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Sociodemographic Determinants of Adherence and Treatment Efficacy in Paediatric Thalassemia Patients from Sarbaz-Rask, Iran

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Abstract: Background: The effective management of iron overload in transfusion-dependent thalassemia (TDT) requires adherence to iron chelation therapy (ICT). However, adherence rates among pediatric thalassemia patients remain suboptimal. This study aimed to evaluate adherence levels and identify sociodemographic and clinical factors impacting ICT adherence in pediatric TDT patients from Sarbaz-Rask, Iran. Methods: This cross-sectional study assessed 58 pediatric TDT patients aged 2–18 years at a thalassemia clinic from April 2021 to March 2022. Adherence was evaluated using the medication possession ratio. Logistic regression and correlation analyses identified predictors of adherence and treatment efficacy based on serum ferritin levels. Results: Adherence was satisfactory in 58.6% of patients and associated with younger maternal age (93.8% for 18–30 years, $p = 0.008$) and urban residency ($p = 0.02$). Logistic regression identified urban residency (OR = 20.265, $p = 0.073$) and a maternal age of 18–30 years (OR = 39.236, $p = 0.005$) as key predictors of adherence. Adherence was not significantly influenced by having a sibling with thalassemia or the maternal educational level. Treatment efficacy was observed in 27.6% of patients. Maternal age impacted adherence in poorly controlled patients ($p = 0.007$). Urban residents showed higher adherence rates, particularly with poor control ($p = 0.017$). Conclusions: Younger maternal age and urban residency emerged as positive predictors of adherence and treatment efficacy in pediatric thalassemia patients from Sarbaz-Rask. Targeted interventions supporting rural families and those with older maternal caregivers may improve adherence and outcomes in this population.

Keywords: thalassemia; iron chelation therapy; adherence; Iran

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1. Introduction

Transfusion-dependent thalassemia (TDT) represents a severe inherited hemoglobinopathy characterized by impaired or absent globin chain synthesis [1]. Patients with TDT require lifelong blood transfusions approximately every three to four weeks from infancy, leading to significant iron accumulation and subsequent secondary hemochromatosis. This condition often results in critical organ failures, pubertal disorders, and diabetes mellitus [2]. Iron Chelation Therapy (ICT) is crucial for mitigating these adverse outcomes, and is generally initiated once serum ferritin levels surpass 1000 ng/mL following 10–20 transfusions or when liver iron concentrations exceed 3 mg Fe/g dry weight [3,4].

Presently, three primary ICT agents are in use: deferoxamine (DFO), which requires extended subcutaneous or intravenous infusions; deferasirox (DFX), favored for its once-daily oral dosing and child-friendly tolerability; and deferiprone (DFP), administered two to three times daily, and known for its effectiveness in removing cardiac tissue iron [5].

Despite advancements in oral ICT formulations, paediatric population adherence rates remain notably low [6]. Adherence to ICT is critical in managing iron overload and preventing severe complications [1,7]. However, adherence rates among pediatric thalassemia patients vary widely, with studies reporting rates from 42% to 99.97% [1,7–9]. Various factors influence adherence, including socio-economic status, healthcare access, medication side effects, and patient or caregiver knowledge and perceptions about the disease and its treatment [9,10].

Several studies have explored the barriers to ICT adherence and the factors affecting it. For instance, Mohamed et al. found that low household income significantly impacts adherence, with only 51.4% of adolescents with TDT in Malaysia showing adherence to ICT [11]. Similarly, Reddy et al. highlighted the role of social support, age, and the social perception of ICT in influencing adherence among children and adolescents with thalassemia [1].

Side effects such as gastrointestinal distress with oral chelators can also hinder adherence, highlighting the need for balancing chelation efficacy with patient adherence [1]. Adherence is typically measured through various methodologies, including the Morisky Medication Adherence Scale (MMAS) [12], pill counts, patient self-reports, and biomarkers like serum ferritin, each possessing unique strengths and limitations [1].

