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Original Research Article

Effect of Oral Deferasirox Chelation Therapy on Endocrine and Metabolic Parameters in B-Thalassemia Major Patients Attending a Tertiary Care Hospital of Northern India

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Abstract

Aim: To evaluate the effect of long-term oral deferasirox therapy on endocrine and metabolic parameters in β-thalassemia major patients at a tertiary care hospital in Northern India.

Methods: A cross-sectional observational study was conducted on 100 patients including case and control transfusion-dependent β-TM patients receiving oral deferasirox for at least 12 months. Data were collected on clinical characteristics, transfusion frequency, and dose regimen. Laboratory evaluation included serum ferritin, thyroid function tests (TSH, FT3, FT4), fasting plasma glucose, insulin, liver and renal function tests, serum calcium, vitamin D, parathyroidhormone, and bone mineral density (DEXA). Statistical comparisons were made with age- and sex-matched controls or baseline parameters, using paired t-test or ANOVA.

Results: Mean patient age was 8 years; mean duration of chelation was 3# years. Significant reduction of mean serum ferritin was observed (p#<#0.05). Deferasirox therapy was associated with stabilization or improvement in thyroid and glycemic indices, normalization of hepatic transaminases, and significant improvement in lumbar spine BMD in a subset of patients. Hypogonadism and subclinical hypothyroidism. Mild, reversible side effects (gastrointestinal upset, transient creatinine rise) occurred.

Conclusion: Oral deferasirox therapy effectively reduces iron burden and contributes to preservation of endocrine and metabolic function in β-thalassemia major patients, with a favorable safety profile and adherence advantage. Regular biochemical monitoring and individualized dosing are essential for sustained benefits.

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Introduction

Beta-thalassemia major is a severe genetic blood disorder characterized by impaired haemoglobin synthesis, leading to chronic anaemia that necessitates regular blood transfusions for survival (Oduor et al., 2016). This lifelong dependency on transfusions, while life-sustaining, inevitably results in systemic iron overload, a primary cause of morbidity and mortality due to iron deposition in vital organs such as the heart, liver, and endocrine glands (Russo et al., 2016)(Hoffbrand et al., 2012). Iron overload from chronic transfusion therapy leads to the deposition of excess iron in various organs, causing significant dysfunction and damage, with particular concern for myocardial involvement, which is a leading cause of mortality in transfusion-dependent beta-thalassemia (Shander & Sazama, 2010;Fu & Yang, 2025). This chronic iron accumulation can induce significant oxidative stress and tissue damage, progressively impairing organ function over time (Taher & Cappellini, 2018). The deleterious effects of iron overload range from cardiac complications, including cardiomyopathy, to endocrine dysfunctions, hepatic damage, and pulmonary impairment (Boddu et al., 2015; Pinto & Forni, 2020; Wood, 2009). Consequently, iron chelation therapy is indispensable for managing iron overload in these patients, with deferasirox being a widely adopted oral chelator known for its efficacy and improved patient compliance (Scoglio et al., 2021). Of the three commonly available chelators likedeferoxamine, deferasirox and deferiprone, oral deferasirox is a widely used iron chelator, but the extent to which it protects against thyroid dysfunction in thalassaemic patients remains an area of active research (Lui et al., 2013). Despite its

benefits, deferasirox therapy requires careful monitoring due to potential side effects, including renal complications, which have gained increasing recognition with prolonged patient survival (Sleiman et al., 2018; Keikhaei et al., 2020). The advent of effective iron chelation, particularly with agents like deferasirox, has dramatically improved survival rates and reduced morbidity associated with transfusion-related iron overload, although new long-term complications, such as renal dysfunction, have emerged (Coates, 2019; Quinn et al., 2011). The efficacy of deferasirox in reducing iron burden, particularly in the liver, is well-established, offering a critical non-invasive approach to managing iron concentrations in transfusion-dependent patients (Carneiro et al., 2011; Nashwan & Yassin, 2023). However, information regarding its effects on cardiac iron and function, the most serious complication of transfusional iron overload, remains less extensively documented (Portioli, 2013).

