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Comparison of liberal versus restrictive transfusion strategies after hip surgery in patients with coronary artery disease: a post hoc analysis of the FOCUS trial

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Abstract

Background There are no clear recommendations for optimal transfusion thresholds for patients with coronary artery disease who undergo noncardiac surgery. By comparing restrictive and liberal transfusion strategies for coronary artery disease combined with hip surgery, this study hopes to provide recommendations for transfusion strategies in this special population.

Methods A total of 805 patients from the FOCUS trial (Transfusion Trigger Trial for Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair) with coronary artery disease combined with hip surgery were divided into two groups based on transfusion thresholds: restricted transfusion (a hemoglobin level of 8 g/deciliter) and liberal transfusion (a hemoglobin threshold of 10 g/deciliter). The primary outcome of this study was a composite endpoint including in-hospital death, myocardial infarction, unstable angina, and acute heart failure. The secondary endpoints included other in-hospital adverse events and 30- and 60-day follow-up events. Analyses were performed by intention to treat.

Results Except for the proportion of congestive heart failure patients, the baseline levels of the two groups were comparable. The median number of transfusion units in the liberal transfusion group was 2 units, and the median transfusion volume in the restricted transfusion group was 0 units. The primary outcome was not significantly different between the two groups (9.2% vs. 9.4%, $p=0.91$). The incidence of in-hospital myocardial infarction events was lower in the liberal transfusion group than in the restricted transfusion group (3.2% vs. 6.2%) (OR = 0.51, $P=0.048$). The remaining in-hospital endpoint events, except for myocardial infarction, were not significantly different between the two groups. The 30-day and 60-day endpoints of death and inability to walk independently were not significantly different between the two groups, with ORs (95% CI) of 1.00 (0.75–1.31) and 1.06 (0.80–1.41), respectively. We also found no interaction between transfusion strategies and factors such as age, sex, or multiple underlying comorbidities at the 60-day follow-up.

Conclusions There was no significant difference in the in-hospital, 30-day or 60-day outcome endpoints between the two groups. However, this study demonstrated that a liberal transfusion strategy tends to reduce

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the incidence of in-hospital myocardial infarction events in patients with coronary artery disease combined with hip surgery compared to a restrictive transfusion strategy. More high-quality studies should be designed to investigate the optimal transfusion threshold in patients with coronary artery disease treated without cardiac surgery.

Keywords Coronary artery disease, Hip surgery, Blood transfusion threshold

Introduction

Red blood cell transfusion is a strategy that rapidly increases the oxygen-carrying capacity of the blood and is widely used in the clinical treatment of patients with anemia to mainly safeguard the oxygen supply in vital organs, such as the heart and brain [1]. Approximately 85 million units of blood are transfused globally each year [2]. Failure to receive timely transfusion treatment can lead to increased mortality in patients with low hemoglobin levels, and conversely, excessive transfusions can lead to an increase in various transfusion-related adverse effects and increased hospitalization costs [3]. Therefore, many physician associations have published guidelines related to red blood cell transfusion thresholds, such as the American Association of Blood Banks (AABB), Society of Thoracic Surgeons (STS), and Society for the Advancement of Blood Management (SABM). The different guidelines mentioned above generally recommend a restrictive transfusion threshold (70–80 g/L) [4–6].

Patients with coronary artery disease (CAD) have myocardial ischemia due to coronary artery stenosis and theoretically require higher hemoglobin concentrations to maintain myocardial needs. However, recommendations for transfusion thresholds in patients with CAD, particularly acute coronary syndrome (ACS), vary from guideline to guideline [7, 8]. Similarly, patients undergoing surgical procedures, especially major orthopedic surgery, theoretically require more hemoglobin to ensure oxygen supply to tissues and organs, but the limited research available supports that patients undergoing orthopedic surgery would benefit better from a restrictive transfusion strategy (< 80 g/L) [9]. Due to the large size of the CAD population, there is a growing interest in patients with CAD scheduled for surgery who have longer hospital stays, more severe disease, and a greater risk of bleeding [10]. This population is also referred to as the "double hit" population because CAD patients may benefit from increase oxygen supply, and the increased metabolic exertion during the perioperative period of hip surgery further elevates oxygen demand. However, none of the studies have focused on the optimal transfusion threshold for this specific population. This population has a higher hemoglobin requirement, so we speculate whether a liberal transfusion strategy would be better for these patients.

