Revista Brasileira de Cirurgia Cardiovascular/Brazilian Journal of Cardiovascular Surgery
ISSN: 0102-7638
revista@sbccv.org.br
Sociedade Brasileira de Cirurgia Cardiovascular

Leiria de Moura da Silva, Leonardo; de Borba Andres, Anna Júlia; Senger, Roberta; Stuermer, Ralf; de Mello de Godoy, Maria Celoni; Mafassioli Correa, Eduardo Francisco; Cóser, Virgínia Maria

Impact of autologous blood transfusion on the use of pack of red blood cells in coronary artery bypass grafting surgery

Revista Brasileira de Cirurgia Cardiovascular/Brazilian Journal of Cardiovascular Surgery, vol. 28, núm. 2, abril-junio, 2013, pp. 183-189
Sociedade Brasileira de Cirurgia Cardiovascular
São José do Rio Preto, Brasil

ORIGINAL ARTICLE

EMC

Rev Bras Cir Cardiovasc 2013;28(2):183-9

Impact of autologous blood transfusion on the use of pack of red blood cells in coronary artery bypass grafting surgery

Impacto da transfusão autóloga no uso de concentrado de hemácias em cirurgias de revascularização do miocárdio

Leonardo Leiria de Moura da Silva[1], Anna Júlia de Borba Andres[2], Roberta Senger[3], Ralf Stuermer[4], Maria Celoni de Mello de Godoy[5], Eduardo Francisco Mafassioli Correa[6], Virgínia Maria Cóser[7]

DOI: 10.5935/1678-9741.20130027

RBCCV 44205-1456

Abstract

Objective: **To evaluate the impact of Cell Saver autologous blood transfusion system (CS) on the use of packed red blood cells (pRBC) in coronary artery bypass grafting (CABG) surgery.**

Methods: **We carried out a retrospective cross-sectional study in 87 patients undergoing primary elective CABG with miniaturized cardiopulmonary bypass (miniCPB), divided in two groups: 44 without-CS and 43 with-CS. We investigated the necessity of absolute use and the volume of packed red blood cells (pRBC) in each group, as well as cardiovascular risk factors, presurgical variables and intraoperative surgical parameters. All data were collected from medical records and there was no randomization or intervention on group selection. Statistical analysis was performed with Student t-test, Mann-Whitney U-test and χ^2 test, with a 5% significance level.**

Results: **There were no significant differences between the two groups in terms of cardiovascular risk factors and pre and intraoperative variables. Evaluating the absolute use of pRBC during surgery, there was a statistically significant difference (*P*=0.00008) between the groups without-CS (21/44 cases; 47.7%) and with-CS (4/43 cases; 9.3%). There was also a statistically significant difference (*P*=0.000117) in the volumes of pRBC between the groups without-CS (198.65±258.65ml) and with-CS (35.06±125.67ml). On the other hand, in the early postoperative period (up to 24h) there was no difference regarding either the absolute use or the volumes of pRBC between both studied groups.**

Conclusion: **Autologous erythrocyte transfusion with CS use reduces the use of intraoperative homologous pRBC in coronary artery bypass grafting surgeries associated with miniCPB.**

Descriptors: **Blood transfusion, autologous. Myocardial revascularization. Erythrocyte transfusion.**

1. Anesthesiologist, MD, MSc. University Hospital of Santa Maria (HUSM). Post-Graduate Program on Health Sciences - Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil. Study design, data collection, anesthesia of the patients, writing, and review.
2. Medical Student. Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil. Data collection, structuring of the database, and review.
3. Perfusionist Nurse. University Hospital of Santa Maria (HUSM), Santa Maria, RS, Brazil. Data collection, management of perfusion of patients, and review.
4. Cardiovascular Surgeon, MD. University Hospital of Santa Maria (HUSM), Santa Maria, RS, Brazil. Surgeon who operated on patients, structuring of the database, review.
5. Anesthesiologist, MD, PhD. Associate Professor of Anesthesiology. Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil. Coorientation of the study, review.
6. Anesthesiologist, MD, TSA. Chief, Division of Anesthesiology. University Hospital of Santa Maria (HUSM), Santa Maria, RS, Brazil. Study design, coorientation to the study, anesthesia of the patients and review.
7. MD, PhD. Attending Physician, Division of Hematology-Oncology. University Hospital of Santa Maria (HUSM). Supervisor Professor at Post-Graduate Program on Health Sciences - Federal University of Santa Maria (UFSM), Santa Maria, RS, Brazil. Orientation of the study, review of data collected, review.

