Transfusion burden and willingness to pay for temporary alleviation of anemia status in transfusion-dependent beta-thalassemia patients in China

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Abstract

Background Transfusion-dependent β-thalassemia (TDT) is one of the global public health concerns highlighted by the World Health Organization. Patients with TDT require regular blood transfusion to survive. However, the availability of blood resources is extremely limited. The purpose of this study was to investigate transfusion burden and willingness to pay (WTP) for temporary remission of anemia status among patients with TDT and to explore the associated factors.

Methods Adult patients with TDT were recruited through cluster sampling across several high-incidence provinces in China. Consenting patients completed online questionnaires on demographic information, transfusion burden and WTP with real-time WeChat communication assistance from researchers. The guiding techniques of double-bounded dichotomous choices and open-ended questions in the contingent valuation method (CVM) were used to obtain participants' WTP for 1 unit of leukocyte-depleted red blood cells. WTP calculations were performed using maximum likelihood estimation, with further insights gained through subgroup analysis based on gender, family monthly income level and convenience of blood transfusion.

Results The analysis included 149 TDT patients from five high-incidence provinces, with an average monthly income of $198.5. Patients received an average of 3.7 units per transfusion, 15.4 times annually, with an average WTP of $70.4 per unit (95% CI [62.0, 78.9]). Estimated WTP for temporary anemia alleviation per transfusion totaled $260.6, exceeding monthly income by 1.32 times. Higher WTP was observed among males, higher-income households, and those with at least junior education. Lower WTP was noted among patients with lower transfusion volumes and those needing to travel for transfusion or during hospitalization for blood transfusion.

Conclusion High WTP indicated a strong desire for temporary anemia relief. Most TDT patients faced significant economic and transfusion burden. The evident gap in meeting clinical needed underscores the urgent demand for innovative treatments to reduce transfusion dependency, potentially transforming TDT care and improving

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socioeconomic well-being and clinical outcomes. These findings supported evidence-based decision-making for TDT pharmacoeconomics and efficient healthcare resource allocation in China.

Key points

1. In China, patients generally had low economic levels and faced high transfusion burden and severe challenges in obtaining transfusion. They received an average of 1.4 blood transfusions per month. In addition, 25.5% of patients did not receive regular transfusion, and 91.9% experienced delayed transfusions.
2. Chinese transfusion-dependent β-thalassemia (TDT) patients, aiming to temporarily alleviate anemic conditions, were willing to pay up to RMB 513.5 (USD 70.4) for 1 unit of leukocyte-depleted red blood cells. This finding may provide valuable insights for future health economic studies focused on TDT.
3. Male gender, higher household income, and education beyond junior high school were correlated with higher WTP. Additionally, patients with lower single-transfusion volumes and more convenience of blood transfusion exhibited higher WTP.

Keywords Willingness-to-pay, Transfusion burden, Anemia, Transfusion-dependent β-thalassemia

Introduction

β-thalassemia is a genetic blood disorder marked by ineffective erythropoiesis and anemia of varying severity, the overall prevalence is 2.21% in China [1], which poses a significant threat to human health. Transfusion-dependent β-thalassemia (TDT) includes β-thalassemia major, some β-thalassemia intermediate and severe HbE/β-thalassemia [2]. It is characterized by chronic and progressive anemia and thalassemia major has been categorized as a rare disease by the National Health Commission of the People's Republic of China [3]. TDT imposes substantial disease burden with lifelong Red blood cell (RBC) transfusions [4] and iron-chelation therapy and significantly restricts their life expectancy and quality of life [5]. Hematopoietic stem cell transplantation is the only cure for β-thalassemia major which often lacks suitable donors [6], and is more suitable for patients aged 2-7 years, for whom there is an age-related risk [2]. Standardized blood transfusion combined with iron-chelation therapy remains the main supportive treatment [7] to provide temporary relief from anemia symptoms.

China's blood supply has faced a 'tight balance,' with shortages that are seasonal, structural, and regional. The red blood cell distribution rate per thousand people, a measure of blood institutions' clinical supply capacity, stood significantly lower than the global average, at 11.1 donations per thousand in 2020 and 3.4 milliliters of red blood cells per capita [8]. Under these circumstances, many TDT patients in China did not receive adequate blood transfusions. A study in Guangxi Province revealed that a mere 26.7% of TDT patients received transfusions as scheduled, whereas 77% were either uncertain about or believed they lacked an adequate blood supply [9]. According to recent research, blood shortages posed a significant challenge to implementing standardized treatment for thalassemia. In China, the recommended standard transfusion threshold for children with thalassemia was 90 g/L. However, due to insufficient blood supply, this standard was often restricted to 60 g/L, resulting in only 32.1% of children receiving the necessary transfusion [10]. In this situation, assessing the transfusion burden for TDT patients could shed light on the current state of clinical blood use for TDT, facilitating a better balance in the supply and demand of blood resources. Currently, there is limited research on the socioeconomic aspects and transfusion burden of β-thalassemia in China, with most studies focusing on individual provinces or specific cities [9].

