

# Effect of Iron-Erythrocyte Metabolism-Related Indexes on Posttraumatic Growth in Patients on Maintenance Hemodialysis (MHD)

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**Purpose:** To investigate the effect of iron-erythrocyte metabolism-related indexes on posttraumatic growth in MHD patients and their caregivers.

**Patients and Methods:** A total of 170 pairs of MHD patients and their caregivers in Shanghai Changhai Hospital were enrolled in this research, which used sociodemographic characteristics, the Posttraumatic Growth Inventory (PTGI), the Perceived Social Support Scale (PSSS), and the Medical Coping Modes Questionnaire (MCMQ). The test data of 141 patients were retrieved from the hospital database.

**Results:** Single-factor analysis showed that the PTGI score of patients with a mean corpuscular erythrocyte volume  $\geq 100$  fL was  $85.4 \pm 19.8$  and those with a mean corpuscular erythrocyte volume lower than 100 fL were  $70.6 \pm 24.7$ ; the PTGI scores of patients with reticulocytes  $>1.5\%$  were  $68.8 \pm 25.8$ , and those with reticulocytes  $<1.5\%$  were  $78.4 \pm 21.1$ ; the PTGI scores of the caregivers whose serum iron was  $>10.6 \mu\text{mol/L}$  were  $78.2 \pm 21.6$ , and those with serum iron  $<10.6 \mu\text{mol/L}$  were  $67.9 \pm 22.8$ . The difference in MCMQ scores between the caregivers with transferrin saturation  $>50\%$  and with transferrin saturation  $<20\%$  was  $18.9 \pm 8.4$ . For the correlation test of serum iron, reticulocyte and PTGI scores for patients, the Pearson correlation coefficients were 0.239 and  $-0.193$ , respectively, and the correlation test between erythrocyte distribution width SD and the score of caregivers MCMQ scale, the Pearson correlation coefficient was 0.225;  $p$  for all was  $< 0.05$ , with significant differences. There was no significant difference in the scores of different scales for total iron binding capacity (TIBC) at different levels.

**Conclusion:** The indexes related to iron erythrocyte metabolism in MHD patients are correlated with ruminant meditation of patients and their caregivers and promotion of posttraumatic growth. Good nutritional status, adequate hematopoietic material, and normal erythrocyte count and function are also important for them.

**Keywords:** caregiver, patient, PTGI, PSSS, MCMQ

## Introduction

People will form negative psychological states after experiencing major traumatic events, such as diseases, wars, and natural disasters. The person who experienced it will think about and review the events in his later life, and with the help of other people in society, he will experience spiritual and psychological growth, enabling him to better adapt to his situation.<sup>1</sup> This positive psychological change is called posttraumatic growth.<sup>2</sup> Maintenance hemodialysis is a traumatic event for patients.<sup>3</sup> Anxiety about life and health, consideration of social disconnection and economic pressure will cause psychological stress, but MHD patients will also experience the process of reflection and adaptation, gradually evolving to a state of posttraumatic growth, which is of positive significance for MHD patients' future treatment and quality of life. Family members who care for hemodialysis patients experience increasing responsibility and stress, but can also experience varying degrees of