Based on these questions, we conducted this post hoc analysis by analyzing data from the FOCUS trial (Transfusion Trigger Trial for Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair; URL: https://www.clinicaltrials.gov; Unique indenter: NCT00071032, 13/10/2003). This study focused on patients with coronary artery disease combined with hip surgery, with the aim of comparing the differences between restrictive and liberal transfusion strategies for the prognosis of this specific population.

Methods

FOCUS study population

The FOCUS study was a randomized, unblinded, parallel, two-group multicenter trial in which patients were recruited from 47 hospitals across the USA and Canada [11]. The purpose of FOCUS was to compare the effectiveness and safety of restrictive versus liberal transfusion strategies in hip fracture patients at high risk for cardiovascular disease. FOCUS obtained ethical approval after adhering to the Declaration of Helsinki [12], and all methods were performed in accordance with the relevant guidelines and regulations. Prior to randomization, each patient signed an informed consent form. The opinions and views expressed in this article do NOT represent those of the FOCUS investigators or the National Institutes of Heart, Lung, and Blood Institute. The article was created using research materials obtained from the National Institutes of Heart, Lung, and Blood Institute's Biologic Specimen and Data Repository Information Coordinating Center (BIOLINCC, https://biolincc.nhlbi.nih.gov/) via an approved proposal. The National Heart, Lung, and Blood Institute should be contacted with requests to obtain the dataset.

For the FOCUS trial, patient outcome data were gathered from in-hospital records and telephone follow-up. Each patient had two telephone follow-up following randomization to evaluate their survival status, recovery (such as their capacity for independent walking, etc.), and other aspects. These visits will take place 30–45 days and 60–90 days later. Within 90 days of surgery, if the patient or a family member could not be reached, the patient was considered lost to follow-up.

Study population for this study

This study summarized and analyzed data from all patients with CHD from the FOCUS study. A history of CAD and hemoglobin levels less than 100 g/L within three days of hip surgery to repair a fracture were required for participation in this study.

Clinical outcomes

The primary outcome of FOCUS is death or the patient's ability to walk 10 feet (or across a room) without human assistance at 60 days after randomization, as determined by telephone interview (patient or proxy). The primary purpose of the original study defining this endpoint was to describe the success of the surgical procedure as well as successful rehabilitation [11].

As our study aimed to compare the difference between a liberal transfusion strategy and a restrictive transfusion strategy in terms of cardiovascular risk, we set the endpoint of this study as a composite endpoint, which included in-hospital death, in-hospital myocardial infarction, in-hospital unstable angina, and in-hospital acute heart failure. This primary endpoint covers a wide range of cardiac complications due to insufficient oxygen supply. The secondary endpoints included (1) other in-hospital adverse events, such as ischemic stroke, pneumonia, and wound infection; (2) death and independence to walk at 30 days; and (3) death and independence to walk at 60 days. Additionally, we assessed several endpoints of functional evaluation, such as instrumental activities of daily living (IADL), physical activities of daily living (PADL), and functional assessment of chronic illness therapy-fatigue (FACIT-Fatigue), at 30 days and 60 days. A previously published study that aimed to assess the functional outcomes of the FOCUS study specified these outcomes and the methods for gathering them in detail [11].

In-hospital myocardial infarction is characterized by any abnormal pattern of biomarkers, specifically cardiac troponin (I or T) levels that surpass 1.5 times the decision limit (the 99th percentile of a reference control group) at least once, accompanied by a rising or falling trend within the first 24 h following a suspected clinical event. Alternatively, it can be identified if CKMB (preferably CK-MB mass) exceeds 1.5 times the decision limit in two consecutive samples, along with ischemic symptoms, ECG changes suggesting ischemia, or imaging findings indicating new loss of viable myocardium or new regional wall motion abnormalities. Additionally, if cardiac biomarkers (troponin, CK-MB) are incomplete or unavailable, the emergence of pathological Q-waves on an ECG compared to baseline is also regarded as indicative of myocardial infarction.