In China, blood is not a commodity. It is collected by blood stations, which are non-profit organizations, and used exclusively for clinical purposes without any trade. Since 2005, a uniform national fee for blood has been in place, with a standard charge of RMB 220 for 200 milliliters. This regulation significantly ensured the safety of blood transfusions. However, the blood price may not reflect its true value. If the price of blood was the sole criterion, the monetary value of blood for patients could be underestimated, potentially impacting the development of innovative technologies aimed at reducing transfusion burden.

Standardized blood transfusion and chelation therapy were major challenges for many developing countries and represent major and unsustainable health burden [11]. Such treatments may cause infections, alloimmunization, damage from trace elements and other transfusion reactions [12]. Therefore, considering the importance of blood and novel therapies to patients, it is essential to provide a perspective that reflects the value of blood and transfusion alternatives. The economic value of health improvements or treatments can be assessed by considering patients' willingness to pay (WTP). The contingent valuation method (CVM) is a classic method commonly used in healthcare to evaluate WTP [13, 14], which overcomes limitations in effectively evaluating the value of medical resources and services in situations where market mechanisms are absent. It enables researchers to

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understand public preferences for healthcare resources and services under various hypothetical scenarios, and thereby assess the value of medical resources and services [15].

WTP elicitation methods are crucial techniques for enhancing the reliability and effectiveness of CVM assessment [16]. There are four primary methods: bidding games, open-ended questions, payment cards and dichotomous choice (DC). DC includes single-bounded, double-bounded and multiple-bounded approaches [17]. The double-bounded approach, known for its advantages such as incentive compatibility, precise variance estimation, and more accurate WTP confidence intervals [18], is widely recognized as superior to the single-bounded approach in terms of both result accuracy and response efficiency [19]. Unlike the triple-bounded method, which can introduce bias due to respondent fatigue [20], the double-bounded approach provides a reliable balance between precision and participant burden. Furthermore, previous studies have consistently shown that the WTP of survey participants was significantly influenced by their economic status [21–24].

Method
Setting
The data were collected from adult TDT patient samples in five high-prevalence provinces in China [4], including Guangdong, Guangxi, Yunnan, Hunan, and Guizhou from March to July 2023.

Definitions and selection criteria
In this study, "anemia status" referred to the state in which patients exhibited anemia symptoms and required blood transfusions for life sustenance. To clarify this concept for participants, the questionnaire was developed with insights from six leading hematologists across China, who concurred that blood transfusion is pivotal for temporary relief from anemia—a concept easily understood by patients as essential for their health. Therefore, the measurement of the willingness of TDT patients to pay for a unit of blood was chosen, reflecting their willingness to temporarily alleviate anemia. The pilot survey confirmed that patients had a positive understanding of the questionnaire.

As the payment unit for WTP, this study focused on 1 unit of leukocyte-depleted suspended red blood cells due to: (1) the recommendation in the 2022 Chinese Guidelines for the Diagnosis and Treatment of Transfusion-Dependent β-Thalassemia, which prescribed these cells for TDT patients unless autoimmune hemolytic anemia necessitates washed red cells [25]; (2) consensus from consulted hematologists affirming its prevalent use in TDT treatment, except in rare cases requiring washed red cells—patients receiving such were thus excluded

from this study; (3) the acknowledged regular need for blood transfusions among patients, who were generally aware of both the required transfusion units and the associated costs.

Study design
This study designed a questionnaire, which was composed of two sections (as detailed in the Supplementary File). The first section encompassed 44 items, concentrating on patient demographics and the burden of transfusion. In this section, the part on blood transfusion treatment-related information comprised details such as the number of units transfused in a single session, the frequency of annual transfusions, the need for hospitalization, experiences with anemia, and chelation therapy. This section was designed to gather information about the patient's transfusion history and aided in the recollection of the transfusion experiences. It also aimed to facilitate patients' mental engagement with the treatment scenario, enhancing their comprehension of the subsequent sections related to WTP.

The second section of the questionnaire focused on the WTP. CVM was used to examine TDT patients' WTP for temporarily alleviating anemia status. The formal survey employed the double-bounded dichotomous choices based on the predetermined bids which were determined by the pre-survey using open-ended questions. In the scenario where blood transfusion offered temporary relief from anemia and no other temporary relief was available, interviewees answered two rounds of questions to assess their acceptance of the bid for 1 unit of leukocyte-depleted red blood cells. The term 'bid' referred to the proposed price that participants were asked to consider in their WTP evaluations. If respondents answered 'yes' to the initial bid (Bid_0), they would be asked about a second higher bid (Bid_H); if they answered 'no,' a second lower bid (Bid_L) would be inquired, as illustrated in Fig. 1. To prevent bias in the initial bid, the study was designed to include 2 sets of bids. Each patient was randomly assigned to complete one set of bids through random number allocation. All bids were derived primarily from the open-ended responses of 20 patients in the pre-survey, and were designed based on the mean and various percentiles, including the 1st, 25th, 50th, 75th, and 99th percentiles [26]. In the pre-survey, the scenario was set to mirror the formal survey, where an open-ended question directly inquired about patients' WTP for one unit of blood to alleviate their anemic status.

