Original Article

A Comparison of the Clinical Outcomes of Minimum and Maximum Hematocrit Levels During Cardiopulmonary Bypass (CPB) in Low-risk Patients Undergoing Coronary Artery Bypass Graft Surgery (CABG): A Cross-sectional Study

Fatemeh Shiravi[1], Mehran Shahzamani[2], Sayyed Alireza Hosseini[2], Davood Shafie[3]

[1]Department of Blood Circulation Technology, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Department of Surgery, Chamran Hospital, Isfahan University of Medical Sciences, Isfahan, Iran, [3]Department of Cardiology, Heart Failure Research Center, Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Background: This study investigated the clinical outcomes at the minimum and maximum levels of hematocrit (HCT) during cardiopulmonary bypass (CPB) in low-risk patients undergoing coronary artery bypass graft (CABG) surgery.

Materials and Methods: In this cross-sectional study, 85 patients who underwent CABG with an ejection fraction of greater than 35% were selected. Based on the HCT range during CPB, patients were divided into two groups: minimum HCT: HCT = 16–18% and maximum HCT: HCT = 25–27%. Then the operation outcomes, amount of drainage, and transfusion were recorded and compared between these groups.

Results: In the middle tube 8 h after surgery and left tube 24 h after surgery, the amount of drainage in the minimum HCT group with mean of 71.00 ± 130.9 and 60.65 ± 71.23, respectively, was significantly lower than the maximum HCT group with mean of 101.5 ± 246.50 and 123.76 ± 93.17, respectively (P value < 0.05). The incidence of cognitive disorders in the maximum HCT group was significantly higher than in the minimum HCT group (11.1% vs. 0%, P value = 0.041). Also, the mean transfusion of packed red blood cell (PRBC) and fresh frozen plasm (FFP) during CPB in the maximum HCT group, with mean of 346.7 ± 86.22 and 396.1 ± 21.05, respectively, were significantly higher than the minimum HCT group with mean of 178.8 ± 80.91 and 136.8 ± 46.77, respectively (P value < 0.05). After CPB, there was no significant difference in transfusion products (P value > 0.05).

Conclusion: According to the results of this study, patients undergoing CABG surgery with maximum HCT level versus minimum HCT level during CPB, need more packed cells and fresh frozen plasma products transfusion, which will be associated with the complication of cognitive impairment.

Keywords: Cardiopulmonary bypass, coronary artery bypass, hematocrit

Address for correspondence: Dr. Sayyed Alireza Hosseini, Department of Surgery, Chamran Hospital, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: drhosseiny@med.mui.ac.ir
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Introduction

Cardiovascular diseases (CVD) are one of the major causes leading to death worldwide, and coronary artery disease (CAD) being the first and the most common cause.[1,2] Coronary artery bypass grafting (CABG) has been shown in studies to be the gold standard therapy for the majority of patients with multivessel coronary artery disease.[3] It should be noted that this surgery may necessitate the use of heart and lung pump technology (CPB, cardiopulmonary bypass).[4]

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Preoperative risk-factor assessment is crucial for patients undergoing CABG because it has been discovered that the improvement or elimination of these risk factors is necessary for the procedure to be successful. Numerous reports have highlighted the potential drawbacks of low hematocrit (HCT) values during CPB; however, the appropriate cutoff of hemodilutional anemia is not yet known since, from many prospective studies, hemodilution during CPB is viewed favorably because it reduces blood viscosity, which enhances peripheral perfusion and blood flow to tissues. In addition, hemodilution in hypothermic procedures combats the tendency toward high viscosity at low temperatures and may reduce the need for blood transfusions.[5-9] The absolute minimum safe HCT level required for maintaining oxygen delivery during CPB and also complications after surgery in case of an increase or decrease of HCT level during CPB in low-risk patients is being debated. The HCT level is used to determine when transfusion is required, but transfusion has numerous risks and appears to worsen outcomes after CABG surgery.[10] By considering these factors, it is possible to take planned precautions to avoid complications after CPB in CABG surgery, thereby reducing the length of hospitalization, the need for blood transfusions, the rate of mortality, and costs. There is very little data on the preoperative evaluation of patients undergoing CABG in the local setting. This study aimed to compare the clinical outcomes of minimum HCT level (16–18%) versus maximum HCT level (25-–27%) during CPB in low-risk patients undergoing CABG surgery.

Materials and Methods

Study design

The population in this cross-sectional study included all CABG candidate patients in the surgery department of Chamran Hospital, affiliated with Isfahan University of Medical Sciences, in 2022.