Statistical analysis

The chi-square test was used to compare the results based on the liberal and restrictive transfusion strategies (analysis by intent to treat) [13]. An overall α-value of 0.05 was used to determine whether different transfusion techniques differed in the primary outcome. The primary outcome analysis is presented as a Mantel–Haenszel odds ratio with 95% confidence intervals. $P<0.05$ was considered to indicate a significant difference.

In terms of secondary analysis, present/absent variables will be used to classify binary outcomes, and a chi-square test will be used to first determine the impact of treatment on these outcomes. Outcomes in multiple categories will be analyzed using chi-square tests with more than one degree of freedom. T tests will be used to examine continuous variables such as functional status scores for instrumental activities of daily living (IADL), lower extremity physical activities of daily living (PADL), and functional assessment of chronic illness therapy-fatigue (FACIT-Fatigue) scale scores.

For the stratified analysis, tests for interaction will be used for this large, well-described patient population to explore the differences in treatment effects of different basic characteristics of the population, such as age, sex, heart failure, cerebrovascular disease, peripheral vascular disease, hypertension, diabetes mellitus, etc., with different transfusion strategies for the endpoint of in-hospital myocardial infarction. P values for interactions for subgroup analyses were generated using an interaction test [13, 14]. P values for interactions <0.05 were considered to indicate significant interactions. Statistical analysis was completed using R version 4.1.2 software (R Foundation for Statistical Computing, Beijing, China).

Results

Characteristics of the participants

A total of 805 patients with coronary artery disease combined with hip surgery were included in this study, including 402 patients in the liberal-strategy group and 403 in the restrictive-strategy group. The overall mean age of this study population was 82.3 years (range, 51 to 101). The baseline characteristics of the two study groups were comparable, except for congestive heart failure (27.9% versus 21.9%, $p=0.048$) (Table 1).

Hemoglobin levels and transfusion

The average hemoglobin level before transfusion was 1.1 g/decilitre greater in the liberal strategy group than in the restrictive strategy group (Table 2). The median number of units transfused was 2.0 (interquartile range, 1 to 2) in the liberal-strategy group and 0 (interquartile range, 0 to 1) in the restrictive-strategy group; 57.7% of patients

Table 1 Baseline clinical characteristics

Variables	Liberal ($n=402$)	Restrictive ($n=403$)	*P* value
Age (years)	82.4 ± 8.5	82.2 ± 8.2	0.75
Male	137 (34.1%)	120 (29.8%)	0.19
Race			
White	385 (95.8%)	384 (95.5%)	
Black	10 (2.5%)	13 (3.5%)	
Asian	6 (1.5%)	2 (0.5%)	
Other	1 (0.2%)	2 (0.5%)	0.44
Congestive Heart Failure	112 (27.9%)	88 (21.9%)	0.048
Cerebrovascular Disease	103 (25.6%)	94 (23.3%)	0.45
Peripheral Vascular Disease	54 (13.4%)	55 (13.6%)	0.93
Hypertension	324 (81.0%)	327 (82.0%)	0.73
Diabetes	119 (29.8%)	125 (31.3%)	0.63
Hypercholesterolemia	182 (49.1%)	173 (43.3%)	0.44
Current smoker	41 (10.0%)	40 (10.0%)	0.93
Creatinine > = 2.0 mg/dL	50(12.5%)	41(10.3%)	0.33
Chronic Lung Disease	91 (22.6%)	89 (22.1%)	0.84
Current Dementia/Confusion	124 (30.9%)	129 (32.0%)	0.76
Cancer	89 (22.1%)	71 (17.6%)	0.10
Fracture Type			
Neck Fracture	167 (41.5%)	167 (41.4%)	0.95
Intertrochanteric Fracture	213 (53.0%)	212 (52.6%)	0.89
Subtrochanteric Fracture	37 (9.2%)	40 (9.9%)	0.74
Reverse Oblique Fracture	4 (1.0%)	2 (0.5%)	0.41
ASA Score	3.1 ± 0.5	3.1 ± 0.5	0.28

Values are mean ± SD or n (%)

in the restrictive-strategy group did not receive a transfusion after randomization (Figs. 1, 2). The lowest postoperative hemoglobin levels in the liberal strategy group were greater than those in the restrictive strategy group.