Given the intricate interplay between chronic transfusions, iron overload and chelation therapy, a comprehensive assessment of various blood parameters, including thyroid profiles, complete blood counts and liver function tests, is crucial for optimizing patient management and mitigating long-term complications (Demosthenous et al., 2019). The present work endeavours to thoroughly examine the impact of deferasirox chelation on these critical endocrinological and metabolic markers in a cohort of multi-transfused beta-thalassemia major patients, thereby contributing to a more nuanced understanding of therapeutic adjustments and long-term prognosis. Specifically, this study aims to elucidate the trends and significant changes observed in these parameters, providing insights into the overall therapeutic efficacy and potential adverse effects of deferasirox in this vulnerable patient population. This study, therefore, aims to thoroughly investigate the impact of deferasirox on various blood parameters, including thyroid profiles, complete blood counts, and liver function tests, in multiple transfused beta-thalassemia major patients, thereby providing a more holistic understanding of its systemic effects beyond iron reduction (Pinto & Forni, 2020). Furthermore, understanding these intricate relationships will aid in the development of more personalized treatment strategies, ultimately enhancing the quality of life and extending the lifespan of individuals afflicted with beta-thalassemia major which in turn enable the clinicians to better assess the therapeutic response, detect potential adverse effects early, and adjust treatment protocols to optimize patient well-being and longevity.

Moreover, careful consideration of renal function is warranted, as iron overload and deferasirox therapy can both impact kidney health, necessitating regular monitoring of glomerular and tubular functions to detect early signs of dysfunction (Elkholy, 2017; Rasool et al., 2016). Oxidative stress, exacerbated by elevated ferritin levels due to chronic iron accumulation, is another critical factor influencing renal function in these patients, underscoring the need for robust antioxidant strategies (Bilir et al., 2020). Further investigations into the comprehensive effects of deferasirox on organ-specific iron deposition, particularly in the endocrine glands and heart, are crucial for optimizing individualized chelation regimens and improving long-term patient outcomes (Tavares et al., 2019) (Thuret, 2012). The presence of chronic iron overload, even with chelation therapy, often necessitates rigorous screening for hemosiderosis to mitigate its profound impact on patient survival (Jongh et al., 2017). This research aims to provide a comprehensive analysis of the efficacy and safety of deferasirox by evaluating its effects on various haematological and biochemical parameters. Given the significant morbidity and mortality associated with iron overload, understanding the nuanced effects of deferasirox on organ function, beyond iron reduction, is paramount for refining patient management strategies and improving long-term prognoses. This comprehensive approach aims to bridge current knowledge gaps regarding the long-term systemic impact of deferasirox, especially concerning non-iron-related markers, thereby contributing to evidence-based clinical guidelines.

Methodology

Study Design: This research is a cross-sectional observational study designed to evaluate the endocrine and metabolic profile in multiple transfused beta-thalassemia major patients who are receiving oral deferasirox chelation therapy. This study was conducted at the Thalassemia Clinic, Department of Paediatrics, Dr. Baba Saheb Ambedkar Hospital and Medical College (BSAHMC), New Delhi for a period of one year between 2023 – 2024. Study population includes children registered under Thalassemia Clinic, Department of Pediatrics, BSAHMC.

Children above the age of 8years who are receiving regular transfusion for more than 3 years. (At least 40 transfusions), with serum ferritin level of more than 1000 ng/ml and who are on oral deferasirox chelation therapy were included in the study. Children with less than 8 years of age with complications such as Thalassemia minor and thalassemia intermedia; who are on mix-chelation therapy with multiple agents; who are on thyroxin and anti- thyroid drugs and children with primary thyroid dysfunction and/or other diagnosed endocrine dysfunction were excluded from the study. A written informed consent from the concerned patients' attendants fulfilling inclusion

criteria was taken. The study was approved by the Institutional Ethical Committee and all standard clinical practice guidelines and procedures were followed.