Work carried out at Post-Graduate Program on Health Sciences (UFSM) and University Hospital of Santa Maria (HUSM), Santa Maria, RS, Brazil.

Correspondence adress:
Leonardo L M Silva
Hospital Universitário de Santa Maria (HUSM) – Anesthesia Services. Av. Roraima, s/n – Prédio 22 – Campus da UFSM – Camobi – Santa Maria, RS, Brazil – Zip code: 97105-900.
E-mail: leonardolms@gmail.com

Article received on November 19th, 2012
Article accepted on May 17th, 2013

Abbreviations, Acronyms & Symbols

AMI	Acute myocardial infarction
ASA	American Society of Anesthesiologists
CABG	Coronary artery bypass grafting surgery
CPB	Cardiopulmonary bypass
CS	Cell Saver autologous blood transfusion system
HUSM	Hospital Universitário de Santa Maria
miniCPB	Miniaturized cardiopulmonary bypass
pRBC	Packed red blood cells

Resumo

Objetivo: **Avaliar o impacto do sistema de autotransfusão com hemoconcentração (SAH) no uso de concentrado de hemácias (CH) em cirurgias de revascularização do miocárdio (CRM).**

Métodos: **Foi desenvolvido um estudo transversal, que incluiu 87 pacientes submetidos a CRM eletiva primária com miniCEC, sendo 44 sem uso do SAH e 43 pacientes com uso do SAH. Foi investigada a necessidade de uso e o volume de CH em cada grupo, bem como fatores de risco cardiovascular, variáveis pré-operatórias e parâmetros cirúrgicos transoperatórios por meio de coleta de dados em prontuários. Não houve randomização ou intervenção na seleção dos grupos. Na análise estatística foram utilizados os testes t de Student, teste U de Mann-Whitney, teste do qui-quadrado, com um nível de significância de 5%.**

Resultados: **Em relação a fatores de risco cardiovascular e variáveis pré e transoperatórias, não houve diferença estatística significativa entre os dois grupos. Quando se avaliou o uso absoluto de CH no transoperatório, houve diferença estatística significativa (*P*=0,00008) entre os grupos sem-SAH (21/44 casos; 47,7%) e com-SAH (4/43 casos; 9,3%). Na análise dos volumes de CH utilizado no transoperatório, também houve diferença significativa (*P*=0,000117) entre os volumes utilizados no grupo sem-SAH (198,65±258,65 ml) e com-SAH (35,06±125,67 ml). Já no pós-operatório imediato (até 24 horas), não houve diferença tanto no uso absoluto como nos volumes de CH entre os grupos que usaram ou não o SAH.**

Conclusão: **A autotransfusão de hemácias possibilitada pelo uso do SAH determina menor uso de CH homólogo no transoperatório de CRM com uso de miniCEC.**

Descritores: **Transfusão de sangue autóloga. Revascularização miocárdica. Transfusão de eritrócitos.**

INTRODUCTION

Cardiovascular diseases are the leading causes of mortality not only in Brazil but also throughout the world [1,2], with acute myocardial infarction (AMI) being the main cause of death. The AMI surgical treatment through coronary artery bypass grafting surgery is an usual procedure, which is frequently associated with cardiopulmonary bypass (CPB) and high rates of homologous blood transfusion, varying from 40 to 90% in most publications [3-5]. Transfusion therapy is associated with several unfavorable outcomes, such as renal dysfunction, cardiac, neurological and immunological complications, among others [6].