Prognostic impact of different blood transfusion strategies

The primary endpoint of this study, the composite endpoint event of myocardial infarction, unstable angina, in-hospital heart failure, or in-hospital death, was not significantly different between the liberal and restricted groups (9.2% vs. 9.4%, $p=0.91$), but the incidence of myocardial infarction was significantly greater in the restrictive-transfusion group than in the liberal-transfusion group (6.2% vs 3.2%, $p=0.048$) (Table 3). Patients who had an in-hospital myocardial infarction had longer hospital stays than did those who did not, with median durations of 6.0 (3.0–21.0) versus 4.0 (2.0–8.0) ($P=0.004$).

For the secondary endpoints, congestive heart failure, ischemic stroke or transient ischemic attack, pneumonia, wound infection, return to the operating room, transfer to the intensive care unit (ICU), and other in-hospital outcomes were not significantly different between the two groups (Table 3). Additionally, no significant differences were found between the liberal and restrictive transfusion groups at 30 and 60 days of follow-up for death or for the self-walking endpoint. Most of the rehabilitation scale results, such as the IADL score, PADL score and FACIT-Fatigue score, did not significantly differ between the two groups (Table 4). Patients with in-hospital infarction in this study had a greater rate of ICU admission (15.2% vs. 3.5%, $P=0.002$).

To explore whether common clinical factors other than transfusion strategies have an impact on in-hospital myocardial infarction, we performed stratified and interaction analyses. We found no interaction between transfusion strategies and factors such as age (< 75 and ≥ 75 years), country (USA and Canada), sex (male and female), or multiple underlying comorbidities regarding in-hospital myocardial infarction as an endpoint (Fig. 3). However, in the subgroup without combined heart failure at baseline, the incidence of in-hospital infarction events may be higher in the restricted transfusion group compared to the liberal transfusion group (20/295 vs. 7/282, OR = 2.73, 95% CI 1.14–6.56).

Table 2 Hemoglobin levels and transfusions

Variables	Liberal ($n=402$)	Restrictive ($n=403$)	*P* value
Hemoglobin level			
Before surgery	11.3 ± 1.4	11.2 ± 1.5	0.51
During eligibility screening	9.0 ± 0.8	9.2 ± 0.5	0.99
Before transfusion	9.0 ± 0.7	7.9 ± 0.6	< 0.01
Estimated blood loss during surgery	217.6 ± 195.4	224.8 ± 273.0	0.69
Transfusions before randomization			
0 units	291/401(72.6)	274/402(68.2)	
≥ 1 unit	111/401(27.7)	129/402(32.1)	0.03
Total no. of units	201	228	
Transfusions after randomization			
0 units — no./total no. (%)	8 (2.0%)	232 (57.7%)	
1 unit — no./total no. (%)	171 (42.8%)	100 (24.9%)	
2 units — no./total no. (%)	136 (34.0%)	52 (12.9%)	
3 units — no./total no. (%)	52 (13.0%)	12 (3.0%)	
≥ 4 units — no./total no. (%)	33 (8.3%)	6 (1.5%)	< 0.001
Total no. of units	750	268	
Transfusion because of symptoms			
Rapid bleeding	1 (0.3%)	7 (1.8%)	0.03
Chest pain	3 (0.8%)	4 (1.0%)	0.71
Congestive heart failure	1 (0.3%)	7 (1.7%)	0.03
Tachycardia or hypotension	12(3.0%)	47 (11.7%)	< 0.01

Values are mean ± SD or n (%)