The Sarbaz-Rask region, nestled in the Sarbaz Mountains and near the Sarbaz River, is home to around 200,000 individuals. The area has a notably high prevalence of TDT and faces significant challenges in managing the disease's complications. Situated within the thalassemia belt, Iran grapples with the substantial healthcare burden of TDT and its complications [13]. By understanding the unique barriers to adherence in this region, healthcare providers and policymakers can develop targeted strategies to improve patient outcomes and reduce the burden of TDT on the healthcare system.

This study aims to uncover the barriers to ICT adherence in this context, assisting healthcare providers and policymakers in developing targeted strategies to enhance patient outcomes and alleviate the healthcare system's load. The consistent psychosocial, economic, and ethnic backgrounds of the Sarbaz-Rask region's inhabitants provide a unique opportunity to investigate adherence behaviors within this demographic reliably.

2. Materials and Methods

2.1. Study Design and Setting

This cross-sectional study was conducted from April 2021 to March 2022 at the day-care thalassemia transfusion clinic of the Velayat Public Hospital in Rask County, Iran. The study aimed to evaluate adherence to ICT and identify the sociodemographic and clinical factors influencing adherence and treatment efficacy among pediatric patients with TDT in a specialized, socioeconomically uniform environment.

2.2. Participant Selection

The study population consisted of pediatric patients aged 2 to 18 years diagnosed with major thalassemia, undergoing regular transfusion therapy, and actively participating in an ICT regimen. Patients were categorized into oral (DFX, DFP) and injectable (DFO) medication groups. The study utilized the Iranian Health Ministry's free care initiative for thalassemia and the socioeconomically uniform community of Rask County to curate a consistent participant base characterized by similar psychosocial, economic, and ethnic backgrounds. This uniformity allowed for a more nuanced exploration of adherence behaviors within this group.

The study employed a robust statistical framework to determine the appropriate sample size. Utilizing the formula $n = (Z^2_1 - \alpha/2 \times p \times (1 - p))/d^2$ where $Z^2_1 - \alpha/2$ was set at 1.96 to reflect a 95% confidence level, the initial sample size calculation yielded 96 participants. This figure was based on an expected adherence proportion of 50% and a desired precision of 10%. However, due to the limited number of eligible patients in the study setting, fifty-eight patients were ultimately enrolled. This pragmatic adaptation

underscores the study's commitment to generating meaningful insights within the context of available resources and the specific characteristics of the target population.

Participants eligible for this study were those diagnosed with major thalassemia, currently undergoing regular transfusion therapies, and actively participating in an ICT regimen. The initiation of ICT was contingent upon patients having serum ferritin levels exceeding 1000 ng/mL or after undergoing 10–15 transfusion sessions, applicable only to individuals aged two years and older. Participants were excluded if they did not consent to participate, adhering strictly to ethical standards. Patients with chronic conditions potentially affecting treatment adherence, such as those with significant cardiac, renal, or hepatic diseases, as well as patients who had undergone bone marrow transplantation, were also excluded. This approach was taken to isolate the effects of ICT on thalassemia from other variables. Additionally, individuals needing to maintain a regular follow-up schedule or those with specific Hematological conditions like sickle cell anemia were excluded, as these factors could confound the treatment outcomes and adherence assessments central to the study's objectives.

2.3. Data Collection

A comprehensive data collection process was implemented, gathering demographic information including patient age, gender, educational background, maternal age, maternal education, family history of thalassemia among siblings, and residential area. Data were collected through interviews conducted by an experienced senior nurse using a structured checklist, with subsequent validation against hospital records. Clinical data, such as type of thalassemia, duration of treatment, and iron chelation regimen, were extracted from medical records. Adherence assessments were conducted through detailed interviews by a senior researcher in a private setting within the transfusion ward, ensuring confidentiality and comfort for the participants. The interviewer adhered to a uniform protocol to reduce bias and maintain uniformity in gathering data.

