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Original Article

Safety and Effectiveness of Reduced Red Blood Cells Consumption in Spine Surgery under the Guidance of West China Perioperative Transfusion Score (WCPTS): A Prospective, Randomized, Controlled Trial

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ABSTRACT

Background: Transfusion trigger and target for surgical patients with hemoglobin (Hb) level between 7-10 per deciliter is not available worldwide, and the decision of whether red blood cells (RBCs) should be administered in these patients is made according to the experience of clinicians without evidences. Based on the physiology of the balance between oxygen supply and consumption, we suggested West China Perioperative Transfusion Score (WCPTS) to be safely applied to the patients undergoing spine surgery with effective reduction of RBCs transfusion.

Methods: We enrolled patients who were aged 15 to 70 years undergoing elective spine surgery with the expected blood loss more than 800 ml or 20% of the patient's whole blood volume. We randomly assigned patients to the WCPTS group (transfusion threshold under guidance of WCPTS) or the liberal-strategy group (transfusion threshold of 10 per deciliter). The primary outcomes were the proportion of patients who received RBCs transfusion and the units of transfused RBCs.

Results: The proportion of patients who received RBCs transfusion in the WCPTS group was significantly lower than that in the liberal-strategy group at all observed time periods (intraoperative: 24.0% vs. 88.2%, $P<0.001$; postoperative: 18.8% vs. 44.7%, $P<0.001$; perioperative: 36.5% vs. 89.4%, $P<0.001$). A median of zero units of RBCs were transfused in the WCPTS group and 3.5 units in the liberal-strategy group during perioperative period ($P<0.001$). The frequencies of in-hospital complication did not differ significantly between the two groups ($P>0.05$), and there were no significant between-group differences in length of stay in hospital, length of stay after operation, stitches removal time, time to normal life, and time to work in the two groups ($P>0.05$).

Conclusions: An objective evaluation of the status of oxygen supply and consumption could be achieved by application of WCPTS for patients with Hb level between 7-10 g/dl, and RBCs transfusion trigger and target could be determined on the basis of the evaluation, thus requirement of RBCs transfusion could be reduced by more than 70% under the guidance of WCPTS safely and effectively.

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Blood transfusions are frequently given to patients undergoing major surgeries (1, 2). However, the indications of perioperative red blood cells (RBCs) transfusion remain not clear and controversial. Guidelines of transfusion in United States, China and United Kingdom (3-5) all suggest that RBCs is rarely indicated when the hemoglobin (Hb) level is above 10 g/dl and is always required in patients with Hb level below 7 g/dl, and the determination of RBCs transfusion in patients whose Hb level is between 7-10 g/dl relies on the physicians' own judgment or experiences for the lack of recommendations about how to objectively evaluate patients' conditions in these guidelines. Besides, the guidelines do not tell the target for RBCs transfusion, and a "safely margin" of Hb concentration of 10 g/dl makes physicians tend to set the transfusion trigger and maintain the target at a relatively higher level, and then leads to easily overuse of RBCs associated with increased transfusion related side effects. That means RBCs transfusion could not be individualized in clinical practice.

How to individualize RBCs transfusion and how to set the reasonable transfusion trigger and target? The physiological theories tell us that the RBC is an oxygen carrier so that the objective of RBCs transfusion is to increase blood capability of carrying oxygen, so as to provide sufficient oxygen to maintain the balance of oxygen supply and consumption (6, 7). Factors associated with oxygen supply are Hb level, arterial oxygen saturation and cardiac output (CO), and oxygen consumption could be reflected by body core temperature clinically (8). If a patient's oxygen supply decreases or oxygen consumption increases, he will need a higher Hb level to maintain this balance, which means that the Hb concentration could be determined by CO, oxygen saturation (SpO_2 or SaO_2), and core temperature. Based on these physiological theories, we suggested an individualized RBCs transfusion strategy, West China Perioperative Transfusion Score (WCPTS, Table 1), to objectively evaluate the status of oxygen supply and consumption for each individual patient with Hb level between 7-10 g/dl, and to further determine RBCs transfusion trigger and target on the basis of the evaluation for perioperative RBCs transfusion.