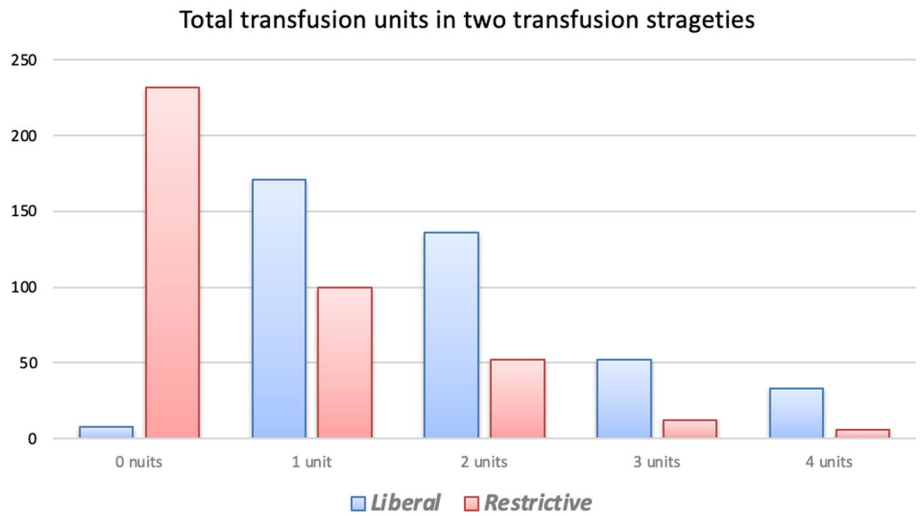

Fig. 1 Total number of transfusion units for the two transfusion strategies. The amount of blood transfused in the liberal transfusion group was greater than that in the restricted transfusion group. However, the specific difference in units was not significant

Discussion

This study aimed to compare the benefit of different transfusion thresholds in a population with coronary artery disease combined with hip surgery. The primary outcome was not significantly different between the two groups. The most meaningful finding of this study was the markedly lower incidence of in-hospital myocardial infarction in patients in the liberal-transfusion group than in those in the restrictive-transfusion group. This means that increasing the transfusion threshold reduces the incidence of perioperative myocardial infarction, and perhaps this is a better option

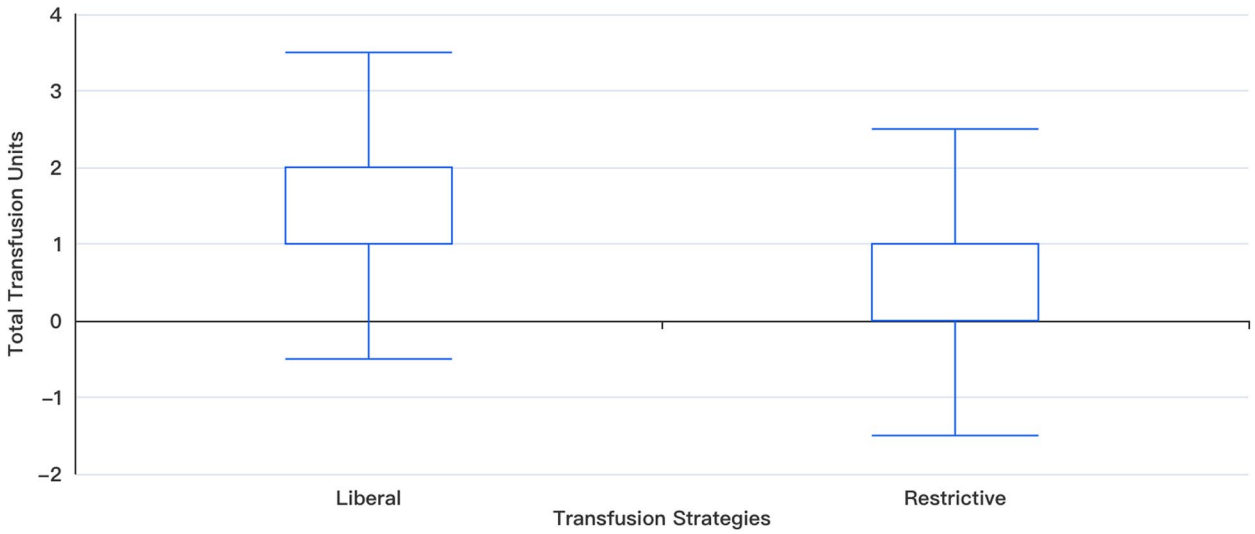

Fig. 2 Box plot of blood transfusion volume for the two groups of patients. The amount of blood transfused in the liberal transfusion group was greater than that in the restricted transfusion group