2.4. Outcome Measures

Adherence Levels: The Medication Possession Ratio (MPR) was used to assess adherence, quantifying how long patients maintained an adequate medication supply. Adherence was determined based on reports from patients, their caregivers, ward nurses, and pharmacy record verifications. Adequate adherence was defined as utilizing medication for five or more days per week or achieving at least 75% adherence [14,15]. Treatment Efficacy: The efficacy of the ICT regimen was also evaluated through ferritin levels, as per the National Iranian Guidelines for Thalassemia Management. Ferritin levels were considered well controlled if below 1500 ng/mL for patients under 16 years and below 2500 ng/mL for those aged 16 years and older, with higher levels indicating poor control [16].

2.5. Statistical Analysis

Data were analyzed using SPSS version 28. Descriptive statistics for normally distributed variables included means and standard deviations. Categorical data underwent chi-squared or Fisher's exact tests and non-parametric data were assessed using the Mann–Whitney U test. Binary logistic regression, with a significance level set at $p < 0.05$, adjusted for potential confounders. Missing data were addressed using multiple imputations, generating five datasets with pooled results. Sensitivity analyses tested the robustness of these findings.

3. Results

3.1. Participant Characteristics

A total of 58 pediatric patients with major thalassemia were enrolled in this study, comprising 21 males (36.2%) and 37 females (63.8%). The mean age of the participants was 8.60 ± 4.45 years, with a range of 2 to 18 years. Most of the patients (82.8%) resided in rural areas, while the remaining 17.2% were from urban settings. Regarding the type of

ICT, 89.7% of the patients were prescribed oral medications, including DFX and DFP, while 10.3% received injectable DFO. The mean serum ferritin level at the initiation of the study was 3120.52 ± 1549.97 ng/mL, indicating significant iron overload among the participants (Table S1).

3.2. Adherence to Iron Chelation Therapy and Associated Factors

Adherence to iron chelation therapy was classified as good in 34 patients (58.6%) and poor in 24 patients (41.4%). Adherence rates varied significantly according to maternal age, with the highest adherence (93.8%) observed among children of mothers aged 18 to 30 years ($p = 0.008$). By contrast, adherence rates were lower in children with mothers aged 31–40 years (50%), 41–50 years (33.3%), and >50 years (50%). Additionally, a significant association was found between urban residency and better adherence ($p = 0.02$), with 90% of urban residents demonstrating adherence compared to 52.1% of rural residents.

Logistic regression analysis was performed to identify sociodemographic and treatment-related factors influencing adherence to ICT. The model showed a good fit (Chi-square = 33.364, df = 16, $p = 0.007$) and explained 43.7% to 58.9% of the variance in adherence status. The analysis revealed that urban residency (OR = 20.265, $p = 0.073$) and younger maternal age (18–30 years; OR = 39.236, $p = 0.005$) were key predictors of adherence. Other factors, such as the ICT regimen type, patient age, sex, ferritin levels, maternal education, and having a sibling with thalassemia, did not significantly influence adherence (Table 1).

Table 1. Logistic regression analysis of factors affecting adherence to iron chelation therapy.

