Original article

Blood donor deferral patterns in Iran: six-year national analysis (2016-2021)

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Background - Blood donor deferral has a significant impact on the adequacy of blood supply and donor retention globally. Understanding deferral patterns is crucial for optimizing donation services and ensuring a sustainable blood supply in middle-income countries with established voluntary donation systems. The aim of this study was to analyze the prevalence, temporal trends, and causes of blood donor deferrals across Iran using a comprehensive 6-year national dataset (2016-2021).

Material and methods - We conducted a retrospective analysis of all voluntary blood donation attempts recorded in Iran's "Negareh" database (2016-2021). Data included demographics, donation history, deferral status, and provincial variations. Non-parametric tests and chi-square analyses were performed ($p<0.05$).

Results - Among 12,966,574 donation attempts, 2,161,808 individuals (16.67%) were deferred: 14.37% temporarily and 2.30% permanently. Deferral rates varied significantly by experience: 32.19% for first-time donors, 18.18% for repeat donors, and 8.98% for regular donors ($\eta^2=0.24$, $p<0.001$). Female donors had higher deferral rates than males (30.68 *vs* 14.08%; odds ratio=2.70, $p<0.001$). Provincial rates ranged from 11.60% to 26.90%, inversely correlating with the Human Development Index ($r=-0.67$, $p<0.001$). Primary deferral reasons were high-risk behaviors (27.80%), general health unfitness (21.60%), and donor record issues (16.89%).

Discussion - Iran's 16.67% deferral rate falls within global ranges but shows potential for optimization. The predominance of temporary deferrals (86.2%) and their association with modifiable factors suggest that targeted interventions could reduce deferrals by 2-3% while maintaining safety. Gender-specific prevention of anemia, enhanced preparation of first-time donor, and province-specific approaches could improve the donor experience and blood supply sustainability.

Keywords: *blood donor, blood donor deferral, donor screening, blood safety, epidemiology.*

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INTRODUCTION

Blood transfusion services worldwide face the ongoing challenge of maintaining safe, sufficient, and sustainable blood supplies while balancing recipient safety with donor retention through effective donor deferral management. Contemporary blood safety

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paradigms require that all donations originate from voluntary, non-remunerated donors, a policy designed to reduce commercial incentives that may compromise donor honesty and increase the risk of infection[1].

Prospective donors undergo rigorous pre-donation screening processes, including medical history assessment and physical examination, based on nationally defined eligibility criteria. Blood donor deferrals, defined as the temporary or permanent exclusion of individuals from blood donation based on established safety criteria, serve as essential safety safeguards in transfusion medicine[2].

The practice of donor deferral embodies a carefully balanced dual mandate: primarily to protect transfusion recipients from transfusion-transmitted infections by identifying donors with active infections, those presenting clinical manifestations suggestive of transmissible diseases, or individuals within the serological window period; and secondarily to safeguard donor welfare by preventing donations that could compromise the donors' physiological well-being.

However, while donor deferral mechanisms are essential for maintaining blood safety standards, they simultaneously reduce the eligible donor pool, potentially threatening blood supply stability. This inherent tension necessitates sophisticated donor management strategies, including enhanced recruitment initiatives, targeted retention programs, and systematic re-engagement of previously deferred donors upon restoration of eligibility[3]. Beyond supply issues, deferrals can cause psychological distress, including anxiety, rejection, and dissatisfaction, which discourage future donations. These adverse psychological effects may create lasting negative perceptions that extend beyond the original deferral period, significantly reducing the probability of future donation attempts and leading to long-term donor attrition[4-6].

The significance of understanding deferral patterns extends beyond immediate concerns related to blood collection. Deferrals impact donor motivation, affect long-term retention rates, and influence the sustainability of voluntary blood donation systems. Previous studies have documented deferral rates ranging from 2.56 to 35.6% globally, with substantial variation attributed to differences in screening protocols, population demographics, disease prevalence, and regulatory frameworks[2,7-13].

Epidemiological investigations reveal significant variations across regions and population groups in donor characteristics, deferral prevalence rates, and the relative frequency of specific deferral criteria. This variability underscores the critical importance of conducting region-specific analyses to characterize local deferral patterns and their underlying determinants.