Table 3 In-hospital outcomes

Variables	Liberal	Restrictive	Odds Ratio (95% CI)	*P* value
Myocardial infarction, unstable angina, in-hospital heart failure, or in-hospital death	37/402	38/403	0.97 (0.61–1.57)	0.91
Myocardial infarction, unstable angina, or in-hospital death	20/401	30/402	0.65 (0.36–1.17)	0.15
Myocardial infarction	13/401	25/403	0.51 (0.26–1.01)	0.048
Unstable angina	0/401	1/403	0.33 (0.01–8.23)	1.00
In-hospital death	13/401	6/402	2.21 (0.83–5.88)	0.10
Physician diagnosis of congestive heart failure	19/401	12/402	1.62 (0.77–3.38)	0.20
Stroke or transient ischemic attack				
On CT or MRI	0/401	0/402		
On physician diagnosis or CT or MRI	1/401	1/402	1.00 (0.06–16.08)	1.00
Isolated troponin elevation	24/401	22/403	1.10 (0.61–2.00)	0.75
Chest radiograph with new or progressive infiltrate	35/401	24/402	1.51 (0.88–2.59)	0.13
New-onset purulent sputum	3/401	3/402	1.00 (0.20–5.00)	1.00
Wound infection	8/401	5/402	1.62 (0.52–4.98)	0.40
Death, myocardial infarction, pneumonia	53/401	49/402	1.10 (0.72–1.66)	0.66
Death, myocardial infarction, pneumonia, thromboembolism, or stroke	50/401	51/402	0.98 (0.65–1.49)	0.93
Returned to operating room	6/401	7/402	0.86 (0.29–2.57)	0.78
Transfer to ICU	18/401	13/402	1.41 (0.68–2.91)	0.36
Time from randomization to discharge	7.1 ± 7.7	7.3 ± 8.0		0.72

Values are mean ± SD or n (%).For all ratios, the liberal-threshold group is in the numerator and the restrictive-threshold group in the denominator

for this special group of patients with CAD combined with hip surgery. The findings of this study are similar to those of a meta-analysis by Docherty et al. in 2016 [15], which noted that the incidence of ACS events was significantly greater in patients treated with a restrictive strategy than in those treated with a liberal transfusion strategy (restrictive transfusion: 59 events/1319 patients versus liberal transfusion: 32 events/1290 patients) for patients with cardiovascular disease in a noncardiac surgical setting. We believe that this conclusion stems from the "double hit" faced by this particular population. On the one hand, patients with CAD inherently suffer from myocardial ischemia, which means that they require a more adequate oxygen

Table 4 Outcomes at 30 days and 60 days

Variables	30-Day Period			60-Day Period		
Age (years)	**Liberal**	**Restrictive**	**OR (95% CI)**	**Liberal**	**Restrictive**	**OR (95% CI)**
Death or inability to walk independently	201/396	203/399	1.00 (0.75–1.31)	159/399	154/401	1.06 (0.80–1.41)
Death	27/396	19/399	1.46 (0.80–2.68)	38/399	29/401	1.35 (0.82–2.24)
Inability to walk independently	174/396	185/399	0.91 (0.69–1.20)	121/399	125/401	0.96 (0.71–1.30)
Function and symptom scales			P Value			P Value
Lower-extremity physical ADL	7.8 ± 3.9	7.7 ± 3.8	0.83	5.8 ± 4.3	5.3 ± 4.3	0.20
Instrumental ADL	3.9 ± 0.5	4.0 ± 0.2	0.03	3.7 ± 0.8	3.7 ± 0.8	0.90
FACIT-Fatigue scale	37.7 ± 8.5	37.8 ± 7.8	0.87	41.1 ± 7.5	41.6 ± 7.7	0.51

Values are mean ± SD or n (%)