To explore the WTP of patients under ideal conditions, this study examined patients' WTP under conditions both with and without economic constraints. Except for the consideration of economic limitations, the descriptions for the two scenarios were otherwise identical. This
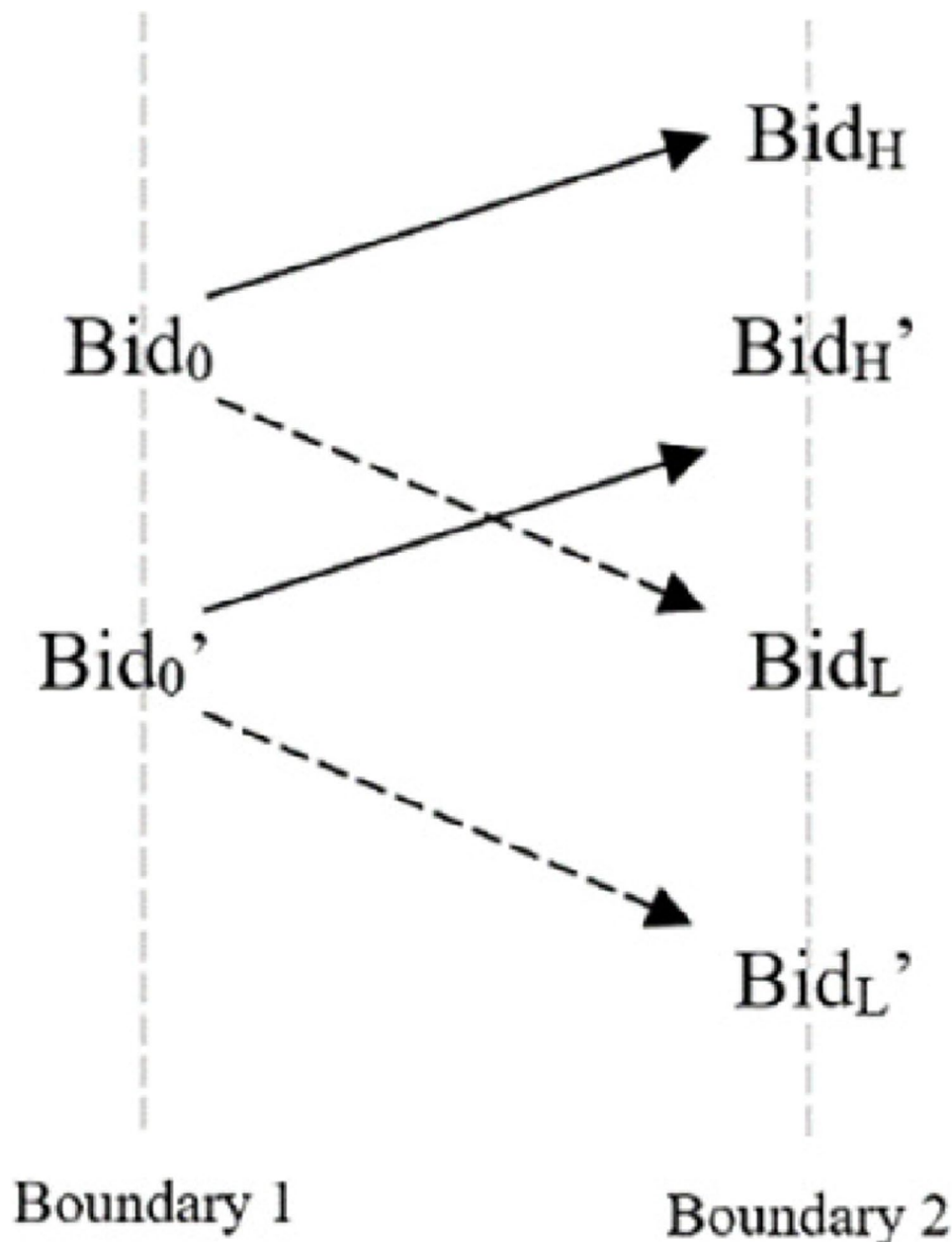
Fig. 1 The dichotomous choice method. Bid_0: Initial bid of the first set; Bid_H: The higher bid of the first set; Bid_L: The lower bid of the first set. Bid_0': Initial bid of the second set; Bid_H': The higher bid of the second set; Bid_L': The lower bid of the second set

required participants to provide answers for both scenarios at each set of bids.

Inclusion/exclusion criteria and sample

Eligible participants were those diagnosed with transfusion-dependent β-thalassemia and willing to participate. Exclusion criteria encompassed the inability to independently complete the questionnaire due to health or cognitive impairments and those prescribed washed red blood cells for transfusion.

Given the rare nature of this disease and the lack of incidence data across provinces in China, coupled with their typically close communication with medical institutions due to the need for long-term transfusions, a convenience sampling approach was adopted. Furthermore, a snowball sampling method was utilized to identify additional participants, which involved asking patients to post recruitment notices in WeChat groups, thereby expanding the sample size to 149 patients. The local hospital hematology department directors explained the nature and purpose of the investigation. Patients who

consented to participate were then contacted by trained investigators through WeChat. Informed consent was obtained from all participants.