Variable	Regression Coefficient (B)	SE	Odds Ratio	*p*-Value	95% Confidence Interval
Age (years)	0.618	1.156	1.855	0.593	0.193 to 17.862
Ferritin Level	0.000	0.000	1.000	0.296	0.999 to 1.000
Sex (Male)	0.247	0.956	1.280	0.796	0.196 to 8.341
Years on ICT	−1.075	1.073	0.341	0.316	0.042 to 2.796
Mother's Age	−0.058	0.142	0.943	0.680	0.715 to 1.245
Maternal Education (Illiterate)	−0.194	1.165	0.824	0.868	0.084 to 8.076
Maternal Education (Educated)	0.126	0.841	1.135	0.881	0.218 to 5.895
Having a Thalassemic Sibling	1.049	1.284	2.856	0.414	0.231 to 35.373
ICT Regimen (Oral)	−1.037	1.433	0.355	0.470	0.021 to 5.885
Residency Area (Urban)	3.009	1.678	20.265	0.073	0.755 to 543.795
Age (2–6 years)	5.434	4.319	228.992	0.208	0.048 to 1,087,785.260
Age (6–10 years)	−1.974	1.185	0.139	0.096	0.014 to 1.417
Age (10–14 years)	−0.405	0.781	0.667	0.604	0.144 to 3.084
Maternal Age (>45 years)	−0.953	3.849	0.386	0.804	0.000 to 728.125
Maternal Age (30 to 45 years)	−1.198	1.311	0.302	0.361	0.023 to 3.944
Maternal Age (18 to 30 years)	3.670	1.309	39.236	0.005	3.018 to 510.122
Constant	6.153	7.616	470.177		

Additionally, the outcomes of siblings with thalassemia were examined. The data revealed that having a sibling with thalassemia did not significantly influence adherence ($p = 0.27$), suggesting that the burden of managing multiple affected children may not impact the adherence behavior for individual patients. Future studies with larger sample sizes are necessary to explore this aspect in more detail.

3.3. Treatment Efficacy and Associated Factors

Treatment efficacy, as determined by serum ferritin levels, was classified as good in 16 patients (27.6%) and poor in 42 patients (72.4%). The mean serum ferritin level at the start of the study was 3120.5 ± 1549.97 ng/mL. No significant differences in treatment efficacy rates were observed based on sociodemographic factors such as sex, age groups, and maternal educational status. Logistic regression analysis, while indicative, faced statistical challenges due to the small sample size, suggesting that the identified predictors should be interpreted with caution. Urban residency and younger maternal age emerged as potential adherence predictors, but further research with larger cohorts is needed to confirm these relationships.

3.4. Impact of ICT Regimen Type on Adherence and Treatment Efficacy

The association between the ICT regimen type and adherence was examined in patients with poor and good treatment efficacy. Among patients with poor control, adherence was evenly split (50% each) for both oral and injectable regimens, with no significant association between regimen type and adherence (p = 1.000). In patients with good control, those on oral regimens showed better adherence (85.7% good, 14.3% poor) compared to those on injectable regimens (50% each), although the association was not statistically significant (p = 0.226). Overall, 59.6% of patients on oral regimens and 50% of those on injectable regimens demonstrated adherence. The total Chi-square analysis indicated no significant association between the ICT regimen type and adherence or treatment efficacy (p = 0.651) (Table 2).

Table 2. Effects of ICT regimen, residency area, and maternal age on drug adherence and treatment efficacy in pediatric thalassemia patients.

Variable	Subgroup	Treatment Efficacy	Drug Adherence	Count	% within Subgroup	*p*-Value
ICT Regimen	Oral	Poor Control	Poor Good	19 19	50% 50%	0.999
		Good Control	Poor Good	2 12	14.3% 85.7%	0.017
	Injectable	Poor Control	Poor Good	2 2	50% 50%	0.999
		Good Control	Poor Good	1 1	50% 50%	0.999
Residency Area	Urban	Poor Control	Good	5	100%	0.004
	Rural	Poor Control	Poor Good	21 16	56.8% 43.2%	0.017
	Urban	Good Control	Poor Good	1 4	20% 80%	0.629
	Rural	Good Control	Poor Good	2 9	18.2% 81.8%	0.629
Maternal Age Group	Under 18	Poor Control Good Control	Poor Good	1 1	100% 100.0%	0.003
	18 to 30	Poor Control	Poor Good	1 11	8.3% 91.7%	0.002
		Good Control	Good Poor	4 12	100.0% 66.7%	
	30 to 40	Poor Control	Poor Good	12 6	66.7% 33.3%	0.003
		Good Control	Poor Good	2 6	25.0% 75.0%	
	More than 40	Poor Control	Poor Good	7 4	63.6% 36.4%	0.054
		Good Control	Poor Good	1 2	33.3% 66.7%	

