Original Article

Efficacy of the "Head-Up Position" in Returning Cardiopulmonary Bypass Blood to the Patient and Reducing the Required Blood Transfusion: A Randomized Trial

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ABSTRACT

Background: All intraoperative strategies that may assist an anesthesiologist with lowering the blood transfusion rate must be considered. We assessed the efficacy of the 30° head-up position at the end of cardiopulmonary bypass (CPB) in returning CPB reservoir blood to patients, reducing the transfusion rate, and conferring hemodynamic stability after the transfer of patients to the intensive care unit (ICU).

Methods: In a single-center clinical trial, 88 adult patients undergoing elective isolated coronary artery bypass graft surgery were randomly allocated to the head-up group (n=44), in which the 30° head-up position was applied during separation from CPB, and the supine group (n=44), in which weaning from CPB was performed in the supine position. All the patients had left ventricular ejection fractions > 35%. The primary end point was the returned volume of filtered CPB blood to the patients. The secondary outcome measures were intraoperative and early postoperative hemodynamic parameters. Additionally, blood products transfused during surgery and in the 1st 6 hours following ICU admission were recorded.

Results: There were no statistically significant differences in intraoperative and early postoperative hemodynamics between the 2 groups except in the returned blood volume to the patients after separation from CPB (714 ± 99 mL in the head-up position group vs 285 ± 78 mL in the supine group; $P = 0.0001$). There were no significant differences between the 2 groups regarding the transfused blood products during surgery and the 1st 6 hours following ICU admission.

Conclusions: Using the 30° head-up position at the end of CPB conferred a higher return of blood to the patients but did not significantly reduce postoperative transfusion. ***(Iranian Heart Journal 2017; 18(1):6-15)***

Keywords: Supine position, Coronary artery bypass surgery, Cardiopulmonary bypass, Blood transfusion, Hemodynamics

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The role of anesthesiologists in the perioperative management of patients undergoing coronary artery bypass grafting surgery (CABG) is expanding. [1] Anesthesiologists must be expert not only in performing safe anesthesia techniques but also in providing all aspects of perioperative care for ischemic heart disease patients. In order to achieve better outcomes, they must consider developments in pharmacological materials and instruments, new surgical techniques, anesthesia management, and monitoring techniques. [1] Although due to the emergence of percutaneous interventions, the number of the patients referred for CABG is reducing, coronary artery disease is still accounts for 1 of 6 deaths in the United States. [2, 3]

It has been reported that 40%–70% of all red blood cell units are transfused throughout surgical procedures. [4, 5] A reduction in only 1 unit of the transfused blood products has been reported to lessen mortality and morbidity; therefore, all intraoperative strategies that may help an anesthesiologist with lowering the blood transfusion rate must be considered. [6, 7]

Some interventions can lower the required homologues blood transfusion volume; they include controlled hypotension, acute normovolemic hemodilution, autologous blood predonation, relative reduction of target hematocrit for transfusion, optimal surgical homeostasis, reducing cardiopulmonary bypass (CPB) time, ultrafiltration during CPB, and finally returning the remaining volume of reservoir and the tubing system just before aortic decannulation at the end of CPB. Stress response to surgery can be modified through surgical method and patient position. [8]

Hypotension and ventricular dysfunction are prevalent perioperative hemodynamic abnormalities in cardiac surgeries. [9, 10] In post-CABG patients undergoing low tidal volume mechanical ventilation, stroke volume variation can predict responsiveness to volume therapy and can assess its hemodynamic effects. [11] Recently, dynamic changes in preload such as pulse pressure variation have been reported to be due to cyclic variations in stroke volume during mechanical ventilation by cardiopulmonary interaction. [12] Also, dynamic variables of preload are important in directing fluid and inotrope therapy in critically ill patients. [13]

Supine position is the commonest position in surgery; hemodynamic reserve is best maintained in this position as the whole body is almost at cardiac level. The compensatory mechanisms of hemodynamic changes are blunted during anesthesia and only a few degrees of head-up or head-down position is enough to produce significant cardiovascular changes. [14]