We hypothesized that WCPTS could be applied to the patients who need RBCs transfusion safely, and compared with liberal transfusion strategy of 10 g/dl, the widely accepted "safe" threshold, RBCs transfusion requirement (such as the proportion of patients who received RBCs transfusion, or the units of transfused RBCs) could be reduced under the guidance of WCPTS without increase of side effects or the cost of hospitalization. Spine surgery, such as spine fusion, correction of idiopathic scoliosis, is always associated with significant hemorrhage (2). So we chose spine surgery to verify our hypothesis in this pilot study.

METHODS

Ethics

Ethical approval for this study (No. 2010-58) was provided by the Biological-Medical Ethical Committee of West China Hospital, Sichuan University, Chengdu, Sichuan, China on 24 December 2010, and informed consent was obtained from each patient or their designated representatives at the preoperative visit (ClinicalTrials.gov Identifier: NCT01345643).

How to Use WCPTS

WCPTS is a dynamic score that to be assessed whenever the decision of allogeneic RBCs transfusion is needed, and it should be carried out when the patient's volume status is clinically normal assessed by senior clinicians.

CO is estimated clinically based on patient's hemodynamic and cardiac rhythm/rate. Assessment tools, such as central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP) or other CO monitoring could be applied for estimation of the CO. Patients with insufficient CO would be administered with adrenaline infusion (or equivalent conversion of other vasoactive agent infusion) to maintain the CO, and the adrenaline infusion rate will be included as points added in WCPTS. For other situations, such as bradycardia, hypotension or massive hemorrhage in which vasoactive drugs may be needed temporarily (for example, atropine, ephedrine, phenylephrine or noradrenaline), these vasoactive drugs will not be included during WCPTS assessment.

If SpO_2 cannot be obtained or measured accurately with pulse oximetry, arterial blood gas analysis is recommended to measure the SaO_2 value. Core body temperature may be measured at either nasopharyngeal, oropharyngeal, tympanic membrane, rectal or esophageal route. Temperature obtained by axillary route with 0.5℃ added can be accepted as core temperature.

The initial score is 7, and the final WCPTS score is the sum of all points plus 7, that is 7, 8, 9, 10, or >10. The score means the RBCs transfusion trigger and target of Hb level of 7, 8, 9, or 10 g/dl respectively, and the transfusion target is the same Hb level as the score. If WCPTS score ⩾10, patients will be managed as if the WCPTS score is 10, which means Hb level should be maintained not less than 10 g/dl during perioperative period.

Patients

From 22 February 2011 through 11 February 2012, we enrolled patients in West China Hospital of Sichuan University and the First Affiliated Hospital of XinJiang Medical University. Telephone follow-up ended on 30 August 2012.

Patients aged 15 to 70 years, with both gender, American Society of Anesthesiologists (ASA) physical status I, II, III or IV, Glasgow Coma Scale (GCS) score of 15, undergoing elective spine surgery with estimated blood loss more than 800 ml or 20% of the patient's whole blood volume, were considered for inclusion. We excluded patients if they declined to undergo a blood transfusion or refused to sign consent, or had pregnancy, psychopathy, coagulopathy, impairment of communication or cognition, and other reasons that not suitable for this trial.

Treatment Assignment and Follow-Up

We randomly assigned patients to the WCPTS group or the liberal-strategy group using computer-generated random numbers, with the group assignments placed in sealed, consecutively numbered, opaque envelopes. After randomization, anesthesiologists, surgeons, and ward nurses were aware of study-group assignments, but the research nurses and statisticians participated in this trial were blind to group allocation.

In the WCPTS group, the Hb threshold of each patient for RBCs transfusion was set under the guidance of WCPTS. In the liberal-strategy group, the threshold was 10 g/dl, which means if the patient's Hb level was decreased less than 10 g/dl, RBCs transfusion should be given to the patient, and only to keep his Hb level not less than 10 g/dl.

Table 1. West China Perioperative Transfusion Score (WCPTS).