posttraumatic growth.<sup>4</sup> At present, the PTGI scale is commonly used in China to evaluate the level of posttraumatic growth;<sup>5</sup> when evaluating the feelings and degrees of social support for MHD patients, the PSSS scale is commonly used.<sup>6</sup> For MHD patients with posttraumatic rumination, the modified MCMQ scale can be used to assess their attitude and coping style.<sup>7</sup> The PTGI, PSSS, and MCMQ scales are widely used in the posttraumatic growth assessment of MHD patients with various tumors, major chronic diseases and accidental injuries, with good reliability and validity.<sup>8,9</sup> There have been many studies conducted on posttraumatic growth in patients with tumors such as breast cancer,<sup>10</sup> and the data are relatively sufficient. The influencing factors of posttraumatic growth for patients on maintenance hemodialysis deserve further research. Previous studies have explored the status and influencing factors of post-traumatic growth, mainly focusing on personality traits, ruminant meditation and social support.<sup>11–13</sup> Posttraumatic growth is predicated on the thinking of the person experiencing it and on changes in cognition; thus, it is possible to explore the relationship between certain objective test data and the patient's posttraumatic growth and further explore the actual impact on the patient of metabolic and other issues reflected in this indicator. Patients with chronic renal insufficiency often also experience anemia symptoms. The impact of anemia on quality of life of the MHD patients is obvious. The direct manifestation of anemia is hypoxia. Long-term chronic hypoxia also increases the cardiac load, and affects calcium and phosphorus metabolism to varying degrees.<sup>14</sup> It affects the MHD patient's ability to perform activities of daily life living (ADL), resulting in a significant decrease in the patient's quality of life, which in turn has an impact on the patient's psychological well-being.<sup>15,16</sup> Previous studies have explored the relationship between quality of life and psychological changes in patients with chronic diseases, as well as the relationship between this impact and further treatment. For people with chronic physical health problems, it is necessary to determine their quality of life during their illness, and evaluate their self-care ability and positive mental health (PMH). Both constructs influence their well-being and the way in which they cope with their illness.<sup>17</sup> Low quality of life scores and depression are associated with higher comorbidity, poorer nutritional status, anemia, lower residual renal function, and higher hospitalization rates.<sup>18</sup> Psychological factors may lead to excessive activation of the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis. These chronic stimuli from the center can induce various pathophysiological reactions, including increased inflammation and hypertension, autonomic nervous system dysfunction, platelet dysfunction, endothelial dysfunction, visceral fat increase and insulin resistance. Therefore, psychological adjustment to chronic dialysis may also be associated with good clinical outcomes.<sup>19</sup> Therefore, for patients with chronic underlying diseases, correction of anemia is beneficial to improve their quality of life and further treatment.<sup>17</sup> This research focuses on the relationship between the indexes related to iron-erythrocyte metabolism in maintenance hemodialysis patients and their caregivers' posttraumatic growth and analyzes the objective significance of test items in relation to this alteration. This research provides new perspectives and ideas for clinical medical staff to improve the posttraumatic growth of these MHD patients and their caregivers.

## Objectives and Methods

### Research Objects

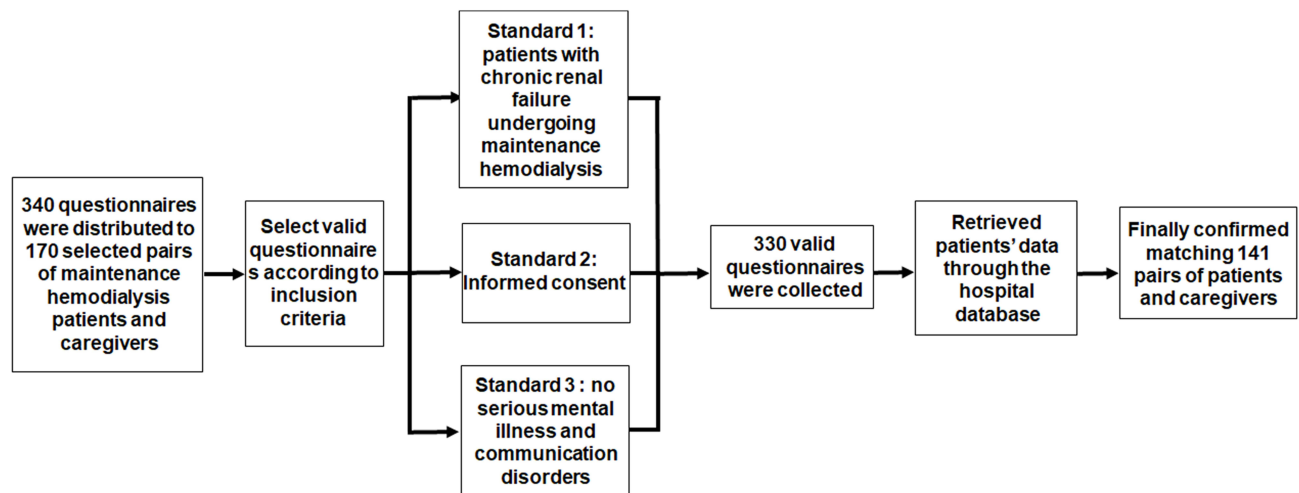
A cross-sectional study design was adopted for this research. A total of 170 patients on maintenance hemodialysis at Changhai Hospital were continuously selected, and 340 questionnaires were distributed. Inclusion criteria for patients were as follows: (1) undergoing maintenance hemodialysis with chronic renal failure; (2) providing signed informed consent; and (3) having no serious mental illness or communication disorder. Finally, 330 valid questionnaires were collected for an effective rate of 97%. The test data of the MHD patients and caregivers were retrieved from the hospital database, and a total of 141 pairs of valid data points were obtained. (Figure 1)

### Research Tools

The questionnaire was composed of four parts: sociodemographic characteristics, PTGI, PSSS and MCMQ.