In the present study, we proposed that some volume of CPB reservoir blood could be pooled to the splanchnic veins and the lower extremity of patients by using the 30° head-up position at the end of CPB through blunting the autonomic nervous system and vascular autoregulation. Before the transport of patients, their position is returned to supine to allow some autotransfusion of pooled blood to the central circulation. Via invasive blood pressure and central venous pressure (CVP) monitoring, as well as monitoring the arterial blood gas and lactate levels, we ensured the return of adequate cardiac preload and avoided overloading the patients. The aim of this blood volume return to the patients was to reduce the rate of homologous blood transfusion after separation from CPB and to prevent hypotension in the early post- CABG period.

METHODS

The research proposal was approved by the institutional ethics committee. Written informed consent was obtained from all the patients. In this single-blind clinical trial, 88 patients (aged between 40 and 60 years) who underwent elective isolated CABG were recruited. All the patients had left ventricular ejection fractions > 35%, were weaned from CPB, and had acceptable arterial blood gas, hemoglobin, and electrolyte profiles. Whitlock et al [14] returned a mean of 280 mL of processed blood from CPB to their patients. We hypothesized a 100-mL difference in the retuned blood volume by applying the head-up position at the end of CPB. Considering an α of 0.05 and a β of 0.1 and by using an online sample size calculator (http://www.stat.ubc.ca/~rollin/stats/ssize/n2.html), we calculated that each group was to comprise 44 patients. The patients were randomly allocated to 2 groups of head-up (n=44) and supine (n=44) by using online software(http://www.graphpad.com/quickcalcs/randomize2/). The randomization list was kept concealed by the head of the anesthesiology department. The participants were entered in the study and assigned to the head-up and supine groups sequentially.

Intraoperative monitoring—including left radial arterial line; systolic, diastolic, and mean arterial pressures; CVP via the right internal jugular vein; ECG; and airway pressure—was performed in both groups. In 23 patients in the head-up group and 21 patients in the supine group, we planned to use a pulmonary artery catheter (PAC) to monitor the cardiac output (CO) during surgery. After the induction of anesthesia, a 7.0-Fr PAC (Swan-Ganz CCO/VIP PAC, Edwards Lifesciences) was placed via the right internal jugular vein and connected to a Vigilance™ monitor (Version 6.3, Edwards Lifesciences).

The anesthetics and techniques were the same in all the patients. The surgical methods of coronary revascularization and CPB priming and technique were similar in both study groups. The only difference between the 2 groups was the 30° head-up at the end of CPB in the head-up group. Returning the volume of the tubing system and the reservoir of the CPB circuit to the patients was continued until a target CVP of 10–12 mm Hg was achieved. Subsequently, aortic decannulation was performed and the patients' position was changed to supine at the end of surgery before transfer to the intensive care unit (ICU). All the hemodynamic parameters and total blood products (packed red blood cell, fresh frozen plasma, and platelet) transfused intraoperatively and within the 1st 6 hours following ICU admission were recorded.

Statistical Analysis

There was no loss to follow-up in the course of the present study. Intention-to-treat statistical analysis was utilized. The collected data were analyzed using IBM SPSS for Windows, version 21.0 statistical package (IBM SPSS Inc, Chicago, IL, USA). The Kolmogorov–Smirnov test was used to evaluate the adaptation of the collected data with normal distributions. The qualitative data were analyzed using the χ^2 test or the Fisher exact test, and the quantitative parameters were analyzed using the independent samples *t*-test. A P value $\leq$ 0.05 was considered statistically significant.

RESULTS

Eighty-eight patients, at a mean age of 58.3 ± 5.9 years old, were studied. All the data were normally distributed according to the Kolmogorov–Smirnov test (all P values > 0.05). The patients were similar in both groups with respect to their demographic and background characteristics (Table 1).