Points added	Adrenaline infusion rate	SpO_2	Body core temperature
0	0	⩾95%	<38℃
+1	<0.05 μg/kg/minute	85-94%	38-40℃
+2	⩾0.06 μg/kg/minute	⩽84%	>40℃

During the perioperative period, whenever the senior clinicians had to decide upon RBCs transfusion, it's important to ensure that patient was normovolemic and Hb level was measured. Then decision on RBCs transfusion would be based on the group allocation. Hb level should be measured in 15 minutes after RBCs transfusion was completed. The mode of anesthesia, anesthetic drugs or their dosage, anesthetic management, anesthetic recording, surgery approach and intensive care unit (ICU) care were not restricted in this study. Decision of administration of fresh frozen plasma (FFP), platelet, cryoprecipitate, or other blood products was made by attending anesthesiologists or surgeons according to their own experience without restriction. Research nurses who were not involved in study implementation and were unaware of study-group assignments telephoned patients or proxies closely at 4, 8, 12, 16, 20, and 26 weeks after hospital discharge. They spoke directly to patients who were accessible by telephone or to proxies if patients were dead or could not talk on telephone.

Primary Outcomes

The primary outcomes were the proportion of patients who received RBCs transfusion, and units of transfused RBCs.

Secondary Outcomes

Secondary outcomes included:

1. Hb level at different time points.
2. Death for any reason within 30 days postoperatively.
3. In-hospital complications, which included: (1) cardiac and pulmonary events such as cardi-