Patient enrollment

The inclusion criteria were nonemergency CABG candidate patients using CPB, for three or four graft surgery, in the age group of 40–70 years with an ejection fraction (EF) greater than 35%, no previous history of heart surgery, no use of extracorporeal membrane oxygenation (ECMO) or balloon pump before surgery, without a history of end-stage renal diseases (ESRD), chronic obstructive pulmonary disease (COPD) and liver diseases, with normal range of HCT (Normal range of HCT level: men: 41– 50%, women: 36– 48%) and Hb (Normal range of Hb level: men: 13.5–17.5 g/dL and women is 12.0–15.5 g/dL). In addition, patients who had hemodynamic instability before surgery, carotid stenosis of more than 70%, left main stenosis, history of cerebral vascular accident (CVA; in the last 6 months), and a history of transient ischemic attack (TIA; in the previous 3 months) and lack of satisfaction to cooperate in the study, were excluded. Based on these criteria, finally, 90 patients were eligible to enter the study, and all of them were included by census.

Procedure

After obtaining the code of ethics from the Ethics Committee of Isfahan University of Medical Sciences (Approval code: IR.MUI.MED.REC.1400.703) and obtaining written consent from eligible patients, they entered the study. At the beginning of the study, the demographic and clinical information of the patients, including age, gender, weight, underlying diseases including diabetes, blood pressure, and recent acute heart attack, were recorded.

The same anesthesia and surgical procedure were used for all the patients. During anesthesia induction, sodium thiopental (Nesdonal brand, Elixir Pharmaceutical Company), pancuronium bromide (PAVULON brand, Tehran Daro Pharmaceutical Company), and fentanyl (Caspian Tamin Pharmaceutical Company) were used. The surgical technique was performed by a skilled single surgeon. Before CPB, isoflurane (Caspin Tamin Pharmaceutical Company) and morphine (Caspin Tamin Pharmaceutical Company) were used, and during CPB, propofol was used as an anesthetic agent. The same cardioplegia solution was used in all cases. The CPB method for all patients included a roller pump, an oxygenator, and an arterial filter. CPB was performed by cannulating the aorta and right atrium. All standard principles and sterilization items were followed, and cooling was done with a heat exchanger at a temperature of 30–32°C, and non-pulse flow was used. The prime solution used included

Table 1: Demographic and clinical characteristics of patients in two study groups

Variable	Maximum hematocrit (n=45)	Minimum hematocrit (n=40)	P
Sex			
Male	25 (55.6%)	19 (47.5%)	0.458
Female	20 (44.4%)	21 (52.5%)	
Age; year	62.7±6.04	62.1±7.6	0.730
Weight; kg	75.12±12.35	71.68±13.25	0.089
Past medical history			
Diabetes	13 (28.9%)	22 (55%)	0.011
Hypertension	27 (60%)	27 (67.5%)	0.474
Acute myocardial infarction	3 (6.7%)	10 (25%)	0.020
Addiction	17 (37.8%)	4 (10%)	0.003

1000 ml of Ringer's lactate, 500 ml of valvone, and 10,000 units of heparin.

Then, during CPB, the HCT level of 45 patients was adjusted in the range of 16–18% (as the minimum HCT level) and the other 45 patients were kept in the range of 25–27% (as the maximum HCT level).[11] This division was considered as the two study groups.

It should be noted that in the group with the minimum HCT level (16–18%), five people were excluded from the study due to their unwillingness to continue the cooperation, and the same 45 people remained in the maximum HCT group. Therefore, the study was followed up on 40 patients in the minimum HCT group and 45 patients in the maximum HCT group.

Outcome measurements

Variables, including the need for transfusion before, during, and after the pump and the amount of drainage at 4, 8, and 24 h after surgery in the intensive care unit (ICU), were evaluated and recorded. Also, the ICU length of stay, the time of extubation, and the occurrence of neurological complications (including the occurrence of stroke and transient cerebral ischemia) were recorded in the checklist for each patient.

Statistical analysis

The collected information was entered into SPSS software (Ver. 26). Qualitative and quantitative data were shown with *n* (%) and mean ± standard deviation (SD), respectively. At the level of inferential statistics, Fisher's exact and Chi-square tests were used to compare the frequency distribution of qualitative data. An Independent *t*-test was used to compare the mean age and weight between the two groups. To compare the mean of other quantitative variables between the two groups, univariate analysis was used by adjusting age, gender, weight, addiction, and past medical history. In all analyses, a significance level of less than 0.05 was considered.

Results

In the current study, from 40 patients in the minimum HCT group, 52.5% were female and 47.5% were male, with the mean age of 62.1 ± 7.6 years, and from 45 patients in the maximum HCT group, there were 44.4% female and 55.6% male, with the mean age of 62.7 ± 6.04 years (*P* value > 0.05). The past medical history of the patients with diabetes, hypertension, and acute myocardial infarction in the minimum HCT group was significantly more than the maximum HCT group (*P* value < 0.05) [Table 1].