There were no significant differences in intraoperative and early postoperative variables between the 2 groups, except in the returned blood volume to the patients after separation from CPB (714 ± 99 mL in the head-up group vs 285 ± 78 mL in the supine group; P = 0.0001) and the remaining volume in the CPB circuit (128 ± 95 vs 523 ± 125 mL, respectively; P = 0.00010) (Table 2). In both studied groups, the crystalloid fluids administered by the anesthesiologist or added by the surgery team were similar. The intraoperative urine output was not significantly different between the 2 groups.

Totally, 30/88 (34%) of our CABG patients received packed red blood cells (PRBCs) during surgery or in the early postoperative period. Also, there were no significant differences between the 2 groups in terms of the transfusion of blood and blood products in the intraoperative period and in the 1st 6 hours following ICU admission (Table 3).

Table 1. Basic characteristics of the patients undergoing CABG with or without applying the 30º head-up position after separation from CPB

	Head-Up Group (n=44)	Supine Group (n=44)	*P*
Age (y)	59.1±6.3	57.4±5.5	0.214
Sex (male)	36(85.7%)	31(73.8%)	0.277
Height (cm)	167±8.0	166±8.9	0.766
Weight (kg)	73.8±10.0	75.1±9.3	0.537
BSA (m^2)	1.81±0.14	1.85±0.13	0.363
Diabetes mellitus	20(47.6%)	22(52.4%)	0.827
Hypertension	26(61.2%)	25(59.5%)	0.823
COPD*	5(11.9%)	6(14.3%)	0.746
LVEF (%)*	47.3±5.7	46.6±6.3	0.589
Blood urea nitrogen (mg/dL)	19.3±6.8	19.0±6.0	0.215
Creatinine (mg/dL)	0.96±0.25	0.89±0.27	0.866
MR*severity (none, mild/moderate/severe)	33/8/1	31/11/0	0.464
TR*severity (none, mild/moderate/severe)	37/5/0	30/12/0	0.057

CABG, Coronary artery bypass graft surgery; CPB, Cardiopulmonary bypass; COPD, Chronic obstructive pulmonary disease; LVEF, Left ventricular ejection fraction; MR, Mitral regurgitation; TR, Tricuspid regurgitation

Table 2. Intraoperative and postoperative variables of the patients undergoing CABG with or without applying the 30º head-up position after separation from CPB

	Head-Up Group (n=42)	Supine Group (n=42)	*P*
CPB time (min)	83.5±30.5	84.6±23.9	0.861
Aortic cross-clamp (min)	47.0±21.7	48.1±15.9	0.815
Coronary graft No. (mean)	3.17±0.85	3.05±0.66	0.477
Crystalloid administered by the anesthesiologist (mL)	2200±588	2032±456	0.148
Crystalloid added to the field by the surgery team (mL)	2588±652	2630±367	0.712
CPB prime and added volume (mL)	2786±825	2754±492	0.829
Waste suction volume (mL)	1032±382	1007±300	0.740
Filtered volume (by the perfusionist) (mL)	1154±845	1163±854	0.964
Returned volume to the patient after separation from CPB (mL)	714±99	285±78	0.0001
Remaining volume in the CPB circuit (mL)	128±95	523±125	0.0001
CO after the induction of anesthesia (liter/min)	4.7±1.1 (n=23)	4.6±1.2 (n=21)	0.744
CO at the end of CPB before the return of the residual volume (liter/min)	4.9±1.3 (n=23)	4.8±1.3 (n=21)	0.800
CO at the end of CPB after the return of the residual volume (liter/min)	5.5±1.6 (n=23)	5.2±1.4 (n=21)	0.513
Intraoperative urine volume (mL)	1319±542	1135±429	0.090
Intraoperative furosemide (mg)	5.9±3.8	4.8±2.9	0.436
Intraoperative inotrope use	21.4%	17.1%	0.549
Postoperative inotrope use	7.1%	14.3%	0.374