Data collection tool and quality control

Data for the questionnaire were collected using the WJX platform (www.wjx.cn). The survey instrument, developed by the research team in Chinese, was subjected to a thorough evaluation process. This involved consultation with six hematology department directors from major tertiary hospitals and four health economics professors. Experts provided recommendations for refining the guided scenarios and minimizing interpretive ambiguity in the questions. After two rounds of revision, all experts deemed the questionnaire to have satisfactory validity and reliability.

A pilot survey was then conducted with 20 patients to assess the questionnaire's rationality, understandability, and readability. Following this survey, researchers conducted one-on-one interviews with participants to ensure accurate comprehension of the questionnaire items. Subsequently, the study conducted both a pre-survey and a formal survey. The surveys were administered by three interviewers who had undergone two days of training and were familiar with the questionnaire, under the supervision of two public health experts. Consistency and completeness checks were performed after the questionnaire was submitted.

Data analysis

Mean, variance and frequency were used for descriptive statistics. Hanemann's indirect utility function [27] was used to estimate WTP, and the estimation method provided by Alejandro L´opez-Feldman et al. [28] was used to estimate the WTP mean and its influencing factors. All analyses were performed in Stata 15.0.

WTP was estimated using the linear function provided, and $u_i \sim N(0, \sigma^2)$. The estimation formula for WTP was $WTP_i(z_i, u_i) = z_i\beta + u_i$. ($z_i$: a vector of explanatory variables; β: a vector of parameters; u_i: an error term; σ: standard deviation)

Based on the probability of responses falling between two boundaries, the "doubleb" command can be utilized to directly estimate β and σ using the likelihood function. Then, the WTP formula becomes simply $\widetilde{z}\prime\widehat{\beta}$. Based on the likelihood function criterion [29], the study employed the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to assess the quality of the models.

Table 1 Patients'WTP in pre-survey

Statistic	Scenario1: Consideration of economic conditions	Scenario2: No consideration of economic conditions
Average value	RMB 589 (SD=1123) [USD 81(SD=154)]	RMB 658 (SD=1111) [USD 90 (SD=152)]
1st percentile	RMB 40 (USD 5)	RMB 100 (USD 14)
25th percentile	RMB 100 (USD 14)	RMB 150(USD 21)
50th percentile	RMB 168 (USD 23)	RMB 235 (USD 32)
75th percentile	RMB 350 (USD 48)	RMB 500 (USD 69)
99th percentile	RMB 5000 (USD 686)	RMB 5000 (USD 686)

Table 2 Design of bids

Type of Bid	The First Set	The Second Set
The initial bid	RMB 250 (USD 34)	RMB 500 (USD 69)
The higher bid	RMB 500 (USD 69)	RMB 1000 (USD 137)
The lower bid	RMB 150 (USD 21)	RMB 250(USD 34)

Results

Setting bids derived from pre-survey analysis

For the pre-survey, the mean WTP along with the 1st, 25th, 50th, 75th, and 99th percentiles are presented in Table 1.

The bids, as detailed in Table 2, were structured into two distinct sets, with each set comprising three separate bids.

Demographic and transfusion burden characteristics

Twenty TDT patients, with an average age of 26.2 years (SD=6.5), participated in the pre-survey. Among these participants, 55% were male. Appendix 1 provides detailed results.

Formal survey questionnaires were obtained from 149 TDT patients across five provinces in Guangdong, Guangxi, Yunnan, Hunan and Guizhou. The patients had an average age of 26.2 years (SD=9.0), and 31.5% of them were students. Most patients (78.5%) had an educational background below a bachelor's degree. A total of 28.2% of patients were unemployed or without employment, 46.3% of the patients had no income at all, and 85.2% of the patients had a monthly per capita family income below RMB 5,000 (USD 685.9). Excluding students, the personal income of other patients was RMB 1979.9 (SD=1601.7), equivalent to USD 271.6 (The exchange rate on November 13, 2023, was 1 USD=7.29 RMB).

Patients' self-perceived health status was classified into four levels: "poor," "fair," "good," and "excellent". Of these, 77.2% of patients rated their health status as "poor" or "fair". Regarding the current transfusion situation, patients had an average transfusion burden of 3.7 units per single blood transfusion (SD=1.2) and an annual transfusion frequency of 15.4 times (SD=11.2). In terms of transfusion history, 25.5% self-reported that they did not receive regular or adequate transfusions, and 28.9%

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received transfusions in different locations, taking an average of 2.5 days per transfusion including pre and post transfusion. A total of 75.2% of the patients required hospitalization for blood transfusions, 76% of whom mentioned complex admission procedures

Delayed transfusions were reported by 91.9% of patients, with the longest delays averaging 41.3 days (median 30 days). Hemoglobin (Hb) levels below 9 g/dl were observed in 67.1% of participants, and 36.2% perceived a timely blood supply as inadequate. Moreover, 83.9% of patients experienced insufficient blood supply during a single transfusion. Symptoms reported included weakness (65.1%), delayed growth (37.6%), and heart failure signs (10.1%). Patients underwent iron monitoring every 4.3 months, on average (SD = 4.5). Deferasirox was the most commonly used iron chelator (59.7%), followed by deferoxamine (26.2%). Patient details are presented in Table 3.