### Social Demographic Characteristics Table

Demographics included MHD patient age, sex, religion, education, work and other personal information; dialysis start time, dialysis duration, self-care ability and other related information; economic information such as the relationship between caregivers and themselves, family income, medical insurance, and economic pressures.



**Figure 1** Process of sample selection.

## PTGI

The PTGI quantitatively assesses the posttraumatic growth level of the experience;<sup>20</sup> the higher the score is, the higher the level of posttraumatic growth and the stronger the adaptability of patients to traumatic events, which is conducive to their subsequent treatment and quality of life.

## PSSS

The PSSS quantitatively assesses the perception level of the patient about the help received from other members of society, including the care and support of relatives, friends, and colleagues; the patient's emotional state; his or her psychological adjustment and ability to regain confidence.<sup>21</sup> The higher the score is, the higher the level of perceived social support, which facilitates the psychological construction and post-traumatic growth of patients.<sup>22</sup>

## MCMQ

The MCMQ evaluates ruminant meditation levels.<sup>23</sup> Ruminative meditation includes intrusive and active parts. The former is actually a negative factor for the patient in the short term and is positively correlated with stress symptoms. The latter is positively correlated with PTG, which is conducive to its subsequent treatment and quality of life. However, the overall quantitative score can evaluate the degree of reflection on traumatic events. The higher the score is, the higher the degree of reflection on traumatic events.

## Data Collection

The data for this research consisted of two parts: the data from the questionnaire and the results of all tests performed at our hospital within two years before the MHD patients completed the questionnaires.

## Ethical Review

First, written approval was received from the Ethics Committee of Shanghai Changhai Hospital. Before data collection, information about the purpose of the research was provided to the participants and the confidentiality of the individuals' identity and voluntary participation was guaranteed. After giving the required explanations, questionnaires were sent to the participants and completed. (Ethics Number B2020-020) This research is in compliance with the Declaration of Helsinki.

## Data Processing

The data were analyzed with SPSS 23.0. The statistical methods included descriptive statistics, independent samples *t*-test, single factor analysis of variance and Pearson correlation analysis. The data are expressed as the mean  $\pm$  standard deviation ( $X \pm SD$ ), and  $P < 0.05$  indicated that the difference was statistically significant.

## Results

### Describe and Analyze the General Conditions of MHD Patients and Their Caregivers

The questionnaires administered to the 141 MHD patients and their caregivers were collected and included in the final analysis. The majority of MHD patients were male (57.4%), while caregivers were female (57.4%); were 50 years or older (>80%), had no religious affiliation, were married, had a junior high school to junior college education, and were retired. The proportion of MHD patients who were employed was noticeably lower than that of caregivers; among the caregivers, the spouse, parents and children accounted for 92.9% of the immediate family members, while nonimmediate family members and others accounted for less than 3%; approximately half (46.8%) of the patients with immediate hemodialysis at the time of discovery had a more rapid progression of renal function deterioration; most MHD patients had been on dialysis for more than six months (90.1%); had medical insurance (87.2% had serious illness medical insurance, 5% general medical insurance, and 7.8% had other medical insurance or paid out of pocket. MHD patients had a monthly household income of less than 2000 yuan (7%), 27% had 2000–5000 yuan, 46.1% had 5000–10,000 yuan, and 19.9% had more than 10,000 yuan. Most MHD patients reported no pressure as a result of medical costs (11.3%) or less pressure (48.9%), but a significant proportion (36.2%) also felt more pressure, and only 3.6% of MHD patients found cost pressure unacceptable Details are shown in [Tables 1](#) and [2](#).

**Table 1** General Conditions of MHD Patients and Caregivers (Sex, Age, Religious Belief, Marital Status, Diploma, and Working Status)

		Patients		Family Members (Caregivers)	
		Number n	Percentage %	Number n	Percentage %
Sex	Male	81	57.4	60	42.6
	Female	60	42.6	81	57.4
Age	18–29 years old	3	2.1	3	2.1
	30–39 years old	9	6.4	21	14.9
	40–49 years old	14	9.9	17	12.1
	50–59 years old	30	21.3	24	17.0
	Over 60 years old	85	60.3	76	53.9
Religious belief	None	120	85.1	118	83.7
	Buddhism	14	9.9	13	9.2
	Christianity	4	2.8	4	2.8
	Other	3	2.1	5	3.5
Marital status	Married	114	80.9	127	90.1
	Dissociation	3	2.1	3	2.1
	Unmarried	15	10.6	6	4.3
	Widowed	9	6.4	5	3.5
Diploma	Below junior high school	15	10.6	9	6.4
	Junior high school	37	26.2	33	23.4
	Senior high school	50	35.5	46	32.6
	Junior college	26	18.4	36	25.5
	Undergraduate	12	8.5	12	8.5
Working status	Bachelor's degree or more	1	0.7	5	3.5
	Employed	12	8.5	41	29.1
	Retired	106	75.2	84	59.6
	Unemployment	11	7.8	4	2.8
	Other	12	8.5	12	8.5