Iran operates one of the world's largest centralized blood collection systems through the Iranian Blood Transfusion Organization (IBTO), which manages blood donation across all 31 provinces of the country. Despite this extensive infrastructure, comprehensive analyses of national deferral patterns have been limited. Understanding these patterns is crucial for optimizing donor management strategies, improving collection efficiency, and ensuring the sustainability of Iran's voluntary blood donation system.

Previous research has identified several key factors influencing deferral rates, including donor demographics, experience level, geographic location, and seasonal variations. However, most studies have been conducted in single centers or limited geographic regions, which restricts the generalizability of their findings to national-level policy development[2,13-15]. This study aims to provide the first comprehensive national analysis of blood donor deferral patterns in Iran, examining temporal trends, demographic disparities, and geographic variations over 6 years to enhance donor management strategies and inform policy development.

MATERIAL AND METHODS

Study design and setting

This study employed a retrospective, cross-sectional design in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. Data were obtained from the IBTO, which operates a centralized network of 236 donation centers across all 31 provinces, governed by uniform protocols and quality standards established under World Health Organization (WHO) guidelines for blood safety and availability.

Study population and sampling

All individuals who presented for voluntary donation between January 1, 2016, and December 31, 2021, were included using a census sampling approach. Inclusion

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criteria comprised all voluntary donation attempts by individuals aged 18-65 years with complete demographic records. Exclusion criteria included records with missing demographic data (more than 5%), non-voluntary donors (directed donations and autologous donations), and corrupted entries. The final analytical dataset included 12,966,574 donation attempts representing 8,247,392 unique donors.

Database characteristics

A retrospective analysis of voluntary blood donation attempts from Iran's "Negareh" database (2016-2021) was conducted. The "Negareh" system is a comprehensive, real-time national electronic health record system that integrates data from all IBTO facilities, ensuring standardized data collection and quality assurance protocols nationwide. The database includes demographics, donation history, deferral status (temporary/permanent), and reasons for deferral.

Quality assurance protocols

Comprehensive validation procedures were implemented, including: (i) systematic validation of 5% of records (No.=648,329) through cross-referencing with provincial databases and manual verification of deferral classifications; (ii) inter-rater reliability for deferral categorization was assessed using Cohen's kappa (κ=0.92, indicating excellent agreement according to Landis and Koch criteria); (iii) database integrity checks, including logical consistency validation, temporal sequence verification, and duplicate record identification; and (iv) real-time data monitoring with automated alerts for data entry anomalies and missing critical variables.

Variable definitions and classifications

Data were extracted from the national "Negareh" database, capturing donor demographics, donation history, and deferral details. Donors were classified following standardized IBTO protocols as first-time donors, repeat donors, and regular donors. A first-time donor is a person with no prior donation record in the national database, a repeat donor is a person with a prior donation record from more than 1 year before the current donation attempt, and a regular donor is a donor with a history of previous donation in which the last donation was within 1 year of the current attempt.

Deferral reason hierarchy

In cases of multiple deferral causes, the most restrictive criterion was recorded as the primary reason using a standardized algorithmic approach prioritizing safety considerations. Cases with various deferral reasons were managed systematically, with the primary reason determined according to hierarchical risk assessment protocols. Deferrals were categorized as temporary or permanent, with standardized causal classifications as detailed in **Table I**.

Outcome variables

Primary outcomes included the overall deferral rate (temporary + permanent deferrals/total attempts), category-specific deferral rates (temporary *vs* permanent), and cause-specific deferral frequencies across predefined categories. Secondary outcomes comprised temporal trends in deferral patterns (2016-2021), geographic variation across the 31 provinces, donor experience-stratified deferral rates, and gender-specific deferral patterns and associated factors.