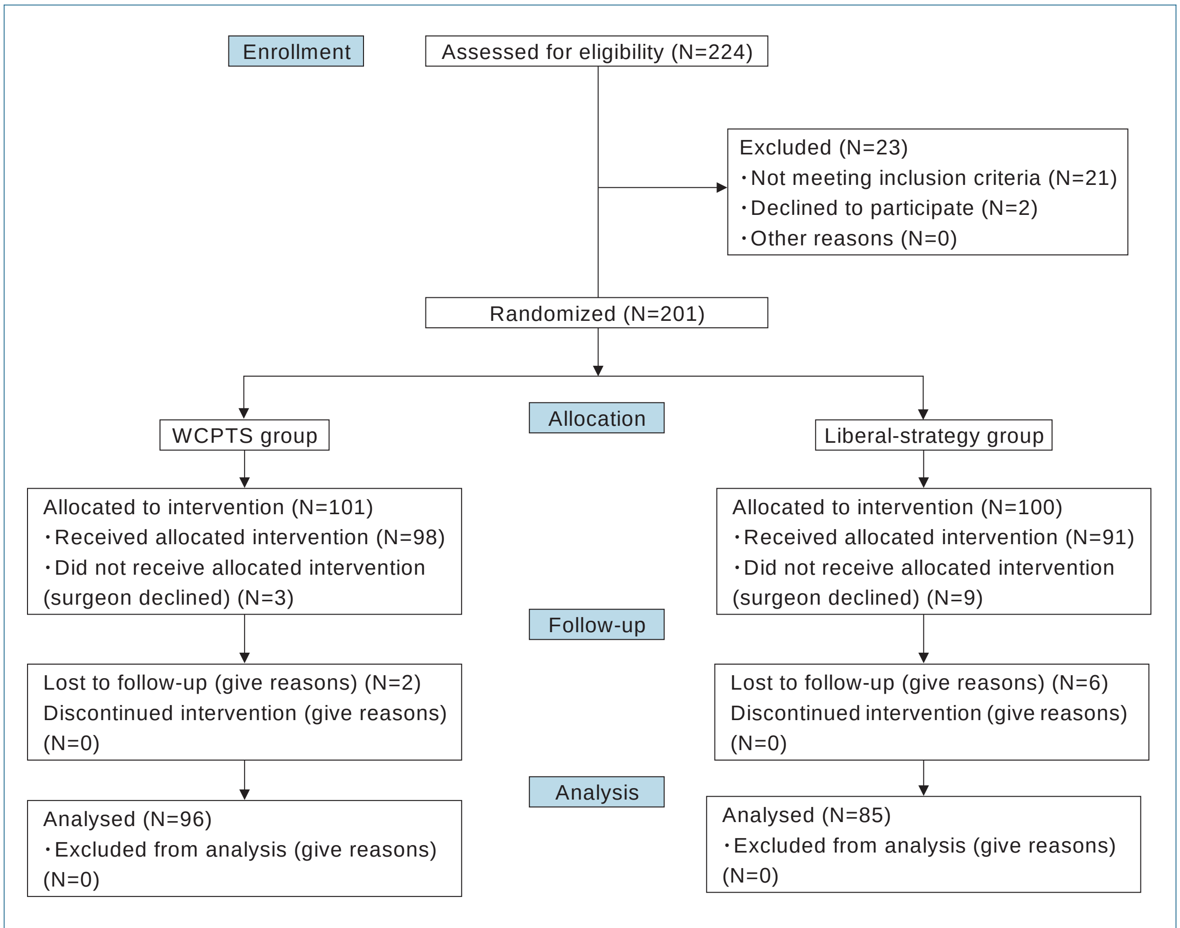

Figure 1. A CONSORT Diaphragm.

ac arrest, arrhythmia, heart failure, pulmonary edema, etc.; (2) febrility without antibiotic treatment; (3) infection needed antibiotic treatment; (4) reoperation for bleeding; (5) deep venous thrombosis; (6) other complications.

4. Length of hospital stay and ICU stay.

5. Costs of hospitalization and transfusion.

6. Stitches removal time, which was defined as the time period (days) from the day of operation to the day of stitches removal.

7. Healing status of surgical incision, which was divided into grade I, II, and III. Grade I was defined as the wound healed nicely without any adverse reaction, grade II was defined as the inflammatory wound without the need of re-incision, and grade III was defined as the wound suppurated with the need of re-incision for clearance.

8. Time to get recovery of daily life and/or working, which was defined as the time period (weeks) from the day of discharge to the day that patient get recovery of normal daily life and/or working.

Statistical Analysis

According to the primary outcome of the proportion of patients who received RBCs transfusion, we considered a difference of 25% (e.g. 50% vs. 75%) between the WCPTS group and the liberal-strategy group to be clinically important. Assuming a type I error protection of 0.05 and a power of 0.90, 77 patients in each group were required for a comparison within the group.

Analyses were performed with the use of SPSS 18.0 software. Data were expressed as mean ± standard deviation (with normal distribution) or median (with skewed distribution). Quantitative data were compared by using unpaired, two-tailed Student's t-test, qualitative data were analyzed by using the X^2 test (Chi-square test), and data with skewed distribution

Table 2. Baseline Characteristics and Information Related to Surgery.

Variable	WCPTS group (N=96)	Liberal-strategy group (N=85)	P value
Age (years)	40.3±18.8	43.4±19.7	0.433
Gender (male/female)	49/47	47/38	0.336
Height (cm)	161.5±7.7	160.9±7.7	0.966
Weight (kg)	58.1±10.3	56.9±13.6	0.120
Body mass index (kg/m^2)	22.3±3.7	21.9±4.7	0.236
Diagnosis (degenerative/trauma/congenital/infectious/tumor)	16/ 36/ 21/ 16/ 7	17/ 26/ 26/ 11/ 5	0.596
ASA (I/II/III/IV)	13/55/27/1	10/48/27/0	
Co-morbidity (number, percent)			0.752
None	66 (68.8%)	56 (65.9%)	
Pulmonary infection (with antibiotics treatment)	6 (6.3%)	3 (3.5%)	0.710
Pleural effussion	7 (7.3%)	10 (11.8%)	0.401
Pulmonary dysfunction	5 (5.2%)	3 (3.5%)	0.303
Hypertension	5 (5.2%)	6 (7.1%)	0.583
Others	7 (7.3%)	7 (8.2%)	0.813
Anesthetic time (minute)	323±83	346±118	0.813
Surgery time (minute)	252±82	267±112	0.114
Intraoperative crystal volume (ml)	1957±961	2071±1084	0.296
Intraoperative colloid volume (ml)	1348±619	1397±699	0.452
Intraoperative urine output (ml)	690±469	804±525	0.616
Estimated blood loss (ml)	1122±657	1296±835	0.126
Intraoperative cell saver use (number, percent)	48 (50%)	47 (55.3%)	0.119
Intraoperative cell saver volume (ml)			0.551
median (minimum, maximum)	500 (0, 1750)	450 (0, 2400)	
mean±standard deviation	380±340	472±461	0.391

were compared by the application of Mann-Whitney U test. A P value<0.05 was considered significant.