**Table 2** General Conditions of MHD Patients and Caregivers (Relationship Between Caregivers and MHD Patients, the Starting Time of Hemodialysis, Time in Dialysis, Medical Insurance, Family Monthly Income, and Economic Pressure)

		Patients		Family Members (Caregivers)	
		Number n	Percentage %	Number n	Percentage %
Relationship between caregivers and patients	Matrimonial	93	66.0		
	Children	26	18.4		
	Parents	12	8.5		
	Siblings	6	4.3		
	Nonimmediate family	1	0.7		
	Other	3	2.1		
Starting time of hemodialysis	Immediately	66	46.8		
	Within 3 months after diagnosis	21	14.9		
	Within 6 months after diagnosis	12	8.5		
	Within 1 year after diagnosis	25	17.7		
	Other	17	12.1		
Time in dialysis	Less than 1 month	3	2.1		
	1–3 months	3	2.1		
	3–6 months	8	5.7		
	6 months–1 year	35	24.8		
	1–3 years	29	20.6		
	More than 3 years	63	44.7		
Medical insurance	Serious illness medical insurance	123	87.2		
	General medical insurance	7	5.0		
	Self-pay	6	4.3		
	Other	5	3.5		
Family monthly income	Less than 2000 yuan	10	7.0		
	2000–5000 yuan	38	27.0		
	5000–10,000 yuan	65	46.1		
	More than 10,000 yuan	28	19.9		
Economic pressure	No pressure	16	11.3		
	Less pressure	69	48.9		
	Greater pressure	51	36.2		
	Unable to withstand	5	3.6		

## Analysis of the PTGI, PSSS and MCMQ Scores

The PTGI score of caregivers ( $76.1 \pm 24.3$ ) was higher than that of MHD patients ( $72.3 \pm 24.4$ ), while the PSSS score profile was higher for MHD patients ( $57.5 \pm 15.4$ ) than for caregivers ( $55.1 \pm 15.5$ ), and the differences were statistically significant ( $p < 0.05$ ). The difference between MCQC scale scores for MHD patients ( $25.9 \pm 15.7$ ) and caregivers ( $25.7 \pm 14.8$ ) was not statistically significant. The results are shown in [Table 3](#).

By analyzing the difference in the scale scores of different levels of TIBC, it is concluded that there is no statistical significance in the difference in the scale scores of different levels of TIBC. The results are shown in [Table 4](#).

Single-factor ANOVA was used to test the difference in scores on the scale of transferrin saturation at different levels, based on the normal upper and lower limits of the test indexes. The results showed that the difference in scores on the MCMQ scale between the caregivers of the group with transferrin saturation  $> 50\%$  and the patient with transferrin saturation  $< 20\%$  was  $18.9 \pm 8.4$ ,  $p < 0.05$ . The results are shown in [Table 5](#).

**Table 3** Comparison of Mean Scores (Independent Sample *t*-Tests) and Standard Deviations of MHD Patients and Caregivers PTGI, PSSS, and MCMQ Scales

		Mean Value	Standard Deviation	t	Significance (Two-Tailed)	95% Confidence Interval of Difference	
						Lower Limit	Upper Limit
PTGI	MHD patients	72.3	24.4	-2.392	0.018	-6.8137	-0.6473
PTGI	Caregivers	76.1	24.3				
PSSS	MHD patients	57.5	15.4	2.238	0.027	0.2725	4.4083
PSSS	Caregivers	55.1	15.5				
MCMQ	MHD patients	25.9	15.7	0.209	0.834	-1.6756	2.0727
MCMQ	Caregivers	25.7	14.8				