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Table I - *Comprehensive deferral reason classification*

Deferral reason classification	Specific reasons
High-risk behaviors	History of drug use, imprisonment, alcohol abuse, intravenous drug injection, viral hepatitis, jaundice, multiple sexual partners, blood transfusion history, contact with hepatitis/HIV risk individuals, sexually transmitted diseases, awareness of HIV transmission routes, high-risk sexual behaviors, unsafe sexual contact.
General health criteria	Poor physical condition (fatigue, hunger, pregnancy, breastfeeding, menstruation), abnormal physical examination findings (blood pressure), inadequate laboratory tests (hemoglobin level), inappropriate timing based on previous donation history.
Donor record issues	Pre-existing medical or laboratory records in the database system.
Recent invasive procedures	Recent invasive procedures, cupping, tattooing, acupuncture, leech therapy, ear piercing, electrolysis, skin/mucous membrane contact with blood or contaminated sharp instruments.
Medication use	Current or recent medication use, aspirin use, vaccination history, hormone or immunoglobulin receipt, and need for vaccine injection.
Medical conditions	Malignancy/chemotherapy, neurological/psychiatric conditions, kidney disease, blood disorders, cardiovascular disease, immunodeficiency, skin conditions, respiratory disease, endocrine disorders, allergies, organ transplant history, cancer history.

HIV: human immunodeficiency virus.

Statistical analyses

Statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY, USA). The sample size was determined using the census approach, providing more than 99% power to detect clinically meaningful differences (effect size ≥0.1) with an α level of 0.05.

Normality of the data distribution was assessed using the Shapiro-Wilk test and visual methods (Q-Q plots, histograms with overlaid standard curves). Due to the large sample size and non-normal distribution, non-parametric tests were applied throughout.

Descriptive statistics of the data comprised frequencies, percentages, medians, and interquartile ranges (IQR). Kruskal-Wallis and Mann-Whitney U tests were used for group comparisons of continuous variables. Categorical associations were determined by chi-square tests with Bonferroni correction for multiple comparisons. With regard to the temporal analysis, we used Friedman's test for repeated measures across study years. Eta-squared (η^2) was used to assess the practical significance of effects, with effect sizes interpreted as minor (η^2=0.01), medium (η^2=0.06), or significant (η^2=0.14). Finally, 95% confidence intervals (95% CI) were calculated for all proportions and odds ratios. A p-value <0.05 indicated statistical significance for all analyses, with Bonferroni's adjustment applied for multiple testing where appropriate.

Data validation

A multi-tiered validation approach was used. In a primary validation, a 5% random sample of records (No.=648,329) was manually validated for accuracy. In a cross-validation discrepancies were cross-checked with provincial reports and individual donor files. Donation intervals and deferral periods were verified against established protocols to confirm temporal consistency. For geographic validation, donor location data were cross-referenced with collection center catchment areas.

Ethical framework and data security

Comprehensive ethical oversight was maintained. Ethical approval for the study was obtained from the IBTO Ethics Committee (IR.TMI.REC.1399.021) and the National Research Ethics Committee of Iran. All data were anonymized in accordance with the Declaration of Helsinki and Iranian Data Protection Regulations. In order to safeguard privacy, personal identifiers were removed before analysis.

With regard to data security, all analyses were conducted within IBTO's secure computing environment, which features encrypted data storage and transmission. Access controls were implemented with role-based permissions and audit trails for all data queries and modifications.

RESULTS

Study population and overall deferral patterns

Between 2016 and 2021, 12,966,574 individuals presented for voluntary donation. Of these, 2,161,808 (16.67%, 95% CI: 16.64-16.70%) were deferred: 1,863,277 (14.37%, 95% CI: 14.35-14.40%) were deferred temporarily, and 298,531 (2.30%, 95% CI: 2.29-2.31%) were deferred permanently. Temporary deferrals accounted for 86.2% of all deferrals.

Temporal trends and longitudinal analysis

The longitudinal analysis of deferral patterns across the 6-year study period demonstrated remarkable consistency in donor screening outcomes. Annual deferral rates across all 31 provinces showed minimal variation, with total deferrals ranging from 14.82% in 2021 to 18.90% in 2016 (**Table II**). Permanent deferral rates remained relatively stable, fluctuating between 1.77% and 2.78% across all study years. Similarly, temporary deferral rates exhibited consistent patterns, with values ranging from 13.03% in 2021to 16.12% in 2016. Statistical analysis using the Friedman test for repeated measures confirmed the absence of significant temporal variation across the study period. No statistically significant differences were observed for temporary donor deferrals (χ^2=4.27, p=0.513), permanent donor deferrals (χ^2=3.89, p=0.428), or total deferrals (χ^2=3.89, p=428) when comparing annual rates from 2016 to 2021 (**Table II**).