In evaluating the amount of drainage in the two groups, it was found that the mean drainage in the minimum HCT group was lower than the maximum HCT group. So in the middle tube 8 h after surgery and in the left tube 24 h after surgery, the amount of drainage in the minimum HCT group with mean of 71.00 ± 130.9 and 60.65 ± 71.23, respectively, was significantly lower than the maximum HCT group with mean of 101.5 ± 246.50 and 123.76 ± 93.17, respectively (*P* value < 0.05) [Table 2].

On the other hand, the incidence of cognitive disorders in the maximum HCT group was significantly higher than in the minimum HCT group (11.1% vs. 0%, *P* value = 0.041). However, death, stroke, and TIA were not reported in both groups (*P* value > 0.05). Although the extubation time and the length of stay in the ICU in the minimum HCT group were lower than the maximum HCT group, these differences were not significant (*P* value > 0.05) [Table 3].

Finally, the mean transfusion of packed red blood cells (PRBC) before CPB in the minimum HCT group was 6.51 ± 14.7. During CPB, transfusion products, including PRBC and fresh frozen plasma (FFP), in the maximum HCT group with mean of 346.7 ± 86.22 and 396.1 ± 21.05, respectively, which were significantly higher than the minimum HCT group with mean of 178.8 ± 80.91 and 136.8 ± 46.77, respectively (*P* value < 0.05). After CPB, there was no significant difference in transfusion products (*P* value > 0.05) [Table 4].

Discussion

HCT is a well-known factor in the pre- and postoperative complications of cardiac surgery. Some studies showed the effect of low HCT levels on outcomes of CPB during

Table 2: Mean drainage in the right, left, and middle tubes during the follow-up times in the three studied groups

Drainage	Maximum HCT (*n*=45)	Minimum HCT (*n*=40)	*P*
Right tube			
4 h after surgery	30.00±16.68	56.20±18.98	0.298
8 h after surgery	38.91±17.38	43.00±12.61	0.950
24 h after surgery	35.61±20.36	38.44±22.03	0.167
Middle tube			
4 h after surgery	230.00±200.12	195.5±104.8	0.872
8 h after surgery	206.71±201.5	130.9±107.00	0.030
24 h after surgery	153.3±114.4	75.36±56.2	0.342
Left tube			
4 h after surgery	136.77±121.6	93.8±74.9	0.192
8 h after surgery	120.32±105.9	73.3±67.4	0.168
24 h after surgery	110.36±93.7	71.23±60.65	0.040

HCT=Hematocrit

Table 3: Comparison of patient outcome, extubation time, and length of stay in ICU in the two study groups

Variables	Maximum HCT (*n*=45)	Minimum HCT (*n*=40)	*P*
Outcome			
Cognitive Disorders	5 (11.1%)	0 (0%)	0.04
Death	0 (0%)	0 (0%)	1.00
Stroke	0 (0%)	0 (0%)	1.00
TIA	0 (0%)	0 (0%)	1.00
Extubation time	12.6±6.4	11.6±9.4	0.37
Length of stay in ICU	7.3±0.9	6.3±0.8	0.44

HCT=Hematocrit

Table 4: Comparison of transfusion before, during and after cardiopulmonary bypass in two study groups

Transfusion	Maximum HCT (*n*=45)	Minimum HCT (*n*=40)	*P*
Before the pump			
PRBCs	0	14.7±6.51	0.141
During the pump			
PRBCs	346.7±86.22	178.8±80.91	<0.001
FFP	396.1±21.05	136.8±46.77	0.003
Platelets	108.5±40.8	61.1±16.60	0.210
Albumin	0	6.53±5.33	0. 355
After the pump			
PRBC	378.5±46.01	305.2±22.00	0.111
FFP	96.3±13.8	189.3±56.36	0.764
Platelets	47.9±8.88	97.9±44.4	0.078
Cryoprecipitate	0	70.5±20.43	0.060

HCT=Hematocrit, PRBCs=Packed red blood cells, FFP=Fresh frozen plasma

CABG.[6,9,11-13] But, in the present study, the effects of both the minimum and the maximum HCT on operation outcomes have been studied and compared. Our results showed a significant association between the minimum and maximum HCT values and clinical results and the incidence of complications after open heart surgery (CABG) during CPB in low-risk patients. Although the incidence of death, stroke, TIA, the mean of extubation time, and length of stay in ICU did not differ significantly between the two groups; however, the number of packed cells and fresh frozen plasma transfusion during the CPB in the minimum HCT group was significantly lower compared to maximum HCT group. It should also be mentioned that due to the difference of HCT levels in men and women of the general population, in the analysis of this study, we have adjusted variables such as gender, age, weight, addiction, and past medical history so that the results based on the effect of the HCT level be more reliable during CPB.