3.5. Impact of Maternal Age on Adherence and Treatment Efficacy

A significant association was found between maternal age and adherence in patients with poor control (Chi-square = 12.152, df = 3, $p = 0.007$; likelihood ratio test $p = 0.003$). This finding suggests that a younger maternal age may facilitate the better management of treatment protocols, particularly in challenging cases. However, the effect of maternal age on adherence was less pronounced in patients with good treatment efficacy ($p = 0.620$) (Table 2). Maternal educational status was examined to determine its impact on adherence. While illiterate mothers constituted 50% of the study population, their children's adherence rates were not significantly different from those with mothers who had primary or high school education ($p = 0.19$). This suggests that educational interventions may not be the sole determinant of adherence behaviors, though they still play a role.

3.6. Impact of Residential Area on Adherence and Treatment Efficacy

The impact of residential areas on adherence and treatment efficacy was analyzed separately for patients with poor and good control. Among urban residents, all patients with poor control (100%) and 80% of those with good control showed adherence. By contrast, rural residents had lower adherence rates, with 43.2% showing adherence under poor control and 81.8% under good control. A significant association was observed between residential areas and adherence in patients under poor control conditions (Pearson Chi-square = 5.676, df = 1, $p = 0.017$). However, no significant association was noted in patients with good control, suggesting that other factors may play a more crucial role under these conditions (Table 2).

Furthermore, Pearson's R and Spearman's correlation analyses were conducted to examine the overall relationship between adherence and residential area. The results showed a negligible overall correlation (Pearson's R = -0.059, $p = 0.658$). However, when analyzing patients with poor control in rural areas, a moderate negative correlation was observed (Pearson's R = -0.368, $p = 0.017$), indicating that poorer adherence is significantly associated with rural residency and potentially older maternal age in this subgroup.

4. Discussion

This study underscores the significant influence of sociodemographic factors on the treatment efficacy and adherence in pediatric thalassemia patients from Sarbaz-Rask, a region characterized by its unique socioeconomic and cultural context in southeast Iran. Our findings indicate that younger maternal age and urban residency emerged as strong predictors of better adherence, reflecting greater access to healthcare resources and more comprehensive health education. The results underscore the need for targeted interventions and support for families in rural areas and those with older maternal age to promote better adherence and treatment outcomes in this population.

Adherence to treatment is indeed crucial for preventing complications linked to iron overload in thalassemia patients. Studies have shown that higher compliance with ICT is associated with lower serum ferritin levels, reduced risks of liver and cardiac diseases, endocrinologic morbidity, and improved Health-Related Quality of Life (HRQoL) [8]. Our study found that 58.6% of patients demonstrated adherence, which is consistent with previous reports. Based on a recent systematic review, the rate of ICT compliance ranged from 20.93% to 75.3% [8]; other systematic reviews reported adherence ranging from 57% to 98.4% with a median of 89.5% [1]. In Iran and the Middle East, adherence to iron chelation therapy ranged from 18.2% to 91.4%, demonstrating varying levels of adherence among thalassemia major patients [7,9,14,17].

The varying levels of adherence to ICT among thalassemia patients in different studies can be attributed to several factors. These include age, social perception of ICT, social support, side effects/discomfort, and the type of chelation therapy used (e.g., deferasirox), and the main reason may be the method of assessment employed (e.g., questionnaire, pill count, direct interview, or biomarkers) [1,7,8] and the time frame used to evaluate the

frequency or quantity of consumed doses (e.g., one or three months) [14,15], as well as how adherence is defined [7].

Our findings are consistent with the literature indicating varied adherence levels in different geographic and socioeconomic settings. For example, studies in more resource-abundant settings have reported higher adherence rates [1,6,8,18], underscoring the impact of healthcare access on patient outcomes. Our results contrast with those from regions with established healthcare infrastructures, where adherence rates can reach as high as 89.5% among similar populations [1,8,14]. This disparity likely reflects differences in healthcare access, socioeconomic factors, and adherence assessment methodologies, which range from self-reports to clinical markers.