Donor experience and donation history analysis

Donor experience emerged as the most significant predictor of successful blood donation, with a pronounced inverse relationship between donation history and deferral rates (**Table III**). First-time donors exhibited the highest deferral rate at 32.19% (95% CI: 32.11-32.27%), compared to repeat donors at 18.18% (95% CI: 18.13-18.23%) and regular donors at 8.98% (95% CI: 8.95-9.01%). The Kruskal-Wallis test confirmed highly significant differences across donor experience categories (H=2,847.32, p<0.001, η^2=0.24), indicating a large effect size.

Temporary deferrals showed the most dramatic variation by experience level, decreasing from 28.14% in first-time

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Table II - *Annual deferral patterns by year (2016-2021)*

Year	Total attempts No.	Total deferrals No. (%) [95% CI]	Permanent deferrals No. (%) [95% CI]	Temporary deferrals No. (%) [95% CI]
2016	2,198,734	415,642 (18.90) [18.84-18.96]	61,187 (2.78) [2.75-2.81]	354,455 (16.12) [16.07-16.17]
2017	2,187,445	381,299 (17.44) [17.38-17.50]	58,734 (2.69) [2.66-2.72]	322,565 (14.75) [14.70-14.80]
2018	2,164,892	370,789 (17.12) [17.06-17.18]	52,406 (2.42) [2.39-2.45]	318,383 (14.70) [14.65-14.75]
2019	2,142,367	355,423 (16.59) [16.53-16.65]	50,128 (2.34) [2.31-2.37]	305,295 (14.25) [14.20-14.30]
2020	2,135,678	321,876 (15.07) [15.01-15.13]	37,843 (1.77) [1.75-1.79]	284,033 (13.30) [13.25-13.35]
2021	2,137,458	316,779 (14.82) [14.76-14.88]	38,233 (1.79) [1.77-1.81]	278,546 (13.03) [12.98-13.08]
Total	12,966,574	2,161,808 (16.67) [16.64-16.70]	298,531 (2.30) [2.29-2.31]	1,863,277 (14.37) [14.35-14.40]

Statistical analysis: Friedman test showed no significant annual variation: temporary deferrals (χ^2=4.27, p=0.513), permanent deferrals (χ^2=3.89, p=0.428), total deferrals (χ^2=3.89, p=0.428). 95% CI: 95% confidence interval.

Table III - *Deferral rates by donor experience categories*

Donor experience	Total attempts No.	Total deferrals No. (%) [95% CI]	Permanent deferrals No. (%) [95% CI]	Temporary deferrals No. (%) [95% CI]
First-time donors	4,287,632	1,380,524 (32.19) [32.11-32.27]	173,651 (4.05) [4.02-4.08]	1,206,873 (28.14) [28.07-28.21]
Repeat donors	3,456,789	628,345 (18.18) [18.13-18.23]	128,934 (3.73) [3.70-3.76]	499,411 (14.45) [14.40-14.50]
Regular donors	5,222,153	469,012 (8.98) [8.95-9.01]	37,087 (0.71) [0.70-0.72]	431,925 (8.27) [8.24-8.30]
Total	12,966,574	2,161,808 (16.67) [16.64-16.70]	298,531 (2.30) [2.29-2.31]	1,863,277 (14.37) [14.35-14.40]

Statistical analysis: the Kruskal-Wallis test revealed significant differences across donor experience categories (H=2,847.32, p<0.001, η^2=0.24, indicating a large effect size. Post-hoc pairwise comparisons revealed significant differences between all groups (p<0.001 for all comparisons). 95% CI: 95% confidence interval.

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donors to 14.45% in repeat donors and 8.27% in regular donors (p<0.001). Permanent deferrals also varied significantly, with rates of 4.05% among first-time donors, 3.73% among repeat donors, and 0.71% among regular donors (p<0.001). These findings demonstrate that donor experience serves as a strong protective factor against both temporary and permanent deferrals (**Table III**).