RESULTS

Study Population

We screened 224 patients and randomly assigned 201 to the WCPTS group (101 patients) or the liberal-strategy group (100 patients) (Figure 1). After randomization, 3 patients in the WCPTS group and 9 patients in the liberal-strategy group were withdrawn because of the surgeon's refusal of participation. There were 2 losses in the WCPTS group and 6 losses in the liberal-strategy group to follow-up, and 96 patients in the WCPTS group and 85 patients in the liberal-strategy group were included for the intention-to-treat analysis.

Baseline characteristics and information related to surgery including anesthetic and surgery time, intraoperative crystal and colloid volume, urine output, estimated blood loss were similar in the two groups (Table 2).

Primary Outcomes

The proportion of patients who received RBCs transfusion in the WCPTS group decreased significantly than that in the liberal-strategy group at all observed time periods (intraoperative: 24.0% vs. 88.2% , P<0.001; postoperative: 18.8% vs. 44.7% , P<0.001; perioperative: 36.5% vs. 89.4%, P<0.001) (Table 3).

A median of zero units of RBCs were transfused in the WCPTS group and 3.5 units in the liberal-strategy group during perioperative period (P<0.001), and units of RBCs in transfused patients were similar in the two groups (P>0.05) at all observed time period (Table 3). In China, a unit of RBCs is equal to 200 ml whole blood, which means a median of 0 ml in the WCPTS group vs. 700 ml whole blood in the liberal-strategy group during perioperative period.

The proportion of patients who received perioperative FFP transfusion, and the volume of transfused FFP decreased in the WCPTS group than those in the liberal-strategy group (P<0.001, Table 2). The costs of perioperative

Table 3. Primary Outcomes.

Variable	WCPTS group (N=96)	Liberal-strategy group (N=85)	P value
The intraoperative proportion of patients who received RBCs transfusion--percent (number/total number)	**24.0% (23/96)**	**88.2% (75/85)**	**<0.001**
The intraoperative units of transfused RBCs			
median (minimum, maximum)	0 (0, 12)	2 (0, 18)	<0.001
mean±standard deviation	0.9±2.0	3.1±2.8	
The intraoperative units of RBCs in transfused patients			
median (minimum, maximum)	3.5 (1,12)	3 (1, 18)	0.952
mean±standard deviation	3.6±2.7	3.5±2.7	
The postoperative proportion of patients who received RBCs transfusion--percent (number/total number)	**18.8% (18/96)**	**44.7% (38/85)**	**<0.001**
The postoperative units of transfused RBCs			
median (minimum, maximum)	0 (0, 6)	0 (0, 27)	<0.001
mean±standard deviation	0.4±1.0	1.5±3.3	
The postoperative units of RBCs in transfused patients			
median (minimum, maximum)	2 (1, 6)	2 (0.5, 27)	0.943
mean±standard deviation	2.4±1.2	3.3±4.4	
The perioperative proportion of patients who received RBCs transfusion--percent (number/total number)	**36.5% (35/96)**	**89.4% (76/85)**	**<0.001**
The perioperative units of transfused RBCs			
median (minimum, maximum)	0 (0,14)	3.5 (0, 45)	<0.001
mean±standard deviation	1.3±2.4	4.6±5.4	
Costs of RBCs transfusion (Yuan)			
median (minimum, maximum)	0 (0, 6300)	1575 (0, 20330)	<0.001
mean±standard deviation	551±989	2151±2557	
The peiroperative units of RBCs in transfused patients			
median (minimum, maximum)	3.5 (1, 14)	4 (1, 45)	0.067
mean±standard deviation	3.7±2.6	5.1±5.5	
The perioperative proportion of patients who received FFP transfusion--percent (number/total number)	**18.8% (18/96)**	**44.7% (38/85)**	**<0.001**
Perioperative transfused FFP per capita (ml)			
median (minimum, maximum)	0 (0, 2100)	0 (0, 4750)	0.001
mean±standard deviation	133±347	288±589	
Costs of FFP (Yuan)			
median (minimum, maximum)	0 (0, 1470)	0 (0, 3320)	0.036
mean±standard deviation	98±269	210±429	
The perioperative volume of FFP in transfused patients (ml)			
median (minimum, maximum)	490 (100, 2100)	450 (125, 4750)	0.759
mean±standard deviation	638±515	624±741	

RBCs transfusion and FFP transfusion decreased significantly in the WCPTS group than those in the liberal- strategy group ($P<0.001$ and $P=0.036$, respectively, Table 2). It is shown that perioperative consumption of FFP was positively correlated with consumption of RBCs (Figure 2, $R=0.832$, $P<0.01$).