## Univariate Analysis

Using the method of independent sample *t*-test, taking the upper or lower normal limit of the test index as the grouping basis, some test indexes are obtained, and the mean value of the scale score is significantly different. Among the indicators related to iron-erythrocyte metabolism, the PTGI score of MHD patients with an average erythrocyte volume  $\geq 100$  fL was higher than that of MHD patients with an average erythrocyte volume  $<100$  fL. The mean value and standard deviation of the score of MHD patients with erythrocyte volume  $\geq 100$  fL were  $85.4 \pm 19.8$ , while the mean value of MHD patients with erythrocyte volume  $\geq 100$  fL was  $70.7 \pm 24.8$ . MHD patients with reticulocytes  $\geq 1.5\%$  had lower PTGI scores ( $68.9 \pm 25.8$ ) than those who had  $<1.5\%$  ( $78.4 \pm 21.2$ ), and caregivers with serum iron  $\geq 10.6$   $\mu\text{mol/L}$  had higher PTGI scores ( $78.3 \pm 21.7$ ) than those with  $<10.6$   $\mu\text{mol/L}$  ( $67.9 \pm 22.9$ ),  $p < 0.05$ . The results are shown in Table 6.

## Comparison of the Differences in Serum Iron at Different PTGI Levels

According to the results of the independent sample *t*-test, the mean values of erythrocyte volume, reticulocytes, and serum iron indexes were further investigated in MHD patients with different PTGI levels (based on the median grouping). The results showed statistically significant differences in PTGI scores for MHD patients and caregivers at different levels, as well as in MHD patients' serum iron. The serum iron difference of MHD patients with PTGI greater than or equal to the median was  $2.17 \pm 0.83$   $\mu\text{mol/L}$  ( $p < 0.05$ ). The serum iron difference of caregivers with PTGI greater than or equal to the median was  $1.69 \pm 0.84$   $\mu\text{mol/L}$ ,  $p < 0.05$ . The results are shown in Table 7.

## Comparison of Differences in Erythrocyte Distribution Width SD at MCMQ Score Levels

Using the median MHD patients and caregivers MCMQ scale scores as the basis for grouping, the results obtained had statistically significant differences in the mean value of the erythrocyte distribution width of the MHD patients for different MCMQ scale score levels. The difference in erythrocyte distribution width SD in MHD patients with a score  $\geq$  the median MCMQ was  $2.67 \pm 1.13\%$  compared with those who had a score  $<$  the median,  $p < 0.05$ . The difference in erythrocyte distribution width SD in caregivers with a score  $\geq$  the median MCMQ was  $2.89 \pm 1.12\%$  compared with the group with a score  $<$  the median,  $p < 0.05$ . The results are shown in Table 8.

## Correlation Test Between Serum Iron, Erythrocyte Distribution Width SD, Reticulocytes and Scores of Each Scale

Bivariate correlation analysis was performed between the MHD patient test data and PTGI, social support scale and MCMQ scale scores. The results showed that in the correlation test between reticulocyte, serum iron and PTGI scores of MHD patients, Pearson correlation coefficients were 0.239 and  $-0.193$ , respectively. In the correlation test between erythrocyte distribution width SD and MCMQ scores of caregivers, the Pearson correlation coefficient was 0.225,  $p < 0.05$ , indicating significant differences. The results are shown in Table 9.

**Table 4** Influence of Total Iron Binding Capacity on PTGI, PSSS and MCMQ Scores of MHD Patients and Their Caregivers (n=132)

		Scores			Variance Homogeneity Test		t	Significance (Two-Tailed)	Difference of Mean Value	Difference of Standard Error	95% Confidence Interval of Difference	
		Mean Value	Standard Deviation		F	Significance					Lower Limit	Upper Limit
PTGI of MHD patients	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	75.6	25.3	Assuming equal variance	0.447	0.505	1.841	0.068	7.7384	4.2032	-0.5770	16.0539
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	67.8	22.8									
PSSS of MHD patients	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	59.0	15.6	Assuming equal variance	1.880	0.173	1.693	0.093	4.4562	2.6327	-0.7522	9.6646
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	54.6	14.6									
MCMQ of MHD patients	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	25.9	16.2	Assuming equal variance	3.164	0.078	0.476	0.635	1.2202	2.5634	-3.8512	6.2915
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	24.6	12.8									
PTGI of caregivers	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	78.6	25.5	Assuming equal variance	1.217	0.272	1.169	0.245	4.8323	4.1348	-3.3480	13.0126
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	73.8	21.6									
PSSS of caregivers	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	55.2	16.5	Assuming equal variance	1.703	0.194	0.282	0.778	0.7598	2.6946	-4.5710	6.0907
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	54.4	14.3									
MCMQ of caregivers	TIBC $\geq$ 45 $\mu\text{mol/L}$ (n=69)	26.0	16.3	Assuming equal variance	8.235	0.005	0.716	0.475	1.7143	2.3941	-3.0260	6.4545
	TIBC < 45 $\mu\text{mol/L}$ (n=63)	24.3	10.9									