Although following treatment protocols is crucial for thalassemia patients managing iron overload, our study indicates that only 27.6% achieve effective control of their ferritin levels, suggesting that adherence alone might not fully predict treatment outcomes. Research shows that treatment success in thalassemia could also depend on various factors, like psychological attitudes towards the treatment, drug interactions, genetic differences, and nutritional status. For example, studies have found that positive expectations and self-confidence in managing their treatment significantly boost adherence to daily chelation therapy, which is critical for managing iron levels [19]. Moreover, the role of knowledge about the disease significantly influences adherence and ultimately treatment efficacy, suggesting that enhancing patient and caregiver education could substantially improve health outcomes [20]. Future research should continue to explore these factors, particularly the genetic and environmental variables, so as to develop more targeted and effective management strategies. Understanding and addressing these comprehensive factors are essential for improving treatment success and the quality of life for those living with thalassemia.

In our study, maternal age emerged as a significant predictor of adherence, with children of younger mothers (18–30 years) showing the highest adherence rates. This might be due to younger mothers having more energy and fewer competing responsibilities, allowing them to focus more on their child's treatment needs. They may also have a fresher understanding of the importance of the treatment, which is crucial for managing their child's condition effectively. A study confirmed that increased knowledge about thalassemia among caregivers, including younger mothers, is closely linked to improved treatment adherence, highlighting the importance of educating caregivers thoroughly [20]. Another aspect to consider is the psychological burden on mothers caring for a chronically ill child, which can affect their quality of life and their ability to manage the treatment effectively [21].

The outcomes of siblings with thalassemia were explored, revealing no significant impact on adherence. This could indicate that families with multiple affected children may develop strategies to manage ICT effectively, or it could reflect a need for more comprehensive family-based support systems. Furthermore, access to treatment centers emerged as a significant factor, with urban residents demonstrating better adherence (p = 0.02). This disparity underscores the challenges faced by rural families, including travel distance, limited healthcare infrastructure, and reduced access to specialized care. Interventions such as mobile health units and telemedicine could bridge this gap, enhancing adherence and overall treatment outcomes in rural areas.

Living in urban areas significantly improves adherence to iron overload therapy among thalassemia patients, primarily due to easier access to healthcare resources and support systems. This is consistent with findings that urban residents often fare better in managing chronic diseases thanks to closer proximity to medical facilities and services [1,22]. However, rural residents face considerable hurdles, such as limited healthcare access and the need to travel long distances for treatment, highlighting the urgent need for healthcare policies that address these disparities and ensure equitable care regardless of geography. For instance, studies show that rural residents often have less access to specialist care and experience varying quality of care, which can impact treatment outcomes in chronic conditions like hepatitis C [23] and cancer [24].

In our study, we found that the type of ICT, whether oral or injectable, did not significantly influence adherence or the effectiveness of treatment for iron overload in thalassemia patients. However, oral medication was associated with lower odds of adherence (OR = 0.355), suggesting possible challenges with the palatability or administration of oral drugs compared to injectable forms. This contrasts with some earlier studies that suggested oral chelators might lead to better adherence and outcomes compared to injectable options [1,7–9,14]. The absence of significant findings in our study could be due to its small sample size or the influence of other unmeasured factors. For instance, comprehensive research has shown that patient satisfaction and adherence improve markedly with oral chelators like deferasirox due to their convenience and less burdensome regimen [25]. Further research with larger and more diverse samples is essential to explore these aspects more deeply.