Secondary Outcomes

The preoperative Hb level was similar in the two groups, the average postoperative Hb level was 1.9 g/dl lower in the WCPTS group than that in the liberal-strategy group ($P<0.001$), and the average Hb levels were 1.4 g/dl lower and 0.9 g/dl lower in the WCPTS group than those in the liberal-strategy group at the time period of 24 hours after operation and discharge, respectively ($P<0.001$) (Table 4).

No death from any cause within 30 days, and no adverse cardiac or pulmonary events were found in neither groups. The frequencies of in-hospital complication did not differ significantly between groups. There were no significant between-group differences in the cost of hospitalization, length of stay in hospital, length of stay after operation, stitches removal time, time to normal life, and time to work in the two groups (P>0.05) (Table 5).

DISCUSSION

In order to get an objective evaluation of the status of oxygen supply and consumption for each individual patient with Hb level between 7-10 g/dl, and further to objectively determine RBCs transfusion trigger and target on the basis of the evaluation, we suggested WCPTS, an individualized RBCs transfusion strategy, and performed a randomized clinical trial involving 181 patients undergoing spine surgery to assess the safety and effectiveness of WCPTS. Based on our findings, we verified our hypothesis that RBCs transfusion could safely reduce (more than 70%, mean 1.3 U vs. 4.6 U) under the guidance of WCPTS.

We achieved a clinically important difference in the use of WCPTS for RBCs transfusion (Table 2). More than 60% of the patients did not receive RBCs transfusion with the application of WCPTS, while this number was only 10% with the liberal- strategy. Besides, reduction of 72% fewer units of RBCs transfusion could be gotten with the guidance of WCPTS when compared with the liberal- strategy. Correspondingly, the costs of RBCs transfusion per capita in the WCPTS group were about 75% fewer than those in the liberal-strategy group. In China, the RBCs consumption is about two thousand tons per year (9), which need four to five millions volunteers' blood donation. If we applied WCPTS strictly during perioperative period, RBCs consumption and blood donation demanding could be reduced substantially.

We also found that the proportion of perioperative FFP transfusion, the volume of transfused FFP, and the cost of FFP decreased with the application of WCPTS. Correlation analysis revealed that consumption of FFP was positively correlated with consumption of RBCs during perioperative period, which suggested that RBCs and FFP were bundling administrated in clinical practice in our hospital, and widespread application of WCPTS in surgical patients would reduce the RBCs and FFP use, save more transfusion expenses, and defuse the crisis of blood deficiency.

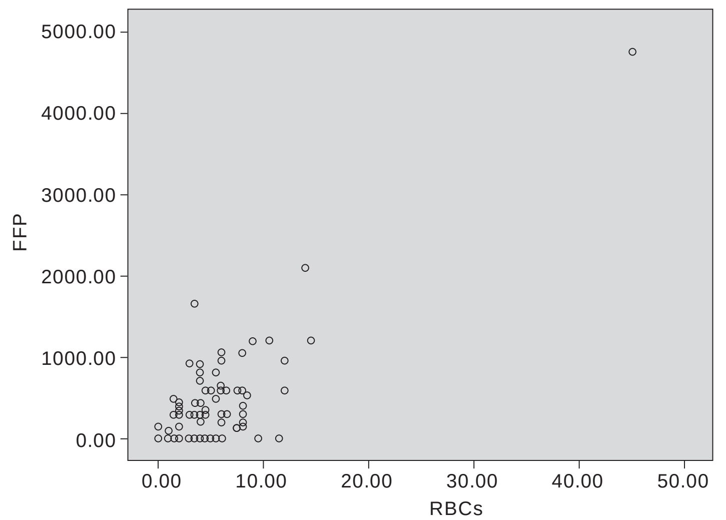

Figure 2. Correlation between Perioperative Transfused RBCs Unit Per Capita (U) and Perioperative Transfused FFP Per Capita (ml). R=0.832, P<0.01.