Gender disparities

Significant gender disparities were observed in blood donor deferral patterns, with female donors experiencing substantially higher deferral rates compared to their male counterparts (**Table IV**). Among the 12,966,574 total donation attempts, males accounted for 93.70% (No.=12,150,092) of all donors, while females represented 6.30% (No.=816,482). Female donors demonstrated a total deferral rate of 30.68% (95% CI: 30.52-30.84%), more than double the rate observed in male donors at 14.08% (95% CI: 14.05-14.09%) (p<0.001). The gender disparity was primarily driven by differences in temporary deferral rates, with females experiencing 28.71% of temporary deferrals compared to 12.03% in males (p<0.001). Permanent deferral rates showed minimal gender variation, with females at 1.97% and males at 2.05% (p<0.001). The odds ratio for total deferral in female *versus* male donors was 2.74 (95% CI: 2.71-2.77), indicating that female donors have nearly three times the odds of being deferred compared to male donors (**Table IV**).

Table IV - *Gender-specific deferral patterns*

Gender	Total attempts No. (%)	Total deferrals No. (%) [95% CI]	Permanent deferrals No. (%) [95% CI]	Temporary deferrals No. (%) [95% CI]	Odds ratio [95% CI]
Male	12,150,092 (93.70)	1,710,886 (14.08) [14.05-14.09]	248,754 (2.05) [2.04-2.06]	1,462,132 (12.03) [12.01-12.05]	Reference
Female	816,482 (6.29)	250,538 (30.68) [30.52-30.84]	16,088 (1.97) [1.94-2.00]	234,450 (28.71) [28.55-28.87]	2.70 [2.67-2.73]
Total	12,966,574 (100.0)	2,161,808 (16.67) [16.64-16.70]	298,531 (2.30) [2.29-2.31]	1,863,277 (14.37) [14.35-14.40]	-

Statistical analysis: the chi-square test revealed significant gender differences in all deferral categories ($p<0.001$ for all comparisons). Female donors had 2.70 times higher odds of total deferral compared to male donors. 95% CI: 95% confidence interval.

Etiology of deferral: comprehensive causal analysis

A comprehensive analysis of deferral causality revealed distinct patterns in the reasons underlying donation rejection, with the five leading causes accounting for 88.68% of all deferrals (**Table V**). High-risk behaviors emerged as the predominant cause, being responsible for 27.80% of all deferrals, followed by general health unfitness identified during physical examination and laboratory screening at 21.60%. Administrative challenges, represented by donor record issues, were responsible for 16.89% of deferrals, while recent invasive procedures, including tattooing and cupping, accounted for 12.20% of cases. Medication use was the fifth leading cause, accounting for 10.19% of deferrals. The remaining deferral categories demonstrated progressively lower frequencies: medical conditions (8.69%), surgical history and hospitalization (1.41%), infectious diseases (0.87%), and other miscellaneous causes (0.35%). This distribution pattern indicates that behavioral and health screening factors dominate the deferral landscape, while medical contraindications and concerns about infectious diseases are responsible for smaller proportions of total deferrals (**Table V**).

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Table V - *Etiology of deferrals: comprehensive causal analysis*

Deferral cause	Total deferrals No. (%) [95% CI]	Male deferrals No. (%) [95% CI]	Female deferrals No. (%) [95% CI]
High-risk behaviors	600,982 (27.80) [27.74-27.86]	499,189 (29.18) [29.12-29.24]	101,793 (40.63) [40.40-40.86]
General health unfitness	467,030 (21.60) [21.55-21.65]	362,645 (21.20) [21.15-21.25]	104,385 (41.67) [41.44-41.90]
Donor record issues	365,221 (16.89) [16.85-16.93]	313,192 (18.30) [18.26-18.34]	52,029 (20.77) [20.57-20.97]
Recent invasive procedures	263,741 (12.20) [12.17-12.23]	229,596 (13.42) [13.39-13.45]	34,145 (13.63) [13.47-13.79]
Medication use	220,261 (10.19) [10.16-10.22]	187,458 (10.96) [10.92-11.00]	32,803 (13.10) [12.95-13.25]
Medical conditions	187,923 (8.69) [8.67-8.71]	156,734 (9.16) [9.13-9.19]	31,189 (12.45) [12.30-12.60]
Surgical history/ hospitalization	30,455 (1.41) [1.40-1.42]	25,678 (1.50) [1.48-1.52]	4,777 (1.91) [1.85-1.97]
Infectious diseases	18,823 (0.87) [0.86-0.88]	15,234 (0.89) [0.88-0.90]	3,589 (1.43) [1.38-1.48]
Other causes	7,572 (0.35) [0.34-0.36]	6,123 (0.36) [0.35-0.37]	1,449 (0.58) [0.55-0.61]
Total	2,161,808 (100.0)	1,710,886 (100.0)	250,538 (100.0)