Analytical results in the formal survey
WTP for temporary alleviation of anemia status
Following randomization, 74 patients participated in the survey for the first set of bidding scenarios, and 75 patients engaged with the second set. Table 4 illustrates the patient responses regarding acceptance or rejection of the two bids presented.

Considering their own economic circumstances, TDT patients had an average WTP of RMB 513.5 per unit of leukocyte-depleted suspended red blood cells (95% CI [452.0-575.0], equivalent to USD 70.4). Furthermore, the study endeavored to assess patients' WTP without considering economic levels. Consequently, the average WTP reported by patients was RMB 1,104.1 (95% CI [931.5-1276.7], equivalent to USD 151.5. See Table 5 for further details on these results.

Factors associated with WTP
To explore the determinants of WTP for 1 unit of leukocyte-depleted red blood cells, the basic model incorporated all possible factors (variable definitions in Appendix 2). The expanded model (Wald chi2(9) = 33.85, $P = 0.0001$) was employed. The analysis revealed the following (Table 6): Considering their financial circumstances, older patients demonstrated a higher WTP, and each additional year of age was associated with a 10.0 RMB increase in WTP ($P = 0.004$). Furthermore, patients with education beyond the junior high school level demonstrated higher WTP than those with education at or below the junior high school level ($P < 0.05$), and male patients showed a higher WTP than female patients ($P < 0.05$). Among other constant conditions, patients with monthly per capita household incomes above RMB 5000 were willing to pay more than those with incomes at or below RMB 3000 ($P < 0.001$). Additionally, the WTP

decreased as the number of units of blood transfused in a single session increased, with each additional unit resulting in a decrease of RMB 76.4 in WTP ($P < 0.001$). Patients with more convenient access to blood transfusions were willing to pay significantly more ($P < 0.05$).

Subgroup analysis
The subgroup analysis results are presented in Table 7.

Gender differences The results of the gender subgroup analysis indicated that male patients showed a higher WTP than female patients. Female patients were willing to pay RMB 444.8 per unit of blood (95% CI [373.0-516.5]), equivalent to USD 61.0, while male patients were willing to pay RMB 580.5 per unit of blood (95% CI [480.2-680.8]), equivalent to USD 79.6.

Income variability The monthly household income subgroup analysis revealed that, in general, patients with higher monthly household incomes expressed a higher WTP per unit of blood. Specifically, patients with monthly per capita incomes at or below RMB 3,000 were willing to pay RMB 448.2 per unit of blood (95% CI [365.4-531.2]), equivalent to USD 61.5. And those with incomes between RMB 3,001–5,000 were willing to pay RMB 465.1 (95% CI [379.1-551.2]), equivalent to USD 63.8. Patients with incomes of RMB 5,001 or above presented the highest WTP at RMB 906.0. (95% CI [686.0-1126.0]), equivalent to USD 124.3.

Access to transfusion services The convenience of blood transfusion subgroup analyses revealed that patients with less convenient access to blood transfusion demonstrated a higher WTP. In this study, convenience of blood transfusion was measured by whether hospitalization was required and whether blood transfusion needed to be performed in a different location. The WTP for patients with convenient access to blood transfusion was RMB 529.4 (95% CI [458.3-600.6]), equivalent to USD 72.6. In contrast, the WTP for patients with inconvenient access to blood transfusion was RMB 457.4 (95% CI [339.4-575.3]), equivalent to USD 62.7.

Discussion
This study investigated transfusion burden and WTP for temporary relief from anemia among adult TDT patients in high-prevalence areas by analyzing factors influencing WTP. From the results, it was clear that patients place a high value on anemia relief, regardless of their financial situation, indicating a significant WTP for health improvements. Patient gender, age, household income, and the number of units transfused in a single session were also associated with their WTP.

Table 3 Basic patient information and transfusion burden

Items	TDT Patient sample (N = 149)	
Gender, n (%)		
Man	82	(55.0)
Woman	67	(45.0)
Age, years (SD)	26.2	(9.0)
Employment status, n (%)		
School students	47	(31.5)
Unemployment	42	(28.2)
Other	60	(40.3)
Occupation, n (%)		
Staff outside the system	37	(24.8)
Staff in the system	8	(5.4)
Self-employed/freelancer	13	(8.7)
Other	91	(61.1)
Degree, n (%)		
Below undergraduate level	117	(78.5)
Bachelor's degree or above	32	(21.5)
Educational background, n (%)		
Below junior high school	42	(28.2)
Junior high school or above	107	(71.8)
Marital status, n (%)		
Unmarried	125	(83.9)
Married	24	(16.1)
Children's condition, n (%)		
Have children	19	(12.8)
Childless	130	(87.2)
Account type, n (%)		
Rural	80	(53.7)
Urban	69	(46.3)
Medical insurance category, n (%)		
Urban Residence Basic Medical Insurance	114	(76.5)
Urban Employee Basic Medical Insurance	26	(17.4)
Other	9	(6.0)
Personal income excluding students, RMB (SD)	1979.9	(1601.7)
Personal income, RMB, (SD)	1446.9	(1627.6)
No income	69	(46.3)
Have income	80	(53.7)
Monthly per capita family income, n (%)		
RMB 3,000 and below	71	(47.7)
RMB 3,001-5,000	56	(37.6)
RMB 5,001-8,000	15	(10.1)
More than RMB 8,001	7	(4.7)
[a] **Self-evaluation burden, n (%)**		
Heavy burden	96	(64.4)
Basic affordability	51	(34.2)
Completely affordable	2	(1.3)
Self-rated health, n (%)		
Poor	34	(22.8)
Average	81	(54.4)
Good	31	(20.8)
Excellent	3	(2.0)
Hb level, n (%)		
Above 9 g/dl	47	(31.5)
Less than 9 g/dl	102	(68.5)