Table 4. Hb Levels (g/dl) at Different Time Points.

	WCPTS group (N=96)	Liberal-strategy group (N=85)	P value
Preoperative	12.0±1.5	12.4±1.8	0.101
Postoperative	8.5±1.1	10.4±1.0	<0.001
24 hours after operation	8.9±1.5	10.3±1.3	<0.001
Discharge	9.5±1.4	10.4±1.3	<0.001

The secondary outcomes including frequencies of in-hospital complication, length of stay in hospital and after operation, stitches removal time, time to normal life and work were found not different significantly between the two groups (Table 4), and these findings suggested that transfusion under the guidance of WCPTS would be safe, at least it would not increase the incidences of complications, hospital stay or medical expenses. Besides, the average Hb levels were significantly lower in the WCPTS group than those in the liberal- strategy group at the time points of postoperation, 24 hours after operation, and discharge (Table 3), and this should be due to the group allocation. Although we had less statistical power for these secondary outcomes, these combined results revealed that higher Hb level postoperatively did not associate with better outcomes after surgery, and recovery of the patients after discharge did not depend on a higher concentration of Hb, which was took for granted in some of surgical clinicians.

According to previous studies concerning

Table 5. Secondary Outcomes.

Variable	WCPTS group (N=96)	Liberal-strategy group (N=85)	P value
Death from any cause within 30 days	0	0	1.000
In-hospital complication (number, percent)			
None	79 (82.3%)	65 (76.5%)	0.538
Febrility without antibiotic treatment	6 (6.3%)	11 (12.9%)	0.124
Infection need antibiotic treatment	5 (5.2%)	3 (3.5%)	0.583
Reoperation for bleeding	1 (1.0%)	2 (2.4%)	0.490
Deep venous thrombosis	1 (1.0%)	1 (1.2%)	0.931
Others	4 (4.2%)	3 (3.5%)	0.877
Proportion of ICU admission (number, percent)	6 (6.3%)	6 (7.1%)	0.827
Length of ICU stay (days) (median [minimum, maximum])	1.5 (1, 11)	4 (1, 7)	0.828
Length of hospital stay (days)	19.4±8.8	21.6±9.1	0.115
Length of stay after operation (days)	11.1±6.5	12. 9±6.8	0.069
Costs of ICU stay (Yuan) (median [minimum, maximum])	10436 (3450, 82118)	25746 (846, 137909)	0.886
Costs of hospitalization (Yuan)	77429±31939	82553±28448	0.260
Stitches removal time (days)	13.9±2.8	14.3±2.4	0.316
Incision healing (Grade I/II/III)	93/3/0	80/4/1	0.483
Patients back to normal life after surgery (number, percent)	68 (70.8%)	66 (77.6%)	0.314
Time to normal life (week)	16.8±4.4	16.9±4.5	0.904
Patients return to work after surgery (number, percent)	53 (55.2%)	55 (63.5%)	0.264
Time to work (week)	20.0±3.2	20.4±3.2	0.544

about restrictive strategy of RBCs transfusion (9-11), patients in the restrictive-strategy group received fewer units of blood than those in the liberal- strategy group without increased serious complications. In consistent with these studies, RBCs transfusion under guidance of WCPTS reduced, and WCPTS could be seen as another form of restrictive strategy. However, even restrictive transfusion strategy did not answer the question about which Hb level should RBCs transfusion be triggered or the transfusion target in an individual patient with Hb level between 7-10 per deciliter. But this question could be solved by the use of WCPTS, a dynamic score that to be assessed whenever the decision of RBCs transfusion is made in an individual patient, even at different time point. If we use WCPTS to guide transfusion, we need to check the patient's Hb concentration, and evaluate the patient's CO (reflected by adrenaline infusion rate), respiratory function (reflected by SpO_2), as well as the oxygen consumption status (reflected by body core temperature). So that the determination of whether the RBCs transfusion should be performed is made by Hb level and individual manifestation of the patient with the WCPTS guided transfusion strategy. In this meaning, WCPTS is an individual strategy of transfusion superior to any other transfusion strategy, and individual strategy should be the new stage for blood transfusion.