**Table 5** Effect of Transferrin Saturation Level on MCMQ Scores of Caregivers (n=115)

Transferrin Saturation		Difference of Mean Value	Standard Error	Significance	95% Confidence Interval of Difference	
					Lower Limit	Upper Limit
<20% (n=3)	20–50% (n=91)	–12.359	7.973	0.124	–28.157	3.439
	>50% (n=21)	–18.857	8.387	0.027	–35.474	–2.240
20–50% (n=91)	<20% (n=3)	12.359	7.973	0.124	–3.439	28.157
	>50% (n=21)	–6.498	3.290	0.051	–13.016	0.020
>50% (n=21)	<20% (n=3)	18.857	8.387	0.027	2.240	35.474
	20–50% (n=91)	6.498	3.290	0.051	–0.020	13.016

## Discussion

### PTGI, PSSS, and MCMQ Scale Scores for Patients on Maintenance Hemodialysis and Their Caregivers

This research shows that the score of MHD patients with PSSS is higher than that of their caregivers, which indicates that MHD patients' perception of help and understanding from other members of society is higher than that of their caregivers. MHD patients tend to receive more care from relatives and friends. This is a factor that facilitates the formation of posttraumatic growth in MHD patients. Both caregivers and MHD patients developed higher levels of posttraumatic growth after experiencing this traumatic event,<sup>24</sup> but caregivers had higher levels of PTGI than MHD patients, which may be due to the difference in the degree of perception of this traumatic event and ruminant meditation between caregivers and MHD patients. Due to the long treatment cycle, heavy economic burden, and many complications of dialysis treatment, the caregivers of MHD patients have to passively assume more family responsibilities, not only in terms of economic burden and daily living care, but also in terms of possible negative emotions of MHD patients, thus the posttraumatic growth level of caregivers will be higher. As a person who has experienced the disease, the MHD patient focuses more on the severity and outcome of his or her illness, so it is easier for the patient to reflect on this event and form an invasive meditation.<sup>25</sup>

### Effect of Iron-Erythrocyte Metabolism on Posttraumatic Growth of Patients on Maintenance Hemodialysis and Their Caregivers

It is well known that patients with chronic kidney disease often present with anemia, the most common cause being erythropoietin (EPO) deficiency.<sup>26</sup> Iron deficiency anemia caused by insufficient iron levels due to digestive system symptoms and chronic consumption is also common. Anemia patients often present with dizziness, weakness, and increased heart rate,<sup>27</sup> which greatly affects the quality of life and treatment cycle of patients, while long-term anemia may correlate with the occurrence and progression of heart failure and deterioration of renal function.<sup>28</sup> Commonly used clinical modalities to correct anemia are iron supplementation (intravenous, oral),<sup>29</sup> Roxadustat, and recombinant human erythropoietin, which usually achieve good results. However, for most patients, more medication is not only a financial burden but also a psychological burden. The results of this research show that higher levels of serum iron suggest adequate hematopoietic material, and the level of caregivers' posttraumatic growth is higher because the high level of serum iron is linked to better objective indicators and control of the disease. When evaluating the iron homeostasis of MHD patients, we should comprehensively consider serum iron and TIBC, as serum iron may be affected by inflammation and other factors. Some studies have explained the role of TIBC in evaluating the muscle performance of MHD patients. High-level TIBC has better muscle strength and cardiac function, and better life treatment and prognosis. However, in our research, we did not find significant differences in the scores of MHD patients and their caregivers in different groups of TIBC. We further considered this question, and it is possible that the positive results were masked by differences in sex, and further statistical analysis based on sex differences still did not reveal significant differences.