Table 3 (continued)

Items	TDT Patient sample (N = 149)	
Need traveling out for transfusion, n (%)		
No	106	(71.1)
Yes	43	(28.9)
Blood transfusion requires hospitalization., n (%)		
No	37	(24.8)
Yes	112	(75.2)
[b]**Unit cost of leukocyte-depleted suspended red blood cells, RMB (SD)**	270.4	(25.1)
Blood transfusion regulated regularly, n (%)		
No	38	(25.5)
Yes	111	(74.5)
Time of Blood transfusions in the past month, n (SD)	1.4	(0.9)
Blood transfusion units per time, n (SD)	3.7	(1.2)
Time of Blood transfusions per year, n (SD)	15.4	(11.2)
Experience of shortage of blood sources, n (%)		
No	12	(8.1)
Yes	137	(91.9)
Experience anemia and delayed blood transfusion, n (%)		
No	24	(16.1)
Yes	125	(83.9)
Self-evaluation of blood supply in medical institutions, n (%)		
Cannot be supplied in time	54	(36.2)
Can be supplied in time	95	(63.8)
Self-assessment of blood shortage, n (%)		
Not scarce	8	(5.4)
General scarce	72	(48.3)
Very scarce	69	(46.3)
Frequency of iron monitoring, months (SD)	4.3	(4.5)
Iron-removing drugs, n (%)		
Deferasirox	89	(59.7)
Deferoxamine	16	(10.7)
Deferiprone	39	(26.2)
Other	9	(3.4)

[a] Patients self-assess the severity of disease burden

[b] Price before reimbursement

Table 4 Patient response statistics

The set of bids	Consideration of economic conditions				No consideration of economic conditions			
	[a] **NN**	**NY**	**YN**	**YY**	**NN**	**NY**	**YN**	**YY**
The first set	6	9	21	34	3	3	10	54
The second set	17	21	24	10	5	6	16	45
Total	23	30	45	44	8	9	26	99

[a] The letter combinations denote the outcomes for two dichotomous boundaries, where NN No/No, NY No/Yes, YN Yes/No, YY Yes/Yes

Adult TDT patients, frequently of lower socioeconomic status, bore a considerable disease-related financial strain, predominantly due to the increasing costs of clinical transfusion and iron chelation therapy with age [4]. A survey conducted in Guangdong Province showed that 53.2% of TDT patients' families were unable to afford essential chelation treatments [9]. Echoing this, our study found that a substantial majority (64.4%) of patients carried heavy disease burden, with a mere 1.3% feeling financially secure against it. The genetic TDT imposed a considerable economic strain on families, and the scarcity of blood resources in China led to frequent delays in transfusions, perpetuating chronic anemia. This anemia significantly curtailed employment opportunities and reinforced the cycle of poverty, as patients are frequently symptomatic and require regular medical attention [4]. Workplace discrimination, stemming from frequent absences due to fatigue and physical stature concerns, further compounded the financial strain, as noted by Wai Cheng Foong (2022), where 77% of patients

Table 5 Estimates of WTP

	[a] Coef.	[b] Std. Err.	z	[c] [95% CI]	Log likelihood	[d] AIC	[e] BIC
WTP- consider the economic level	¥513.5 ($70.4)	31.4 (4.3)	16.4	452.0-575.0	-194.4	392.8	398.8
WTP-without considering economic level	¥1104.1 ($151.5)	88.1 (12.1)	12.5	931.5-1276.7	-135.4	274.9	280.8

[a] coefficient

[b] the standard error of the coefficient

[c] confidence interval

[d] Akaike information criterion

[e] Bayesian information criterion

Table 6 Expanded model results

Beta	Coef.	Std. Err.	[95% Conf. Interval]	
**Age	10.0	3.5	3.2	16.9
**Gender (1 = female)	157.5	58.4	43.0	272.0
**Education (1 = having education level of junior high school or above)	149.8	68.7	15.2	284.4
Family monthly per capita income between RMB 3000 and RMB 5000	-10.1	58.8	-125.3	105.1
***Family monthly per capita income above RMB 5000	359.4	94.0	175.1	543.7
Hemoglobin level (1 = less than 9 g/dL)	-19.3	62.0	-140.8	102.3
[a] ** Convenience transfusion (1 = No)	-170.2	69.3	-306.0	-34.4
***Number of single blood transfusion units	-76.4	23.8	-123.0	-29.8
Self-assessment of blood shortage (1 = very shortage)	20.6	57.3	-91.7	132.8
[b] _cons	334.2	157.0	26.6	641.9
WTP	522.2	28.2	466.9	577.4
Log likelihood	-176.2			
AIC	374.4			
BIC	407.5			

[a] Blood transfusion without the need to travel to a different location or be hospitalized

[b] Constant term

***$P < 0.001$; **$P < 0.05$

reported job-related difficulties [30]. The anxieties over future life and career prospects were palpable among 70.3% of patients, as reported by Sarah H Siddiqui (2014) [31]. The adverse effects of anemia on daily activities and work performance necessitated innovative therapies to alleviate the dependency on blood transfusions, offering a potential reprieve from the transfusion cycle and its economic consequences.