* CABG, Coronary artery bypass graft surgery; CPB, Cardiopulmonary bypass; CO, Cardiac output

Table 3. Transfused units of blood and blood products in the patients undergoing CABG with or without applying the 30º head-up position after separation from CPB

			Head-Up Group (n=44)	Supine Group (n=44)	*P*
Intraoperative	Packed RBC*	[0/1/2/more] (units)	27/15/0/0	27/12/1/2	0.504
	FFP*	[0/1/2/more] (units)	38/1/4/2	39/0/2/1	0.384
	Platelets	[0/1/2/more] (units)	33/2/5/2	40/0/2/0	0.114
Early ICU	Packed RBC	[0/1/2/more] (units)	25/13/3/1	29/8/3/2	0.344
	FFP	[0/1/2/more] (units)	33/1/6/2	36/1/5/0	0.315
	Platelets	[0/1/2/more] (units)	35/2/4/1	37/3/2/0	0.589

RBC, Red blood cell; FFP, Fresh frozen plasma

Figure 1 demonstrates the variations of systolic and diastolic blood pressures and the heart rate in both study groups. There were no significant differences in hemodynamics between the head-up and supine groups. As Figure 2 shows, the patients' PaO_2 decreased from the end of CPB to the ICU admission. It, however, remained at clinically acceptable levels. There were no statistically significant differences between the 2 groups regarding the PaO_2 or $PaCO_2$ levels during the study period. Figure 3 shows that serum lactate levels slightly deceased and the base deficit increased slightly during CABG. However, their levels were not altered to the levels to be considered harmful to the patients. There were no significant differences between the 2 groups regarding these parameters. The patients' hematocrit and hemoglobin levels decreased during CPB in acceptable degrees and returned to clinically acceptable values in the ICU, without significant differences between the 2 groups (Fig. 4).

We also recorded the patients' CVP and the mean airway pressure during surgery and up to 1 hour after admission to the ICU. There were minimal changes in airway pressure in both groups. The mean CVP in both groups decreased at the end of CPB (to about 4 mmHg), but returned to about 8 mm Hg and increased up to 10 mm Hg 1 hour after admission to the ICU (Fig. 5).

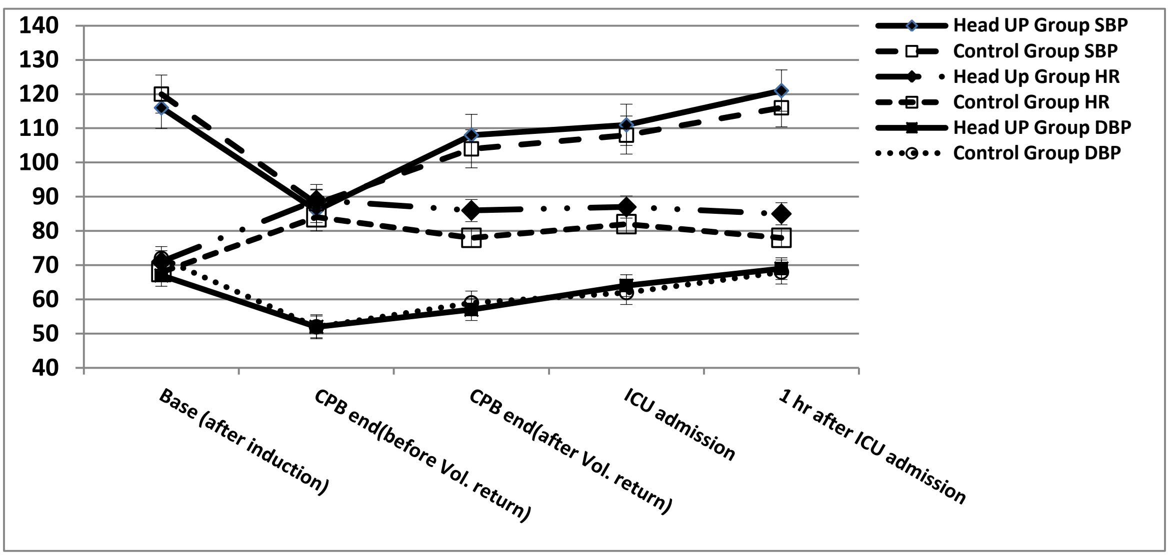

Figure 1. Hemodynamic variations of the patients undergoing coronary artery bypass graft surgery with or without applying the 30º head-up position after separation from CPB.