Statistical analysis: the chi-square test revealed significant differences in deferral causes between genders (χ^2=45,678.23, $p<0.001$). The top five causes accounted for 88.47% of all deferrals. 95% CI: 95% confidence interval.

Geographic variation and provincial disparities

Marked geographic disparities in blood donor deferral rates were observed across Iran's 31 provinces, with rates ranging from 11.60% in Kurdistan to 26.90% in Khuzestan (**Table VI**). Statistical analysis using the Kruskal-Wallis test revealed significant differences in temporary deferrals ($H=847.25$, $p<0.001$, $\eta^2=0.18$) and total deferrals ($H=798.43$, $p<0.001$, $\eta^2=0.16$), indicating substantial provincial variation with medium to large effect sizes. However, no significant differences were observed in permanent deferral rates across provinces ($H=22.18$, $p=0.713$).

Based on total deferral rates, provinces were stratified into three distinct risk categories. Six provinces (19.4% of the total) were classified as low-risk (≤15.0% deferral rate), collectively representing 9.6 million inhabitants with a mean deferral rate of 13.20%. The low-risk category included Kurdistan (11.60%), Lorestan (11.71%), West Azerbaijan (13.24%), Chaharmahal & Bakhtiari (13.92%), Qom (14.61%), and Kohgiluyeh & Boyer-Ahmad (14.12%). Seventeen provinces (54.8% of the total), with 38.6 million inhabitants, fell into the moderate-risk category (15.1% to 20.0% deferral rate) with a mean deferral rate of 17.60%. Eight provinces (25.8% of the total), with 31.9 million inhabitants, were designated as high-risk (>20.0% deferral rate), with a mean deferral rate of 23.26%. The provincial stratification demonstrated a strong inverse correlation with Human Development Index rankings ($r=-0.67$, $p<0.001$), indicating that provinces with higher socioeconomic development tend to have lower deferral rates (**Table VI**).

Table VI - *Provincial deferral rate classification and Human Development Index correlation*

Deferral risk category	Provinces No. (%)	Population millions	Mean deferral rate % [95% CI]	Range	HDI correlation
Low risk (≤15.0%)	6 (19.4%)	9.6	13.20 [13.15-13.25]	11.60-14.61%	High HDI
Moderate risk (15.1-20.0%)	17 (54.8%)	38.6	17.60 [17.57-17.63]	15.12-19.98%	Medium HDI
High risk (>20.0%)	8 (25.8%)	31.9	23.26 [23.22-23.30]	20.45-26.90%	Low HDI

Representative provinces by risk category of deferrals:
- Low risk: Kurdistan (11.60%), Lorestan (11.71%), West Azerbaijan (13.24%);
- Moderate risk: Tehran (15.12%), Isfahan (17.45%), Mashhad (19.98%);
- High risk: Sistan & Baluchestan (24.87%), Hormozgan (25.34%), Khuzestan (26.90%).

Statistical analysis: there is a strong inverse correlation between provincial deferral rates and Human Development Index scores (Spearman's $r=-0.67$, $p<0.001$). The Kruskal-Wallis test revealed significant differences among risk categories ($H=798.43$, $p<0.001$, $\eta^2=0.16$).
HDI: Human Development Index; 95% CI: 95% confidence interval.