Furthermore, the hospital admission process, necessitating navigation across multiple departments, was cited as onerous by numerous respondents, significantly consuming time and energy. Moreover, in light of blood shortages, some hospitals enforced strict criteria, requiring patients to exhibit low hemoglobin levels or additional medical complications to qualify for inpatient blood transfusions. Thus, the standardization of clinical blood management protocols could markedly alleviate the burden associated with transfusion.

Even though patients had a low economic status, they consistently faced high disease burden. Their WTP for temporary relief from anemia was still high, and their actual payment willingness may be higher due to costs beyond the blood itself. On average, each patient received 3.7 units of blood per transfusion session, with an annual average of 15.4 transfusion sessions. The WTP of RMB 1,900 (USD 260.6) for survival in a single session and RMB 29,259 (USD 4,013.6) annually for temporary relief from anemia could be roughly calculated. However, a single transfusion involves more than just the value of the blood itself. It also includes various costs, such as pretransfusion tests to prevent immunological reactions,

Table 7 Results of subgroup analysis

Factor	Gender		Family per capita monthly income			Convenience transfusion	
Category	Male	Female	RMB 3,000 and below	RMB 3,001–5,000	RMB 5,001 and above	Yes	No
Coef.	580.5	444.8	448.2	465.1	906.0	529.4	457.4
Std. Err.	51.2	36.6	42.3	43.9	112.3	36.3	60.2
z	11.4	12.1	10.6	10.6	8.1	14.6	7.6
[95% CI]	480.2-680.8	373.0-516.6	365.4-531.2	379.1-551.2	686.0-1126.0	458.3-600.6	339.4-575.3
Log likelihood	-102.4	-87.9	-95.4	-72.1	-15.2	-151.3	-42.5
AIC	208.7	179.8	194.9	148.3	34.3	306.6	89.0
BIC	213.5	184.2	199.5	152.3	36.5	312.1	92.0

medical equipment costs, hospitalization costs, and iron chelation costs.

This study found that elderly and higher-income patients exhibited a higher WTP, consistent with previous research [32–34]. Since TDT is hereditary, patient age indicates suffering duration. Elderly patients may face more severe transfusion challenges, valuing their health and survival more, therefore demonstrating a higher WTP. The majority of Chinese families with thalassemia patients face substantial economic burden, with 90% earning less than RMB 60,000 (USD 8230.5) annually [5]. Nonetheless, patients with lower incomes exhibited a considerable WTP for temporary relief from anemia, underscoring the importance they place on managing their condition. Patients with monthly incomes of RMB 3,000 or less exhibited WTP values as high as RMB 448.2, nearly half of those with incomes exceeding RMB 5,000. Besides, the study's findings revealed that patients with at least a junior high school education showed a higher willingness to pay (WTP), a correlation supported by other literature [35, 36]. This positive association between education level and WTP may stem from the fact that higher education often correlates with a higher economic status. Furthermore, individuals with advanced education were likely to possess a more comprehensive understanding of anemia's health implications and to hold greater expectations for their quality of life, thus demonstrating a higher WTP.

The amount of blood transfusion and its convenience also influence patients' WTP. Patients who required a greater number of units of blood in a single transfusion session expressed a lower WTP. The increase in the number of blood transfusion units led to higher economic burden. Consequently, patients may reduce their WTP for each unit of blood due to concerns about the high medical costs. Additionally, as the volume of transfused blood increases, the marginal health benefits per unit of blood may diminish, resulting in a decreased WTP among patients.

Patients with more convenient blood transfusions exhibited a higher WTP. This could be attributed to the fact that the convenience of blood transfusions may enhance psychological comfort and reduce anxiety associated with the procedure, thereby increasing WTP. Furthermore, convenient transfusion conditions may save patients additional costs such as transportation, examination, and cost of hospitalization, thus potentially increasing their WTP for blood.

These findings suggested that when formulating medical policies and blood transfusion services, it was necessary to consider the economic status and needs of different patient groups. To improve the accessibility and equity of medical services, more support and subsidies may be required for patient groups with weaker economic capabilities. At the same time, improving the convenience of blood transfusion services, such as by optimizing appointment processes and reducing waiting times, may also help to enhance patients' WTP.

Strengths and limitations of the study

This study was the first to investigate patients' willingness to pay for transfusions to alleviate anemic conditions. The burden of transfusion and TDT patients' recognition of the value of health could provide data insights for future related health economic research.