CPB, Cardiopulmonary bypass

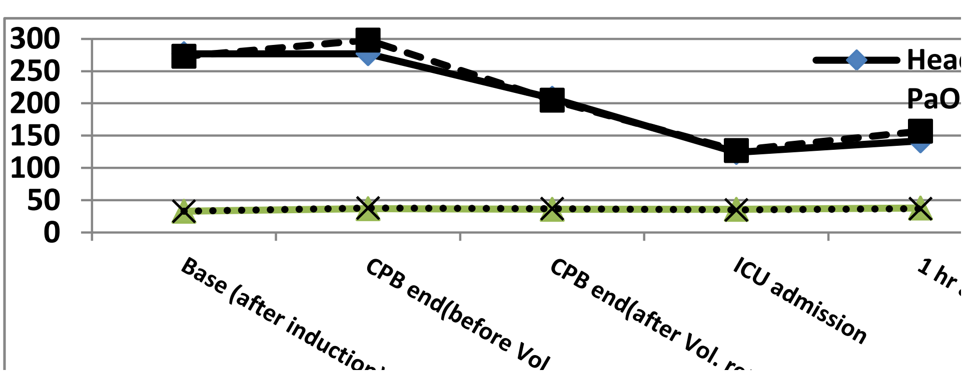

Figure 2. Arterial blood gas fluctuations of the patients undergoing coronary artery bypass graft surgery with or without applying the 30º head-up position after separation from CPB.

CPB, Cardiopulmonary bypass

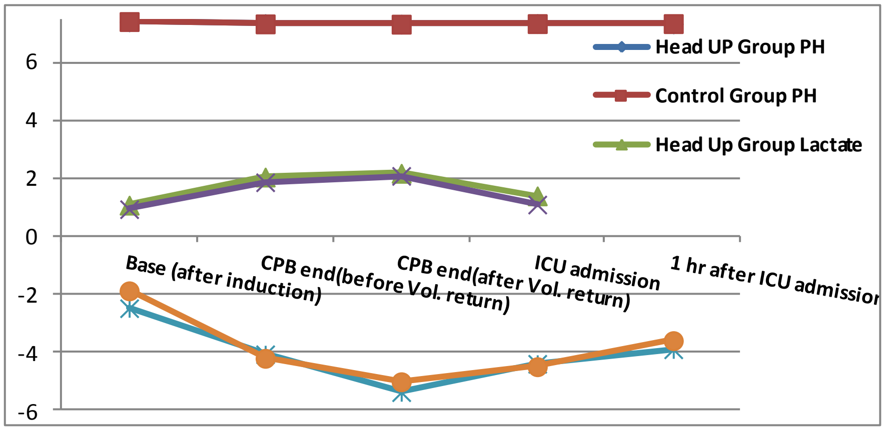

Figure 3. Acid-base variations of the patients undergoing coronary artery bypass graft surgery with or without applying the 30º head-up position after separation from CPB.