From the current study, we found some limitations in WCPTS. Firstly, the lowest score of WCPTS is 7, and the corresponding Hb level of 7 g/dl has been proved to be adequate in health human (1). According to Weiskopf's report (12), Hb concentrations of $\leqslant$ 6 g/dl could only produce reversible subtle impairment of human function in health volunteers without other impairment of organs, so that most of the patients undergoing elective surgery could bear Hb level of 6-7 g/dl based on Weiskopf's study theoretically, and this is supported by ASA guideline for RBCs transfusion (3) that "RBCs should usually administered when Hb concentration is less than 6 g/dl". Therefore, the initial score of WCPTS could be decreased to 6. Secondly, the patients' value of oxygen saturation during surgery was always above 95% because of the fresh gas flow of high concentration of inspired oxygen (FiO_2), and it would be non- ethical if we turned down the FiO_2 to evaluate the patient's real pulmonary function. So we changed this item into FiO_2 needed to maintain $SpO_2 \geqslant 95\%$ to assess the respiratory factor of oxygen supply. Thirdly, considering that the heart is most sensitive to the misbalance between oxygen supply and consumption, a higher oxygen carrying capacity is desirable in patients with coronary artery stenosis (13). Although patients with history of angina were not included in this study, the presence of angina and condition when angina occurred should be considered as an important item in WCPTS. This modified WCPTS was proposed to guide the RBCs transfusion for surgical patients with Hb between 6-10 g/dl (Table 6), and we needed a prospective RCT with big sample and long term follow-up to verify the safety and effectiveness of the new WCPTS. Besides, the sample size calculation was dependent on proportion of RBCs transfusion, and it may be not powered to show intergroup differences in secondary outcomes including proportion of ICU admission, length of ICU stay, length of hospital stay, etc. To address these issues, the large-scale clinical trials are still required.

The current practice was to consider blood transfusion of the Hb level between 7-10 g/dl, but in control group we gave blood to patients when hemoglobin level was below 10 g/dl. In fact, transfusion strategy of 10 g/dl is the widely accepted "safe" threshold, and RBCs transfusion when Hb decreases less than 10 g/dl does not run against the current guideline. In term of outcomes, there was no proof of which one was better between liberal and restrictive transfusion strategy in patients undergoing major surgery, so we chose the conservatively relative higher Hb threshold of 10 g/dl based on the assumption that acute anemia from blood loss in hemorrhagic surgery was associated with insufficient oxygen supply resulting injury to organism. Besides, if we did not set the fixed hemoglobin level but let the decision of transfusion made according to physicians' own judgment in the control group, it's easy for physicians to learn how to apply WCPTS in clinical transfusion, and the decision of whether to give patient transfusion could be based on WCPTS in both groups, which would bring bias in this study. However, in the future study, we need to add another group according to the current clinical practice as the restrictive transfusion strategy to test and verify modified WCPTS.

Table 6. West China Perioperative Transfusion Score (WCPTS, modified).

Points added	Adrenaline infusion rate	FiO_2 to keep SpO_2 ≧95%	Core body temperature	History of Angina
0	Not required	≤35%	<38℃	No
+ 1	≤0.05 μg/kg/minute	36-50%	38-40℃	On exertion
+ 2	≥0.06 μg/kg/minute	≥51%	>40℃	During normal daily living or at rest

In conclusion, an objective evaluation of the status of oxygen supply and consumption could be achieved by application of the individualized transfusion strategy, WCPTS, for the surgical patients with Hb level between 7-10 g/dl, and RBCs transfusion trigger and target could be determined on the basis of the evaluation, thus requirement of RBCs transfusion could reduce under the guidance of WCPTS safely and effectively.

The authors deny any conflict of interests.

These studies are attributed to Department of Anesthesiology, West China Hospital, Sichuan University, Chengdu, Sichuan, 610041, P.R. China, and Department of Anesthesiology, the First Affiliated Hospital of Xinjiang Medical University, Urumqi, 830054, Xinjiang, China.

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