antiplatelet therapy, anticoagulants and diuretics.[13,14]

In addition, emerging evidence highlights the importance of genetic factors such as HFE mutations (*C282Y, H63D*) in altering iron indices without true deficiency, especially in Central European populations.[15] The use of advanced biomarkers like soluble transferrin receptor (sTfR) and hepcidin is also under consideration to improve identification of functional ID not captured by traditional thresholds.[16,17]

Lastly, low adherence to guideline-recommended IV iron therapy remains a persistent issue in clinical practi-

**Table 4 – Sensitivity analysis of eligibility based on hemoglobin cut-off thresholds**

| HGB cut-off (g/L) | New eligibility (N) | Cumulative eligible (N) | % of total |
|---|---|---|---|
| ≤150 | 82 | 82 | 46.6% |
| 151–155 | 26 | 108 | 61.4% |
| 156–160 | 14 | 122 | 69.3% |

ce, even among eligible patients.[18,19] Understanding the barriers to implementation, including logistical, economic, and clinician-related factors, will be essential for improving uptake and patient outcomes. The forthcoming study will incorporate longitudinal follow-up and collect outcome data including hospitalization, NYHA class, and mortality to clarify whether revised eligibility criteria, especially regarding HGB, can be applied safely and effectively in broader clinical populations.

## Conclusions

In this retrospective cohort of patients with HF and LVEF <45%, ID was highly prevalent, yet nearly half of affected individuals were ineligible for intravenous iron therapy when a HGB threshold of ≤150 g/L was applied. Our findings demonstrate that modest increases in this threshold substantially expand treatment eligibility without compromising the identification of clinically relevant ID.

Patients excluded solely based on elevated HGB levels frequently exhibited laboratory features of functional ID and neurohumoral activation, suggesting a potentially unmet therapeutic need. Although ESC guidelines do not restrict intravenous iron therapy based on HGB, reimbursement policies and regulatory frameworks continue to reflect trial-based thresholds.

These findings highlight the need for a more individualized, physiology-driven approach to intravenous iron eligibility in HF. Prospective studies are warranted to determine the safety and efficacy of expanding current treatment criteria to patients with preserved or elevated HGB levels who nonetheless exhibit biochemical ID and clinical instability.

### CRediT author statement

Jozef Dodulík: Conceptualization, data curation, formal analysis, writing – original draft, project administration; Kristýna Podzemná: Data acquisition, investigation, writing – review & editing; Klára Musiolová: Data acquisition; Jiří Plášek: Visualization, validation, writing – review & editing; Jiří Vrtal: Methodology, supervision, resources; Jan Václavík: Supervision, critical revision, final approval.

### Conflict of interest

The authors declare that they have no competing interests.

### Funding

This research received no external funding.

### Ethical statement and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. The research protocol was approved by the Ethics Committee of the University Hospital Ostrava (Reference No. 150/2025). Due to the retrospective and anonymized nature of the analysis, the requirement for individual informed consent was waived by the Ethics Commitee.

### Consent for publication

Not applicable.

### Acknowledgments

The authors thank the staff of the Heart Failure Unit at University Hospital Ostrava for their contribution to patient care and data collection.

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