**Table 6** Effects of Mean Corpuscular Volume, Reticulocyte and Serum Iron Levels on PTGI Scores of MHD Patients and Caregivers

		PTGI Scores			Variance Homogeneity Test		t	Significance (Two-Tailed)	Difference of Mean Value	Difference of Standard Error	95% Confidence Interval of Difference	
		Mean Value	Standard Deviation		F	Significance					Lower Limit	Upper Limit
Mean corpuscular volume and PTGI of MHD patients	$\geq 100\text{fL}$ (n=12)	85.4	19.8	Assuming equal variance	1.817	0.180	2.001	0.047	14.7581	7.3744	0.1718	29.3444
	$<100\text{fL}$ (n=123)	70.7	24.8									
Reticulocytes and PTGI of MHD patients	$\geq 1.5\%$ (n=74)	68.9	25.8	Assuming equal variance	2.196	0.141	-1.996	0.048	-9.5216	4.7699	-18.9727	-0.0706
	$<1.5\%$ (n=40)	78.4	21.2									
Serum iron and PTGI of caregivers	$\geq 10.6\text{ umol/L}$ (n=72)	78.3	21.7	Assuming equal variance	0.179	0.673	2.230	0.028	10.3384	4.6354	1.1452	19.5316
	$<10.6\text{ umol/L}$ (n=33)	67.9	22.9									

**Table 7** Differences in Serum Iron Levels Between High and Low PTG Levels

		Variance Homogeneity Test		t	Degree of Freedom	Significance (Two-Tailed)	Difference of Mean Value	Difference of Standard Error	95% Confidence Interval of Difference	
		F	Significance						Lower Limit	Upper Limit
MHD patients	Assuming equal variance	2.283	0.134	2.61	103	0.010	2.17	0.83	0.52	3.82
Caregivers	Assuming equal variance	2.283	0.134	2.61	103	0.010	1.69	0.84	0.02	3.36

**Table 8** Differences in Erythrocyte Distribution Width SD Between High and Low MCMQ Levels

		Variance Homogeneity Test		t	Degree of Freedom	Significance (Two-Tailed)	Difference of Mean Value	Difference of Standard Error	95% Confidence Interval of Difference	
		F	Significance						Lower Limit	Upper Limit
MHD patients		0.154	0.696	2.372	89	0.020	2.67	1.13	0.434	4.915
Caregivers		0.372	0.544	2.577	89	0.012	2.89	1.12	0.663	5.133

**Table 9** Correlation Test Between Serum Iron, Erythrocyte Distribution Width SD, Reticulocytes and Scores of Each Scale

		PTGI of MHD Patients	PSSS of MHD Patients	MCMQ of MHD Patients	PTGI of Caregivers	PSSS of Caregivers	MCMQ of Caregivers
Serum iron (n=105)	Pearson correlation	0.239*	0.172	0.111	0.174	-0.086	0.055
	Significance (Two-tailed)	0.014	0.079	0.258	0.076	0.380	0.576
Erythrocyte distribution width SD (n=91)	Pearson correlation	0.059	0.051	0.145	0.168	0.075	0.225
	Significance (Two-tailed)	0.579	0.633	0.170	0.111	0.481	0.032
Reticulocytes (n=114)	Pearson correlation	-0.193*	-0.144	0.041	-0.126	-0.109	0.026
	Significance (Two-tailed)	0.040	0.126	0.667	0.180	0.248	0.782

**Abbreviations:** PTGI, the Posttraumatic Growth Inventory; PSSS, the Perceived Social Support Scale; MCMQ, the Medical Coping Modes Questionnaire.

According to the analysis, the TIBC of MHD patients with chronic kidney disease and long-term hemodialysis usually remained normal or low for a long time, so the number of MHD patients at a high level was too small to make a significant difference. However, another indicator showed that the caregivers in the group with higher transferrin saturation had higher scores of ruminant meditations. In our analysis of this result, we considered that transferrin saturation comprehensively reflected the MHD patient's serum iron content and total iron binding capacity, and strongly supported the role of iron homeostasis in the posttraumatic growth of MHD patients and their caregivers. In contrast, elevated reticulocytes usually suggest the promotion of bone marrow erythropoiesis,<sup>30</sup> and patients with low blood erythrocyte counts and insufficient oxygen-carrying capacity will be prone to systemic symptoms such as malaise and dizziness. The results of this research show that MHD patients with high reticulocyte levels have low levels of posttraumatic growth, because high reticulocytes suggest that their peripheral blood red blood cells are insufficient and that MHD patients are more likely to be in a state of anemia and hypoxia. The larger mean erythrocyte volume, commonly seen in megaloblastic anemia, may be due to folic acid and vitamin B12 deficiency, implying poorer erythrocyte function.<sup>31</sup> However, the result was that MHD patients had higher PTGI scores, a finding that did not