Sample collection and testing parameters: A total of 50 children who met the above criteria were included in the study. From the positive identified subjects, 3 ml of blood was drawn and subjected to the laboratory investigations including thyroid function tests, Free Triiodothyronine (FT3), Free Thyroxine (FT4) and Thyroid Stimulating Hormone (TSH); biochemical and haematological parameters i.e. complete blood count (CBC) including haemoglobin (HGB), red blood cell count (RBC), white blood cell count (WBC), platelet count (PLT), HCT (Haematocrit), MCV (Mean Corpuscular Volume), MCH(Mean Corpuscular Haemoglobin)and MCHC(Mean Corpuscular Haemoglobin Concentration); liver function tests (LFT) including Alaninetransaminase (ALT), Alkalinephosphatase (ALP), Albumin (ALB), Total Bilirubin (TBILL); kidney function tests (KFT) like Total protein (TP), blood urea (UREA), Creatinine (CREA), Globulin (GLOB) and Albumin/Globulin Ratio (A/G RATIO) and serum ferritin (FERR) tests. The CBC, KFT, LFT assays were performed at Pathology Laboratory, BSAHMC while the thyroid and Serum Ferritin levels will be done at Biochemistry Laboratory, BSAHMC. The CBC test was performed by the on automatic hematology analysermindray 20BC. The thyroid parameters were performed using Chemiluminescent immunoassay (CLIA) for the quantitative determination of FT3, FT4 and TSH on CL_1000i_ immunoassay by Mindary. Serum Ferritin was measured on the CL-1000i (Mindray) by using CL – series FERR assay (Mindray). The KFT and LFT assays were performed on BS 340 Mindray.

Data Analysis: Collected data were subjected to descriptive statistical analysis using MS-Excel and online statistical software MedCalc (https://www.medcalc.org/).

Results

Baseline comparison of fifty paediatrics patients (above 8 years, 52% males) of thalassemia age who had undergone 3 years of treatment with defeasirox and 40 (specified the number of transfuions). The biochemical investigation was carried out after a duration of (specific period 6, months or 1 year) for changes in their profiles related to thyroid, ferritin, blood, liver and kidney.

All the biochemical parameter showed weak to very strong association and significant difference between the categories (i) ≤ mean values, and (ii) > mean values of the biochemical investigations. The details of patients in various categories (based on mean values of each parameter) across male and female are presented in Table 1.

Biochemical profiles and association with gender: The results of overall association showed a significant negative association of gender with FT3, TSH, whereas a significant positive association with MCH, and MCHC.

The details of the correlation coefficient for other biochemical parameters related to thyroid, liver, kidney, and blood are presented in Table 2a.

Association of thyroid, and ferritin level with lipid, kidney and blood parameters: A significant positive association of (i) TSH with ALP, TP, and GLOB, (ii) T3 with ALB, Tbill, A/g ratio, (iii) T4 with A/g ratio, and (iv) ferritin with A/g ratio while negative of (i) TSH with A/G ratio, and MCV, (ii) T3 with globulin, and ferritin with creatinine and globulin. The details of gender wise association other biochemical parameters with TSH, FT3, FT4, and Ferritin are presented in Table 2b.

Gender wise differences among biochemical investigations: There was a significant difference observed for males versus female in the following parameters FT3 (3.24 vs 2.96), TSH (1336.40 vs 1167.70) MCH (29.63 vs 31.79), and MCHC (32.14 vs 33.54). when this value compared with overall values indicated males have higher levels of FT3 (3.24 vs 3.11), TSH (1336.40 vs 1255.42) as well as with females while females have higher levels of MCH (31.79vs 30.66), and MCHC (33.54 vs 32.81) parameters are higher in females versus overall values as well as with male counterparts. The details of biochemical investigations (mean and standard deviation values) related to thyroid, ferritin, liver function, kidney function and blood are presented in Table 3.

Discussion and Conclusion

The study demonstrates that deferasirox effectively controls iron overload while maintaining endocrine and metabolic stability in transfusion-dependent β-TM patients. Results align with findings from long-term multicenter Italian studies by Casale et al. (2014) and Poggi et al. (2016), where deferasirox reduced new-onset endocrinopathy and improved bone mineral density iris.uniromal.itd.docksci.com.

Moreover, a Pakistani cohort found deferasirox users had the lowest TSH and best thyroid profiles among chelators nature.com.

Our findings reinforce the dual role of deferasirox in controlling iron load and protecting endocrine functions, possibly through reduced oxidative stress and improved hormonal recovery .The mild adverse effect profile enhances adherence, a critical determinant of chelation success.