CPB, Cardiopulmonary bypass

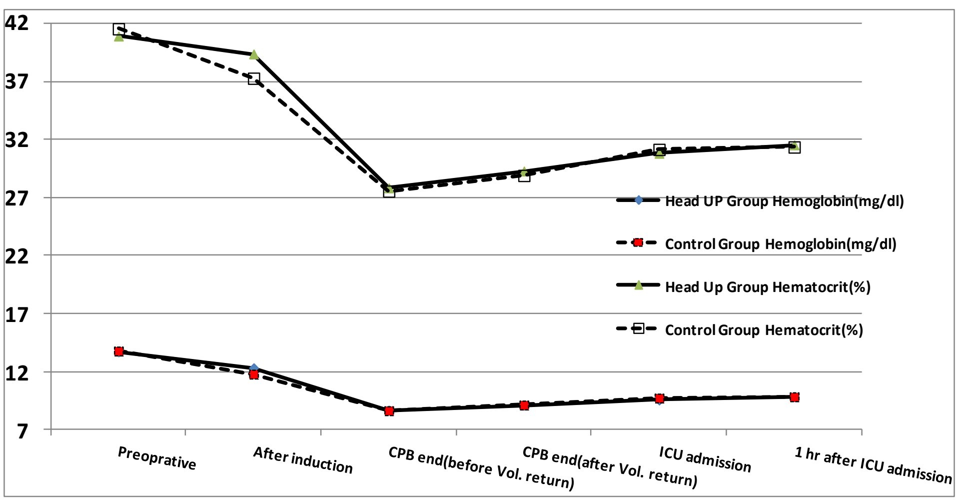

Figure 4. Blood levels of hemoglobin and hematocrit in the patients undergoing coronary artery bypass graft surgery with or without applying the 30º head-up position after separation from CPB.

CPB, Cardiopulmonary bypass

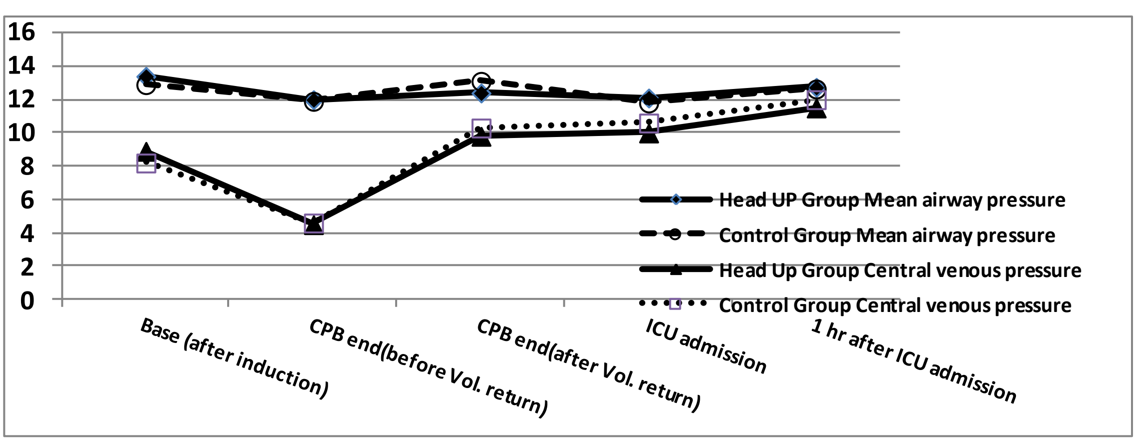

Figure 5. Mean airway and central venous pressures of the patients undergoing coronary artery bypass graft surgery with or without applying the 30º head-up position after separation from CPB.

CPB, Cardiopulmonary bypass

DISCUSSION

We hypothesized that retuning more filtrated CPB residual blood volume to patients by applying head-up positioning at the end of CPB and then re-directing the pooled blood of the splanchnic veins and the lower extremities to the central circulation by returning the patients to supine position during their transfer to the ICU could prevent hypovolemia and hypotension and also, this “autotransfusion” might reduce the need to homologous transfusion in the postoperative period.

We succeeded in returning a mean value of 429 mL of filtered (processed) blood to our patients after separation from CPB through the application of the 30º head-up position. Although this return volume is clinically significant, we could not find any significant differences in hemodynamic parameters (blood pressure or the CO) and also in the number of the required blood product units between the 2 study groups.