meet expectations. To clarify the effect of this index, it would be worthwhile to further explore the effect of folic acid and vitamin B12 differences. From another perspective, exploring whether there was a difference in the mean values of serum iron indicators between caregivers and MHD patients with different PTGI levels, the results showed that MHD patients with high levels of PTGI had higher serum iron indicators, a result consistent with the aforementioned conclusion that high levels of serum iron form high levels of PTGI. We also explored differences in the erythrocyte distribution width SD at different MCMQ scale score levels for MHD patients and caregivers. The results showed that MHD patients and their caregivers with higher MCMQ scores had a larger erythrocyte distribution width SD; that is, the higher the ruminant meditation level and the reflection level on events was, the higher the erythrocyte distribution width SD. Bivariate correlation analysis between serum iron, erythrocyte distribution width SD, reticulocytes and the scores of each scale showed that serum iron was positively correlated with the MHD patient's PTGI, reticulocytes were negatively correlated with the MHD patient's PTGI, and the erythrocyte distribution width SD was positively correlated with the caregiver MCMQ scale score. In summary, we can clarify the correlation between iron-erythrocyte metabolism-related indicators and the traumatic growth of MHD patients and caregivers, and further analysis can infer that maintaining iron homeostasis and normal erythrocyte number and function has a facilitating effect on the posttraumatic growth of MHD patients and caregivers.<sup>32</sup>

## Conclusion

This research investigated the effect of iron-erythrocyte metabolism-related tests on PTGI, PSSS, and MCMQ scale scores. The results showed that serum iron was positively correlated with MHD patients' PTGI. Caregivers with high transferrin saturation had higher MCMQ scores than those below the reference value, suggesting that good nutritional levels and adequate hematopoietic material are beneficial for posttraumatic growth of MHD patients and caregivers. In contrast, reticulocytes are negatively correlated with the MHD patient's PTGI, and the high level represents a low level of red blood cells in the MHD patient's blood and a promotion of bone marrow erythropoiesis. Mean erythrocyte volume and erythrocyte distribution width also suggest the impact of differences in erythrocyte morphology and distribution on their function, which in turn affects MHD patients' and caregivers' ruminative meditation and posttraumatic growth. Therefore, medical workers should focus on the indicators related to iron-erythrocyte metabolism in maintenance hemodialysis patients and should pay attention to improving MHD patients' nutritional status, and timely supplementation with iron, folic acid and vitamin B12, to improve anemia and promote posttraumatic growth of MHD patients and their caregivers.

## Summary

The innovation of this research is that, on the one hand, it analyzes the relationship between objective test indexes related to iron-erythrocyte metabolism and posttraumatic growth, whereas previous studies were limited to MHD patients' general social information and subjective scores. On the other hand, in addition to analyzing MHD patients' posttraumatic growth, this research also targets the family members who take care of them, promoting their posttraumatic growth, which is also important for taking care of MHD patients, facilitating their compliance with treatment and obtaining a better quality of life. The limitation is that the research is a cross-sectional study design, and it is not possible to infer causality but only to determine the correlation between serum iron, reticulocytes and other relevant tests and posttraumatic growth. In addition, the clinical indicators of MHD patients are diverse, and the association of various indicators and their influence on each other are not well controlled for covariates. We did not collect sample data of MHD patients and caregivers from the perspective of longitudinal comparison, because the longitudinal comparison requires a long time, which makes data collection more difficult. If longitudinal comparisons are used, the long research period results in missing data when MHD patients proceed to kidney transplantation, transfer to another hospital, or die. To ensure the objectivity of the post-traumatic growth level of the research subjects, the caregivers in this research are the main caregivers of the selected MHD patients. With a longitudinal comparison approach, changes in caregivers may occur during the data-tracking process, which will affect the representativeness of data on the assessment of caregivers' posttraumatic growth. Further longitudinal studies could be conducted in the future to explore the causal relationship between the corresponding indicators and posttraumatic growth between MHD patients and caregivers. The relationship

between other systemic metabolic indicators and posttraumatic growth of MHD patients and caregivers can also be further explored.

## Statement of Informed Consent

All participants (including MHD patients and their caregivers) had read and signed the informed consent form of this research. Participation in this research was voluntary for each individual. Everyone was allowed to ask questions and all questions were answered.

## Author Contributions

In this research, Xin-Rui Liang was responsible for writing the manuscript, as well as data and funding support for the project. Wen-Hao Dong was responsible for writing the manuscript and conducting the statistical analysis. Wen-Di Bi was responsible for writing and revising the manuscript. Jing-Jing Li and Yan-Qiu Weng were responsible for the collection and organization of the questionnaire results. Ling-Juan Zhang and Zhi-Yong Guo were responsible for the guidance of manuscript revision. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors report no conflicts of interest in this work.

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