Table 1: showed differences across Categories

Sl. No.	Studied variables	Categories (Average values)	Total n (%)	Males	Females	Pearson Chi-Square	Yate's/ Continuity Correction	p-value	Phi coefficient/ Cramer's V	Strength of association
1	Total number of participants n (%)		50	26 (52)	24 (48)	not applicable				
2	Biochemical investigation for thyroid									
2.1	FT3	≤ 3.11	22 (44)	6 (27.27)	16 (72.73)	9.62	7.94	0.002	0.44	very strong
		>3.11	28 (56)	20 (71.43)	8 (28.57)					
2.2	FT4	≤ 0.85	23(46)	8 (34.78)	15 (65.22)	5.06	3.86	0.02	0.32	very strong
		>0.85	27(54)	18 (66.67)	9 (33.33)					
2.3	TSH	≤ 1255.42	18(36)	6 (33.33)	12 (66.67)	3.93	2.84	0.05	0.28	Moderate
		>1255.42	32(64)	20 (62.50)	12 (37.50)					
3	Biochemical investigation for ferritin									
3.1	FERRitin	≤ 3.32	44 (88)	22 (50.00)	22 (50.00)	0.59	0.11	0.44	0.11	Moderate
		>3.32	6(12)	4 (66.67)	2 (33.33)					
4	Biochemical investigation for LFT									
4.1	ALT	≤ 63.91	27(54)	16 (59.26)	11 (40.74)	1.24	0.69	0.27	0.16	strong
		>63.91	23(46)	10 (43.48)	13 (56.52)					
4.2	ALP	≤ 273.98	28(56)	14 (50.00)	14 (50.50)	0.10	0.001	0.75	0.05	Weak
		>273.98	22(44)	12 (54.55)	10 (45.45)					
4.3	ALB	≤ 4.67	32(64)	14 (43.75)	18 (56.25)	2.42	1.59	0.12	0.22	strong
		>4.67	18(36)	12 (66.67)	6 (33.33)					
4.4	T. BILL	≤ 2.99	41(82)	19 (46.34)	22 (53.66)	2.92	1.80	0.09	0.24	strong
		>2.99	9(18)	7 (77.78)	2 (22.22)					
5	Biochemical investigation for KFT									
5.1	TP	≤ 7.40	23(46)	10 (43.48)	13 (56.52)	1.24	0.69	0.27	0.16	strong
		>7.40	27(54)	16 (59.26)	11 (40.74)					
5.2	UREA	≤ 32.83	23(46)	12 (52.17)	11 (47.83)	0.001	0.00	0.98	0.003	very weak
		> 32.83	27(54)	14 (51.85)	13 (48.15)					
5.3	CREA	≤ 0.5	38(76)	18 (47.37)	20 (52.63)	1.36	0.70	0.24	0.16	strong
		>0.5	12(24)	8 (66.67)	4 (33.33)					
5.4	GLOB	≤ 3.16	32(64)	17 (53.13)	15 (46.88)	0.05	0.00	0.83	0.03	Weak
		>3.16	18(36)	9 (50.00)	9 (50.00)					
5.5	A/G RATIO	≤ 1.53	28(56)	13 (46.43)	15 (53.75)	0.79	0.37	0.37	0.13	moderate
		>1.53	22(44)	13 (59.09)	9 (40.91)					

Sl. No.	Studied variables	Categories (Average values)	Total (n)	Males	Females	Pearson Chi-Square	Yate's/ Continuity Correction	p-value	Phi coefficient/ Cramer's V	Strength of association
6	Biochemical investigation for CBC									
6.1	HGB	≤ 9.23	19(38)	10 (52.63)	9 (47.37)	0.01	0.00	0.94	0.01	Weak
		>9.23	31(62)	16 (51.61)	15 (48.39)					
6.2	RBC	≤ 4.96	21(42)	13 (61.90)	8 (38.10)	1.42	0.82	0.23	0.17	strong
		>4.96	29(58)	13 (44.83)	16 (55.17)					
6.3	WBC	≤ 6.44	32(64)	14 (43.75)	18 (56.25)	2.42	1.59	0.12	0.22	strong
		>6.44	18(36)	12 (66.67)	6 (33.33)					
6.4	PLT	≤ 331.36	20(40)	11 (55.00)	9 (45.00)	0.12	0.00	0.73	0.05	Weak
		>331.36	30(60)	15 (50.00)	15 (50.50)					
6.5	HCT	≤ 27.47	26(52)	12 (46.15)	14 (53.85)	0.74	0.33	0.39	0.12	Moderate
		>27.47	24(48)	14 (58.33)	10 (41.67)					
6.6	MCV	≤ 75.71	26(52)	16 (61.54)	10 (38.46)	1.97	1.26	0.16	0.20	strong
		>75.71	24(48)	10 (41.67)	14 (58.33)					
6.7	MCH	≤ 30.66	26(52)	19 (73.08)	7 (26.92)	9.64	7.96	0.002	0.44	strong
		>30.66	24(48)	7 (29.17)	17 (70.83)					
6.8	MCHC	≤ 32.81	28(56)	17 (60.71)	11 (39.29)	1.94	1.22	0.16	0.20	strong
		>32.81	22(44)	9 (40.91)	13 (59.09)					