Statistical analysis in our study revealed that demographic factors such as sex, age groups, and mothers' educational status did not significantly impact the treatment efficacy rates in thalassemia patients. This suggests that other, less straightforward factors might be influencing the treatment outcomes. Indeed, our findings point to a complex interplay between factors like adherence to ICT, the patient's living environment, and maternal age, which all contribute to how effectively pediatric thalassemia is managed. These insights underline the importance of targeted interventions that focus not only on educating and providing resources to caregivers, especially in rural settings and among older caregivers [7,9,26] but also on broadening access to healthcare resources to improve adherence rates and treatment results. Understanding the diverse needs and challenges faced by caregivers, as well as the specific dynamics of thalassemia management in different settings, is crucial for developing effective strategies [10].

To better contextualize our findings, we compare our results with previous studies on adherence to iron chelation therapy in pediatric thalassemia patients in Table 3. In our study, we found that ferritin levels, a common marker of iron overload, did not significantly predict treatment adherence. This observation suggests that adherence may be influenced by factors other than just physiological markers. Indeed, research indicates that while ferritin levels can provide insights into iron levels in the body, they may not directly correlate with a patient's behavior regarding treatment adherence [2,27,28]. One recent study noted that while ferritin levels were significantly reduced with better adherence to iron chelation therapy, many patients still showed poor adherence despite knowing the importance of managing their ferritin levels [28]. This highlights the complexity of adherence behaviors and underscores the need to consider psychological and social factors in managing thalassemia.

Table 3. Comparison of adherence rates and influencing factors in pediatric thalassemia patients across recent different studies.

Study	Sample Size	Adherence Rate	Significant Factors	Other Findings
Current Study	58	58.6%	Urban residency, younger maternal age	No significant influence of ICT regimen type, patient age, sex, ferritin levels, maternal education, and having a sibling with thalassemia.
Mohamed et al. [11]	70	51.4%	Monthly household income, serum ferritin levels	No significant association with knowledge on thalassemia.
Locke et al. [1]	43 studies	42.0–99.97%	Medication type (oral iron chelators), fewer side effects, perception and understanding of medication	Lower serum ferritin levels, improved cardiac outcomes.

Table 3. *Cont.*

Study	Sample Size	Adherence Rate	Significant Factors	Other Findings
Lee et al. [8]	20 studies	81.2%	Adherence based on administration frequency	No significant correlation between adherence and mean serum ferritin level.
Reddy et al. [7]	36 studies	Not specified	Age, social perception of ICT, social support, side effects/discomfort	Improved cardiac, hepatic, and endocrine outcomes with increased adherence.
Baumgartner et al. [14]	6 studies	46–92%	Various thresholds depending on disease and medication	No standard threshold; variability in adherence measures.
Kvarnström et al. [9]	89 studies	Not specified	Patient-specific, illness-specific, medication-related, healthcare and system-related, sociocultural, logistical, and financial factors	Communication and information as key facilitators.

Our study highlights several strategies for healthcare providers and policymakers to improve treatment outcomes. Enhanced access and support in rural areas can be addressed through the development of mobile health units and the expansion of telehealth services, which have been shown to significantly increase healthcare access for rural populations [29]. Educational interventions are also crucial; raising awareness and education about thalassemia and the importance of treatment adherence can lead to better health outcomes. Furthermore, supporting caregivers through programs that provide psychological and social support is essential, as these are critical components in the treatment process. Implementing personalized care plans that consider the socioeconomic and cultural background of patients and families may also improve adherence to treatments.

5. Conclusions

This study highlights the suboptimal adherence rates (58.6%) and treatment efficacy (27.6%) among pediatric thalassemia patients in the Sarbaz-Rask region of Iran. Urban residency and younger maternal age were identified as positive predictors of better adherence, underscoring disparities in healthcare access between urban and rural areas. No significant correlations were found between adherence rates and other socioeconomic factors, such as the educational levels of mothers or adolescents, nor the length of the ICT regimen. These findings highlight the need for targeted interventions to improve adherence and treatment efficacy, particularly in rural settings where healthcare resources are less accessible.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/thalassrep14030008/s1, Table S1. Demographic characteristics of the study population and patients with adherence to the ICT regimen.

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