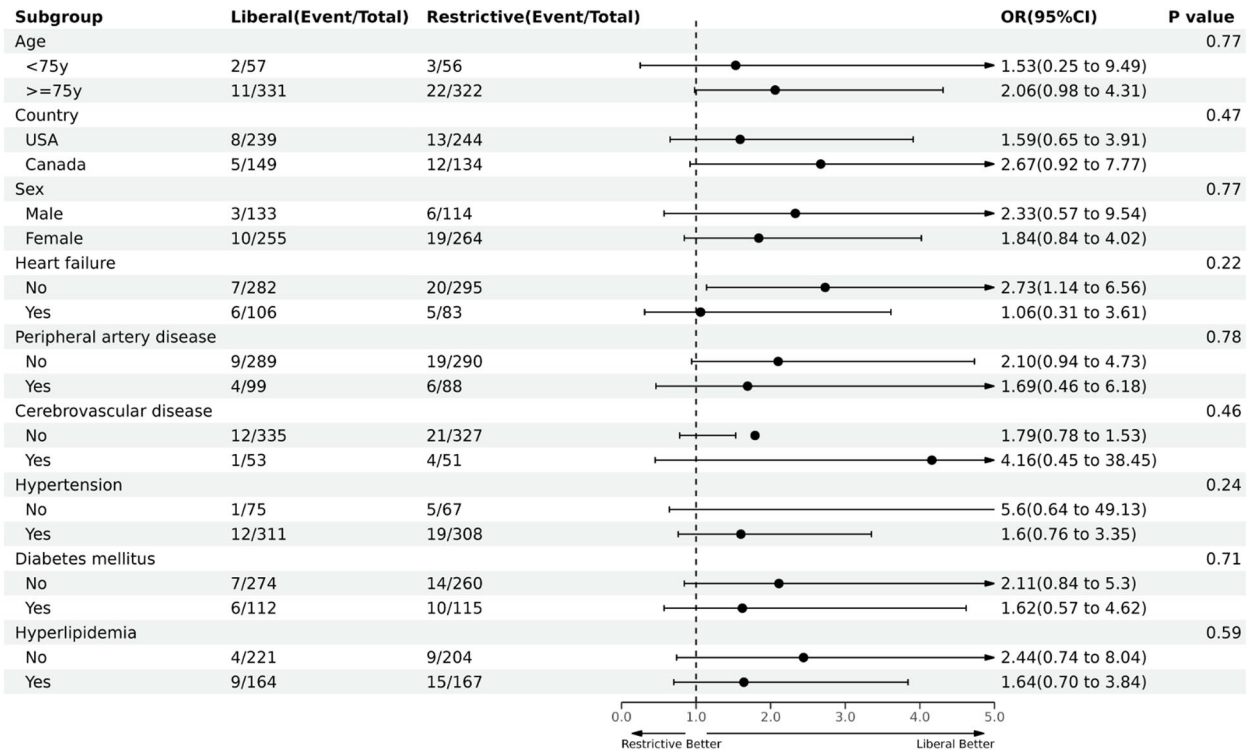

Fig. 3 Stratified analysis and interaction analysis. No significant interactions were found between factors such as age, sex, country, hypertension status, diabetes mellitus status, etc., and different transfusion strategies regarding in-hospital myocardial infarction as an endpoint

supply; on the other hand, the increased systemic metabolic exertion during the perioperative period of hip surgery also represents a greater oxygen demand.

However, other studies, such as the one by Hollis et al., have concluded the opposite, suggesting that patients with coronary artery disease undergoing noncardiac surgery should be managed with a more restrictive transfusion strategy [16]. However, most of these studies were retrospective rather than prospective randomized controlled designs, so there is still a need for validation in prospective randomized controlled studies with larger sample sizes.

Subgroup and stratified analyses suggested that for patients with nonheart failure, there was a significant increase in in-hospital myocardial infarction in the restricted transfusion group compared with the liberal group. This may imply that in clinical practice, cardiovascular physicians may have more freedom in using a liberal transfusion strategy in patients without combined heart failure at baseline.

In addition to the "double hit" of CAD plus noncardiac surgery (hip surgery), which is the focus of this study, another very typical "double hit" group is the population undergoing cardiac surgery, which has a high cardiac demand for oxygen and at the same time needs to suffer from perioperative exertion. The Transfusion Indication Threshold Reduction (TITRe2) study included patients who underwent cardiac surgery and demonstrated lower all-cause mortality at 90 days in the liberal-transfusion group than in the restrictive-transfusion group (2.6% vs 4.2%, $p=0.045$), although there was no significant difference in the primary endpoint events between the two groups [17]. Similarly, a meta-analysis that included a total of 3352 patients who underwent cardiac surgery suggested that restrictive blood transfusions increase mortality [18]. Furthermore, in a recent study by Carson et al., it was similarly demonstrated that liberal transfusion might be superior to restrictive transfusion in patients with acute myocardial infarction [19].