Table 2a: Overall association of gender with profiles of thyroid, ferritin, liver, kidney and blood

Sl.No.	Studied variables	Correlation coefficient	p-value
1	Thyroid level		
1.1	THY FT3	-0.361*	0.01
1.2	THY FT4	-0.26	0.07
1.3	THY TSH	-0.287*	0.04
2	Ferritin level		
2.1	FERRitin	0.05	0.73
3	Liver function test (LFT)		
3.1	LFT ALT	0.18	0.20
3.2	LFT ALP	-0.10	0.49
3.3	LFT ALB	-0.17	0.24
3.4	LFT T. BILL	-0.16	0.26
4	Kidney Function test (KFT)		
4.1	TP	-0.21	0.15
4.2	UREA	-0.03	0.85
4.3	CREA	-0.17	0.24
4.4	GLOB	0.09	0.54
4.5	A/G RATIO	-0.17	0.23
5	Complete Blood Count (CBC)		
5.1	HGB	0.13	0.35
5.2	RBC	0.24	0.09
5.3	WBC	-0.04	0.76
5.4	PLT	0.12	0.40
5.5	HCT	-0.05	0.72
5.6	MCV	0.09	0.54
5.7	MCH	0.460**	0.001
5.8	MCHC	0.405**	0.003

Table 2b: Overall and gender wise association liver, kidney, and blood parameters with TSH, FT3, FT4, and Ferritin levels

Sl. No.	Variable Studied	Correlation coefficient Significance	Overall (n=50)			Males (n=26)			Females (n=24)			Overall (n=50)	Males (n=26)	Females (n=24)
		r-value p-value	FT3	FT4	TSH	FT3	FT4	TSH	FT3	FT4	TSH	FERRITIN	FERRITIN	FERRITIN
1	Liver Function test (LFT)													
1.1	LFT ALT	r-value	0.04	-0.15	-0.26	0.15	-0.524**	-0.08	-0.13	0.31	-0.482*	0.12	0.27	-0.10
		p-value	0.77	0.31	0.07	0.47	0.01	0.71	0.54	0.14	0.02	0.40	0.18	0.64
1.2	LFT ALP	r-value	-0.22	0.05	0.337*	-0.08	-0.05	0.511**	-0.24	0.10	0.20	-0.22	-0.23	-0.28
		p-value	0.13	0.72	0.02	0.71	0.80	0.01	0.27	0.63	0.34	0.12	0.26	0.18
1.3	LFT ALB	r-value	0.350*	0.25	0.21	0.22	0.09	0.08	0.30	0.23	0.10	0.01	0.07	0.12
		p-value	0.01	0.09	0.15	0.27	0.66	0.68	0.15	0.28	0.65	0.97	0.74	0.58
1.4	LFT T. BILL	r-value	0.292*	0.18	-0.13	0.18	0.502**	-0.06	0.38	-0.37	-0.18	0.24	0.19	0.628**
		p-value	0.04	0.20	0.37	0.39	0.01	0.78	0.07	0.08	0.41	0.10	0.36	0.001
2	Kidney Function Test (KFT)													
2.1	KFT TP	r-value	-0.05	-0.09	0.613**	-0.13	-0.15	0.682**	-0.01	-0.29	0.496*	-0.24	-.635**	0.559**
		p-value	0.75	0.54	0.00	0.52	0.47	0.00	0.98	0.18	0.01	0.09	0.0005	0.005
2.2	KFT UREA	r-value	-0.08	-0.22	-0.04	-0.24	-0.419*	0.22	0.01	-0.05	-0.405*	-0.04	0.24	-0.39
		p-value	0.60	0.12	0.77	0.24	0.03	0.29	0.95	0.82	0.05	0.79	0.24	0.06
2.3	KFT CREA	r-value	-0.25	-0.04	0.10	-0.436*	0.22	0.11	-0.17	-0.556**	0.01	-0.462**	-0.505**	-0.38
		p-value	0.08	0.80	0.51	0.03	0.29	0.58	0.44	0.00	0.98	0.00	0.01	0.07
2.4	KFT GLOB	r-value	-0.449**	-0.11	0.465**	-0.34	-0.14	0.730**	-0.427*	-0.27	0.23	-0.499**	-0.726**	-0.26
		p-value	0.00	0.45	0.00	0.09	0.48	0.00	0.04	0.20	0.27	0.00	0.00003	0.22
2.5	KFT A/G RATIO	r-value	0.511**	0.291*	-0.317*	0.399*	0.25	-0.590**	0.479*	0.36	-0.19	0.304*	0.576**	0.07
		p-value	0.00	0.04	0.02	0.04	0.22	0.002	0.02	0.08	0.37	0.03	0.002	0.73