Institutions vary considerably in their transfusion practices for CABG. [15] In a study performed by Stover at al, [15] a substantial variability (27%–92%) in transfusion practice was observed in institutions for PRBCs. Elsewhere, Lokosky et al [16] found that the transfusion of small (1–3) units of PRBCs was common, yet different, across geographic areas. The authors posited that differences in regional practice, consisting of transfusion triggers and perioperative anemia management, might affect variability in the transfusion rates of PRBCs. Other investigators have also presented similar findings on the institutional variability of transfusion practice. [17-19]

On the other hand, it seems that there is also a significant variability in transfusion practice among surgeons and also among anesthesiologists within a single institution. Frank et al [20] reported a significant discrepancy in this regard among surgical services and techniques, and also among individual surgeons and anesthesiologists. The use of the RBC salvage technique, fresh frozen plasma, and platelets varied 3-4 times among individual surgeons compared with their colleagues carrying out the same surgical technique. In the present study, the surgical operations were performed by 7 different surgeons and 6 anesthesiologists. Given the significant individual variability in transfusion practice among our hospital’s surgeons and anesthesiologists, this powerful confounding factor may have overcome small differences in blood-saving properties via the application of the head-up position and the return of the reservoir blood to the patients at the end of CPB in our intervention group.

Some studies have demonstrated the beneficial effects of returning the hemoconcentrated residual CPB volume to patients on biochemical and clinical patient outcomes in the postoperative period but not on either coagulation parameters or postoperative bleeding following cardiac surgery. [21, 22] Daane et al [23] suggested that processing and transfusing the residual CPB volume had no effects on complement activation, hemostasis, or the postoperative blood loss and volume of transfusion in their cardiac surgery patients. As was previously mentioned, various techniques are used to return the CPB residual blood to patients with different laboratory and clinical results. In our study, we sought to demonstrate the new technique of the head-up position so as to redistribute the venous and splanchnic blood to the lower body segments and to allow the return of the CPB residual blood to the patients at the end of CPB. On average, we managed to return 400 mL of filtered and hemoconcentrated residual CPB blood to our patients; however, this technique failed to show any beneficial effects on postoperative hematocrit levels or needs for transfusion in our patient population.

In 2013, Bubenek-Turconi et al [24] compared 2 methods of measuring the CO (ie, noninvasive Nexfin [NAPCO] and PAC) in cardiac surgical patients before and after preload-modifying maneuvers, including fluid challenge or passive leg-raising maneuver. Both methods reliably showed preload-induced changes in the CO in the stable patients. We used continuous CO monitoring using PAC in nearly half of our patients. Although a small increase was observed in the head-up group, in comparison with the supine group, we could not find any significant increase in the CO by returning more residual CPB reservoir blood volume to the patients after separation from CPB. The small sample size of the study might have contributed to the absence of any statistically significant increase in the CO in the head-up group after CPB.

CONCLUSIONS

In this single-center clinical trial, through the application of the 30º head-up position, a mean value of 429 mL of filtered (processed) blood was returned to the CABG patients after separation from CPB. This volume return, despite being clinically significant, was statistically insignificant. Additionally, no significant differences were observed in the hemodynamic parameters (blood pressure and the CO) and also in the number of required blood product units between the 2 study groups.

Limitations

This trial was a single-center study, performed on 88 CABG patients, which limits its generalizability. Further, we succeeded in measuring the CO only in 23 patients in the head-up group and 21 patients in the supine group. This lowers the study's power regarding advanced hemodynamic monitoring to assess effects of the head-up position at the end of CPB. In our study, the patients underwent surgery by 7 different surgeons and 6 different anesthesiologists. Regarding the significant individual variability in transfusion practice among our hospital's surgeons and anesthesiologists, this powerful confounding factor might have contributed to small differences in blood-saving properties through the application of the head-up position and the return of the reservoir blood to the patients at the end of CPB in our intervention group.

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