In this study, the median number of transfusion units in the liberal-transfusion group was 2 units, which was only 2 units greater than that in the restrictive-transfusion group, but the incidence of in-hospital myocardial infarction was reduced by 49%. A reduction in the incidence of in-hospital infarction events will directly reduce the length of stay and the cost of hospitalization for patients, a benefit that will far outweigh the cost of blood transfusions. However, the relevant part of the health economics evaluation was not included in this study, and no definite conclusions could be drawn. In the TITRe2 study [17], there was no significant difference in the mean postoperative cost at 3 months between the restricted and liberal transfusion groups (£10,636 vs £10,841, $p=0.71$), even though patients who used a liberal transfusion strategy spent more on red blood cell units than did those in the group who used a restricted transfusion strategy (£427 vs £287, $P<0.001$). The cost of blood transfusion was relatively low (approximately 3% of the overall cost) and thus did not have a substantial impact on the total cost, which may be the cause of the lack of difference in total cost between the two groups. The fact that the liberal transfusion group had significantly lower all-cause mortality at 90 days without increasing overall treatment costs suggests that the liberal transfusion strategy has greater health economic benefits.

Other outcomes in this study, such as in-hospital outcomes of heart failure, in-hospital stroke, wound infection, pneumonia, and other in-hospital outcomes, as well as all-cause mortality at 30 days and 60 days and recovery, were not significantly different. In this study, patients with in-hospital infarction had a greater rate of ICU admission and a longer median hospital stay than did those without infarction. It is possible that individuals with in-hospital infarction who receive more aggressive care, extra attention, and treatment—including admission to the intensive care unit and extended in-hospital supportive care—might obscure the infarction risk associated with the restriction transfusion group.

In addition, it has been previously shown that patients with acute coronary syndrome (ACS) may require different transfusion thresholds than those with chronic coronary syndrome (CCS) [15, 20]. The criterion for coronary artery disease included in the original FOCUS study was the presence of evidence of coronary artery disease in the past. Based on clinical experience, patients with ACS are generally not scheduled for hip surgery in the acute phase. We considered that the population included in this study was primarily patients with chronic coronary syndrome (CCS); therefore, the conclusions of this study may be more appropriate for the population with CCS.

Limitations

The five main limitations of this study are as follows. First, the FOCUS study was conducted from 2004 to 2009, more than a decade from the present day. The clinical scenario today has changed from the past, which may have led to a decrease in the weight of the findings of this study. Second, as an unplanned subgroup analysis, this study may be underpowered due to an insufficient sample size, which could ultimately lead to bias in the results. Third, we assessed intervention effects on multiple endpoints, which has the inherent risk of multiplicity. Fourth, the choice of primary composite outcome in the study may be a limitation, as liberal transfusion could increase heart failure while decreasing ischemic events and death, suggesting that the effect of the intervention for each component of a composite outcome would ideally go in the same direction. Fifth, although this study revealed a statistically significant difference in the rate of MI between the two groups, the small absolute number of acute MI events could not completely rule out the possibility of a chance occurrence, indicating the need for further research with a larger sample size to investigate this issue.

Conclusion

There was no significant difference in the 30-day or 60-day outcome endpoints between the two groups. However, a liberal transfusion strategy tends to reduce the incidence of in-hospital myocardial infarction events in patients with coronary artery disease combined with hip surgery compared to a restrictive transfusion strategy, accompanied by a decrease in hospitalization length and ICU care. This study will hopefully provide more evidence on transfusion strategies for CAD patients planning noncardiac surgery. Larger randomized trials should

specifically focus on transfusion strategies for this particular population.

Abbreviations

AABB	American Association of Blood Banks
CAD	Coronary artery disease
ACS	Acute coronary syndrome
FOCUS	Transfusion Trigger Trial for Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair
PADL	Lower-extremity physical activities of daily living
IADL	Instrumental activities of daily living
CCS	Chronic coronary syndrome
OR	Odds ratio
CI	Confidence interval

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Conflicts of interest
The authors report no conflicts of interest.

Authors' contributions
The statistical analysis was performed by JY Zhang, ZX Chen. JY Zhang wrote the manuscript. ZX Chen and Y He conceived, instructed, reviewed, and revised the manuscript. All authors read and approved the final version of the manuscript.

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Availability of data and materials
The dataset of the FOCUS trial is available via reasonable request to the National Heart, Lung and Blood Institution. The dataset used and analyzed during the current study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All subjects from the FOCUS trial signed informed consent forms before participating in the trial. Our current study was approved by the Biomedical Research Ethics Committee of West China Hospital.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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