After CABG, fluid accumulation in the pleural spaces is common, occurring in 41– 97% of cases. This fluid accumulation usually occurs within the first 24 h after surgery and is visible on chest X-rays (CXR). The fluid typically accumulates around the lower lobe of the left lung in small amounts, but bilateral accumulation is possible.[12,13] So, according to the findings of the current study, the amount of drainage in the middle tube 8 h after the CABG surgery and the left tube 24 h after the CABG surgery was significantly lower in the minimum group than in the maximum HCT group. According to a previous study, patients who underwent CABG surgery had higher-than-normal chest drainage in the left and middle drains, with the least amount of drainage present when entering the ICU. There was a significant relationship between the amount of hemoglobin, HCT, and the amount of drainage after surgery and the duration of heart disease, the number of grafts performed, and the duration of connection to the ventilator.[14-16] In our study, the lowest amount of drainage was also reported in the minimum HCT group. In fact, it seems that adjusting the patient's HCT level during CPB to a minimum level of 16–18% can prevent more transfusion and reduce the amount of drainage during CPB and after CABG surgery. These approaches can be effective in minimizing complications after surgery.

Pala *et al*.[17] showed that low preoperative HCT levels are linked with an increased rate of mortality after CABG; however, in our study, no death or stroke has been observed, even in the minimum HCT group. A study of 1,766 consecutive adult patients who had isolated CABG found that the lowest HCT value on CPB and blood transfusions were independent risk factors for postoperative low-output syndrome and renal failure considering that poor renal function has been listed as one the important preoperative risk factors for CABG.[17,18] Their findings also showed that anemia caused by CBP was not associated with death.[19] Previous research has shown that women who have CABG have a higher risk of complications and mortality than men. It could be because the normal-range HCT for women is lower than for men, and subjects with lower than normal HCT levels had increased blood loss and need for blood products transfusion compared to participants who had normal HCT levels.[18,20,21] Stammers *et al*.[22] discovered that women receive three times more blood transfusions than men. So it was discovered that perfusion strategies aimed at gender differences can reduce unnecessary blood transfusions. In our study, the rate of blood products consumption, such as packed cells and fresh frozen plasma received during the pump, was significantly higher in the minimum HCT group than in the maximum HCT group, but the number of other products consumed before, after, and during the pump did not differ significantly between the two groups even though most of the participants in our study in the minimum HCT group of 16–18% were women and people with less weight than the other group.

On the other hand, our study showed that the frequency of cognitive disorders in the minimum HCT group was significantly lower than in the maximum HCT group. In this regard, the estimated incidence of cognitive disorders in the first week after heart surgery is between 20 and 70%, with 10–40% still showing cognitive impairment 6 weeks later.[23]

Yuhe *et al*.[24] investigated whether shortening the CPB circuit could consistently reduce postoperative cognitive complications in a study. With a 38.9% incidence, neurocognitive dysfunction is one of the most common complications of CABG surgery. Also, in bypass patients, the reduction of hemodilution and the reduction of inflammatory processes resulted in better brain protection compared to the opposite group, resulting in a 10-fold reduction in stroke. However, cognitive complications in the two groups were 50% in the first quarter after the operation, and no significant difference was observed. Hence, the researchers concluded that shortening the cardiopulmonary circuit with bypass improved cellular function and neurocognitive outcomes after it was performed.

It has been stated that low HCT levels in patients admitted to ICU are the risk factor for increased mortality and the need for mechanical ventilation, while higher HCT levels reduce the need for blood transfusion and the use of mechanical ventilation for a shorter period. Kumar *et al*.[18] also, in a longitudinal study on 82 CABG patients, reported that patients with lower than normal HCT levels had increased duration of ICU stay, while the results of the present study showed that the average extubation time between the two groups is not significantly different.

Therefore, although conducting this study for the first time with the aim of comparing the minimum and maximum levels of HCT on CPB in patients undergoing CABG in the occurrence of complications, the need for transfusion and the amount of drainage can be considered as strengths of this study. However, the small sample size and lack of comparison of different ranges of HCT are the limitations of this study. For this reason, it is suggested that future studies with a larger statistical population will do a comparative evaluation of the effect of different levels of HCT on primary and secondary complications after CABG surgery.

Conclusion

According to the results of the current study, patients undergoing CABG surgery with maximum HCT level need more packed cells and fresh frozen plasma products transfusion, which will be associated with the complication of cognitive impairment. However, patients with minimum levels of HCT on CPB required less transfusion and less drainage after surgery. Considering that high transfusion and drainage can have an effective role in the occurrence of complications in patients, it seems that in low-risk patients undergoing CABG surgery, the minimum HCT can be adjusted during CPB to avoid complications and the need for further transfusion as much as possible.

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Conflicts of interest

There are no conflicts of interest.

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