This study had several limitations. First, for the sake of patient understanding, this study concretized the concept of sustaining life with blood transfusion. However, in reality, the costs of temporarily alleviating their anemia status also included the costs of testing, iron chelation, etc. Blood was only the most crucial component of transfusion therapy, and it may not fully represent patients' WTP to temporarily alleviate their anemia status. Second, due to limitations in the research conditions, this study employed online questionnaires for data collection, compared to face-to-face interviews, this method may have resulted in less accurate responses.

Conclusion

This study investigated transfusion burden of patients and explored the WTP for temporary relief from anemia among patients from Chinese provinces with a high prevalence of TDT. The study pinpointed key determinants of WTP, notably age, gender, income, education, the convenience of blood transfusion and the number of units transfused in a single session. The results indicated that patients exhibit a high WTP for temporary relief from anemia and that thalassemia imposes significant burden of blood transfusion on patients. The evident gap in meeting clinical needs underscores the urgent demand for innovative treatments that can lessen transfusion dependency, potentially transforming the care landscape for TDT, improving patients' socioeconomic well-being, and enhancing overall clinical outcomes. This research contributed to a deeper understanding of TDT's transfusion burden, serving as a valuable resource for pharmacoeconomic studies and informing effective healthcare resource allocation in China.

Appendix 1

Table 8 Basic patient and transfusion burden information in pre-survey

Gender, n (%)		
Man	11	(55.0)
Woman	9	(45.0)
Age, years (SD)	26.2	(6.5)
Employment status, n (%)		
School students	5	(25.0)
Unemployment	3	(15.0)
Other	12	(60.0)
Occupation, n (%)		
Staff outside the system	5	(25.0)
Staff in the system	1	(5.0)
Self-employed/freelancer	2	(10.0)
Other	12	(60.0)
Degree, n (%)		
Below undergraduate level	12	(60.0)
Bachelor's degree or above	8	(40.0)
Educational background, n (%)		
Below junior high school	1	(5.0)
Junior high school or above	19	(95.0)
Marital status, n (%)		
Unmarried	17	(85.0)
Married	3	(15.0)
Children's condition, n (%)		
Have children	3	(15.0)
Childless	17	(85.0)
Account type, n (%)		
Rural	12	(60.0)
Urban	8	(40.0)
Medical insurance category, n (%)		
Urban Residence Basic Medical Insurance	14	(70.0)
Urban Employee Basic Medical Insurance	6	(30.0)
Personal income, RMB, (SD)	2111	(1699.0)
Self-evaluation burden, n (%)		
Heavy burden	13	(65.0)
Basic affordability	7	(35.0)
Self-rated health, n (%)		
Poor	7	(35.0)
Average	7	(35.0)
Good	6	(30.0)
Hb level, n (%)		
Above 9 g/dl	5	(25.0)
Less than 9 g/dl	15	(75.0)
Need transfuse blood from different places, n (%)		
No	17	(85.0)
Yes	3	(15.0)
Blood transfusion requires hospitalization, n (%)		
No	4	(20.0)
Yes	16	(80.0)
Blood transfusion regulated regularly, n (%)		
No	3	(15.0)
Yes	17	(85.0)

Time of Blood transfusions in the past month, n (SD)	1.58	(0.8)
Blood transfusion units per time, n (SD)	3.53	(1.0)
Time of Blood transfusions per year, n (SD)	16.4	(8.02)
Experience of shortage of blood sources, n (%)		
No	0	(0.0)
Yes	20	(100.0)
Experience anemia and delayed blood transfusion, n (%)		
No	0	(0.0)
Yes	20	(100.0)
Frequency of iron monitoring, months (SD)	5.7	(7.8)
Iron-removing drugs, n (%)		
Deferasirox	13	(65.0)
Deferoxamine	3	(15.0)
Deferiprone	4	(20.0)

Appendix 2

Table 9 Definition of variables

Variable	Meaning	Variable type and coding
Age	Age	Continuous variable
Gender	Gender	Classification variable, 0= male, 1= female.
Education	Whether having an education level of junior high school or above.	Classification variable, 0= no, 1= yes.
family monthly income between RMB 3000 and RMB 5000	The monthly per capita household income is between RMB 3000 and RMB 5000.	The dummy variable, with the reference variable being monthly per capita household income below RMB 3000.
family income above RMB 5000	The monthly per capita household income is above RMB 5000.	The dummy variable, with the reference category being monthly per capita household income below RMB 3000.
Hb level	Hb level	Classified variables; 0= greater than 90g/L, 1= less than 90g/L.
Convenience transfusion	Whether blood transfusion requires going to another place and hospitalization.	Classified variables; 0=No need for transfusion in another location or hospitalization procedures, 1= Need for transfusion in another location or hospitalization procedures
Number of single blood transfusion units	Number of single blood transfusion units	Continuous variable
Self-assessment of blood shortage	Self-assessment of blood shortage	Classified variables; 0= no shortage or general shortage, 1= very shortage.

Abbreviations
WTP   Willingness to pay
CVM   Contingent valuation method
RBC   Red blood cell
DC   Dichotomous choice

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-024-11547-2.

Supplementary Material 1.

Availability of data and materials
The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethical Review Committee at the China Pharmaceutical University. After being informed about the study's purpose and importance, informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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