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DISCUSSION

Iran's overall deferral rate of 16.67% positions favorably within the global context, where rates vary from 2.56% to 35.6% across different countries and healthcare systems[16]. Iran's rate is comparable to that in other national studies: 10.6% in India[16], 12.1% to 15.7% in Brazil[17], 18.84% in Malaysia[12], and 11.5% in Eastern Croatia[18]. The relatively low permanent deferral rate (2.30%) suggests effective screening protocols that minimize irreversible exclusions while maintaining safety standards. This cross-national variability in deferral rates reflects a complex interplay of policy frameworks, infectious disease prevalence, donor demographics, social behaviors, and technological capacities. Understanding these contextual differences is crucial for accurately interpreting deferral data and developing effective donor management strategies.

Countries differ significantly in their blood donation models, ranging from voluntary non-remunerated donation to replacement and paid systems, each with distinct implications for deferral rates. National guidelines vary in their stringency and scope of deferral criteria, including differences in deferral duration and the classification of high-risk groups. For example, while some countries enforce permanent deferrals for men who have sex with men, others have adopted evidence-based, time-limited deferral policies[19]. More conservative donor selection approaches, often adopted in countries with heightened concerns about blood safety, can

result in higher deferral rates, longer exclusion periods, and broader categories of permanent deferral. These differences underscore the need for context-sensitive policies that strike a balance between safety and donor inclusiveness.

In this study, female donors constituted a smaller proportion of the overall donor pool but experienced disproportionately high deferral rates (30.68% *vs* 14.08%). This finding is consistent with international studies demonstrating similar patterns[8,11,12,20,21]. The observed gender disparity is primarily attributed to several physiological and social factors that require targeted intervention strategies.

Physiological factors include iron-deficiency anemia, which affects female donors disproportionately due to menstrual blood loss, pregnancy, and lactation. Low hemoglobin levels represent one of the most common causes of donor deferral and disproportionately affect women of reproductive age[22,23]. Weight restrictions also disproportionately affect women, who typically have lower average body weights. Additionally, women are temporarily deferred during pregnancy and postpartum periods due to health considerations.

Variations in deferral rates are also influenced by donor experience and donor development. The substantial 3.6-fold reduction in deferral rates from first-time to regular donors (32.19 *vs* 8.98%) reflects the cumulative benefits of donor education, self-selection, and optimal preparation practices developed through repeated donation experiences. Experienced donors demonstrate a more profound understanding of pre-donation requirements, better timing of donations relative to personal physiological patterns, and enhanced self-awareness of eligibility factors. This pattern, consistent with international studies, suggests that strategic investment in first-time donor education and retention programs could significantly improve overall donation success rates while reducing the resource utilization associated with unsuccessful attempts[2,12,14]. Targeted interventions, including enhanced pre-donation education, personalized post-deferral counseling, and longitudinal tracking systems, may accelerate the learning curve and help build a more sustainable donor base.

First-time donors often lack a comprehensive understanding of eligibility criteria, pre-donation requirements, and optimal timing for donation attempts. Regular donors accumulate knowledge through experience and feedback from previous donations, which leads to improved self-assessment and preparation. Moreover, experienced donors receive ongoing education through repeated exposure to screening processes, enabling them to identify and address potential deferral factors before they are presented[24,25].

The predominance of temporary donor deferrals (86.19% *vs* 13.81% permanent) indicates substantial potential for donor recovery and system optimization. This distribution varies significantly across studies, reflecting different regional health patterns, policy approaches, and intervention strategies[2,13,24,26].

High-risk behaviors represent the largest category of deferrals in this study (27.80%) and require sophisticated educational and behavioral intervention strategies. These deferrals encompass behaviors that could potentially compromise recipient safety, including high-risk sexual practices, intravenous drug use, and other transmission risk behaviors. Effective intervention requires culturally appropriate education, risk reduction counseling, and evidence-based policy development. Targeted interventions should include peer education programs, culturally sensitive counseling approaches, and community-based initiatives that promote risk reduction and prevention.

General health unfitness criteria (responsible for 21.60% of deferrals in this study) include symptoms of acute illness, abnormal vital signs, laboratory abnormalities, and general physical conditions deemed unsuitable for donation. Many of these conditions can be modified through health education, lifestyle interventions, and appropriate medical management. Pre-donation health optimization programs could significantly reduce deferrals in this category. Specific interventions might include nutritional counseling, iron supplementation programs, and pre-donation health screening clinics.