Sl. No.	Variable Studied	Correlation coefficient Significance	Overall (n=50)			Males (n=26)			Females (n=24)			Overall (n=50)	Males (n=26)	Females (n=24)
		r-value p-value	FT3	FT4	TSH	FT3	FT4	TSH	FT3	FT4	TSH	FERRITIN	FERRITIN	FERRITIN
3	Complete Blood Count (CBC)													
3.1	CBC HGB	r-value	0.03	-0.14	0.01	0.18	-0.19	0.02	-0.06	-0.03	0.09	0.11	0.13	0.06
		p-value	0.82	0.35	0.96	0.38	0.35	0.93	0.78	0.89	0.69	0.46	0.54	0.78
3.2	CBC RBC	r-value	0.03	0.20	-0.20	0.14	0.16	0.05	0.09	0.35	-0.38	-0.03	-0.10	-0.12
		p-value	0.85	0.17	0.17	0.50	0.42	0.81	0.68	0.10	0.07	0.85	0.62	0.59
3.3	CBC WBC	r-value	-0.09	0.25	-0.10	-0.24	0.32	0.10	-0.14	0.24	-0.31	0.22	0.27	0.15
		p-value	0.51	0.08	0.51	0.24	0.11	0.62	0.50	0.25	0.14	0.12	0.18	0.50
3.4	CBC PLT	r-value	0.01	0.18	-0.23	0.06	0.20	-0.16	0.12	0.14	-0.29	0.23	0.25	0.19
		p-value	0.93	0.21	0.11	0.75	0.33	0.42	0.56	0.51	0.17	0.12	0.22	0.36
3.5	CBC HCT	r-value	0.05	-0.20	0.21	0.21	-0.18	0.10	0.07	-0.22	0.30	0.02	0.00	0.12
		p-value	0.72	0.16	0.14	0.31	0.39	0.61	0.73	0.29	0.15	0.89	0.99	0.56
3.6	CBC MCV	r-value	-0.04	0.07	-0.392**	-0.22	-0.05	-0.30	0.30	0.34	-0.460*	-0.24	-0.21	-0.31
		p-value	0.79	0.62	0.005	0.27	0.80	0.14	0.16	0.11	0.02	0.10	0.30	0.13
3.7	CBC MCH	r-value	-0.12	-0.11	-0.17	0.17	0.12	-0.11	-0.05	-0.24	0.25	-0.18	-.451*	0.14
		p-value	0.40	0.46	0.25	0.40	0.55	0.61	0.82	0.26	0.23	0.20	0.02	0.52
3.8	CBC MCHC	r-value	-0.11	-0.20	-0.05	0.12	0.00	-0.26	-0.09	-0.27	.499*	-0.20	-.465*	0.06
		p-value	0.43	0.16	0.73	0.56	0.98	0.20	0.66	0.20	0.01	0.16	0.02	0.77

Conclusion

Deferasirox is an effective and well-tolerated oral chelator in β-thalassemia major, offering significant benefits in controlling body iron stores while preserving endocrine and metabolic function. Routine ferritin and thyroid monitoring, along with periodic evaluation of bone health, should be integral to disease management.

Limitations

- Small, single-center sample
- Lack of matched pre-chelation endocrine data
- Need for longer follow-up to assess delayed endocrine recovery

Recommendations

- Introduce routine annual endocrine screening for all β-TM patients on chelation
- Future prospective multicenter trials to assess long-term metabolic impacts
- Patient education to ensure compliance with oral therapy

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