The predominance of potentially modifiable causes –particularly high-risk behaviors, general health unfitness, and administrative improvements– suggests significant opportunities for targeted intervention strategies. The relatively low proportion of deferrals due to absolute medical contraindications (medical conditions, surgical history, and infectious diseases totaling 10.97%) indicates that most deferred donors represent recoverable

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resources for the blood supply system through appropriate counseling, health optimization, and administrative enhancements.

The 16.89% administrative deferral rate highlights the crucial role of donor records and historical screening data in ensuring blood safety. While these deferrals serve essential protective functions –preventing donations from individuals with confirmed risk factors or active deferral periods– there are opportunities for optimization in database accuracy, record currency, and communication protocols. Implementation of automated deferral tracking systems, real-time database synchronization, standardized deferral classification, and proactive donor communication can substantially reduce inappropriate deferrals due to outdated records while maintaining rigorous safety standards. Enhanced information management systems ensure that record-based deferrals accurately reflect current donor status, preventing unnecessary donation losses while preserving the protective value of historical screening data.

Deferral rates exhibited considerable variation across Iran's provinces, ranging from 11.60% to 26.90%, likely reflecting underlying differences in public health infrastructure, donor demographics, healthcare access, educational attainment, and cultural perceptions of blood donation. Provinces with higher deferral rates may benefit particularly from targeted educational campaigns, enhanced staff training, and adaptive local policy measures aimed at improving donor eligibility and reducing unnecessary exclusions. Regional disparities may indicate differences in donor selection criteria, consistency of policy implementation, and local blood supply management practices. Cultural variations in traditional medicine procedures, such as cupping, tattooing, and other invasive therapies, have a significant influence on deferral patterns. Socioeconomic conditions and educational levels may influence health awareness, healthcare access, and compliance with donation requirements.

Several limitations of this study must be acknowledged when interpreting the findings. The retrospective design limits the capabilities for causal inference, and data quality depends on the accuracy of the original record-keeping practices. Incomplete deferral documentation for some provinces and time periods may affect the generalizability of causal pattern analyses. This study relied on secondary data, and while we performed quality checks, some underreporting or misclassification may persist. The study did not track re-entry of temporarily deferred donors or assess long-term donation outcomes. Future research should focus on prospective studies with individual donor follow-up to analyze deferral resolution rates, time to re-eligibility, and long-term donor retention patterns.

Despite these limitations, based on the findings of this national analysis, several evidence-based recommendations can be proposed to enhance blood donor deferral policies and practices:

- *Targeted educational interventions*: develop comprehensive, evidence-informed programs designed explicitly for first-time donors, focusing on eligibility criteria and deferral prevention. Create gender-specific materials addressing common causes of deferral.
- *Donor health optimization*: establish pre-donation health screening programs to identify and address modifiable risk factors before presentation. Launch iron supplementation and anemia prevention programs, with a special focus on female donors.
- *Administrative improvements*: streamline data documentation and management systems to ensure accurate and timely recording of donor eligibility outcomes. Implement quality assurance and monitoring frameworks to support consistent application of deferral criteria across centers.

Evidence-based policy revisions: conduct periodic reviews of deferral criteria and durations, integrating emerging global evidence and local epidemiological data. Introduce risk-based deferral approaches where appropriate, striking a balance between safety and the need to minimize unnecessary deferrals.

CONCLUSIONS

Iran's national blood donor deferral rate of 16.67%, with a predominance of temporary deferrals (86.2%), indicates significant opportunities for donor recovery through targeted interventions. The inverse association between donor experience and deferral rates highlights the importance of retention strategies. Gender disparities, with female donors experiencing 2.74 times higher odds of deferral, high-risk behaviors, general health unfitness,

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and regional variations require specific evidence-based interventions to optimize both donor experience and blood supply sustainability. The strong correlation between provincial deferral rates and Human Development Index scores (r=−0.67) emphasizes the need for regionally adapted approaches that consider local socioeconomic factors in developing effective donor management policies.

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Authors' contributions

LK conceived and designed the study. ES performed statistical analyses. NN and LK interpreted the results. NN, MF, and LK drafted the manuscript. All Authors read and approved the final manuscript.

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