There is no consensus regarding an ideal value of hemoglobin or hematocrit which suggests transfusion in cardiac surgeries. The American Society of Anesthesiologists (ASA) recommends that pRBC transfusion in patients with serum level of hemoglobin between 6 and 10 g/dL be based on the risk of developing complications or organic lesion by inappropriate oxygenation [7]. The latest consensus concerning perioperative transfusion in cardiac surgery identified six variables as being important risk indicators of pRBC transfusion: old age, small total amount of red blood cells (anemia or small body size), use of antiplatelet or antithrombotic drugs, reoperation or complex procedures, emergency procedures and non-cardiac comorbidity. This same study stated, with a level A of evidence (class I), that all measures of pre and perioperative blood conservation must be taken into this group of patients, since they correspond to the greatest part of hemocomponent transfusions [8].

Among mechanical strategies to reduce the necessity of homologous pRBC transfusion, we find the so-called Cell Saver (CS). It is a specialists' consensual opinion (level C of evidence and class IIb recommendation) that the use of autologous blood transfusion through mechanisms such as Cell Saver is reasonable, during surgeries with cardiopulmonary bypass [8]. However, there are few studies related to the impact of this practice on the real necessity of pRBC transfusion in cardiac surgeries with CPB, especially in coronary artery bypass grafting surgeries.

The present study aims to evaluate the impact of Cell Saver on the necessity of pRBC use in coronary artery bypass grafting surgeries associated with miniCPB which were carried out at the University Hospital of Santa Maria (HUSM).

METHODS

We carried out a retrospective cross-sectional study in patients who had their health care provided by the Division of Cardiac Surgery of HUSM, undergoing CABG surgery from January 2011 to October 2012. All patients were operated by the same surgical team, with right atrial and aortic cannulation, mild hypothermia and blood cardioplegia, and perfusion managed by only one professional. The same group of anesthesiologists was in charge of all patients' anesthesia care, following the indicative criteria of pRBC transfusion: metabolic acidosis, bad peripheral perfusion, cerebrovascular disease, peripheral vascular disease, hemodynamic instability and mixed venous saturation (SvO_2) <75%.

Patients with ischaemic heart disease undergoing CABG associated with miniCPB, either using hemocomponents or

not in the intra or postoperative periods were included in the study. The exclusion criteria were: combined cardiac surgery, previous cardiac surgery, emergency surgery, surgery indication for non-ischaemic heart disease and the use of hemocomponents in priming constitution in the circuit in miniCPB.

To determine the minimum sample size, we collected a pilot sample of 10 cases from the group without CS use (without-CS) and 14 cases in the group with CS use (with-CS), considering a 5% significance level, a power of 80% and a sample error (e_0) of 0,5 pRBC bags, with standard deviations estimates of 1.287 and 0.938, respectively, totalizing 44 patients in each group. Upon determining the necessary minimum sample size, we selected the last 44 patients who underwent coronary artery bypass grafting surgery with miniCPB and did not make use of CS, as well as the first 43 that used it. As randomized selection of patients was not used in the study, the occurrence of sample selection bias is possible. However, we intended to minimize it through a linear selection of patients, in which the first half did not use CS and the second half did. There was no change in the anesthetic-surgical technique in both groups of patients.

The Cell Saver System (autoLog® Autotransfusion System, Medtronic) is composed of a console which is responsible for its operation and programming, as well as a disposable set which includes a vaccum, cardiotomy reservoir, centrifugation reservoir, waste bag, blood collection reservoir bag, which is assembled in each surgery. The CS operation was managed by the same perfusionist who was responsible for performing the cardiopulmonary bypass. This system has been used as a routine in cardiac surgeries which are carried out at HUSM since the end of the year 2011.

We investigated cardiovascular surgical risk factors such as hypertension, smoking, diabetes mellitus, COPD, renal dysfunction and previous AMI through an instrument for collecting data, developed for this specific purpose. We also collected information related to the surgical procedure (CPB time and aortic clamp, the amount of grafted blood vessels) and the anesthetic procedure (ASA classification, blood typing and Rh factor, left ventricular ejection fraction and previous and postoperative hematocrit and hemoglobin), as well as the use or not of hemocomponents in the intra and immediate postoperative periods (up to 24h). To evaluate whether there was some difference in the use of pRBC, the χ^2 test was applied in the groups, using the program called Statistica v. 9.1 (Statsoft Inc., Tulsa, OK, USA). The present study was approved by the UFSM Research Ethics Committee (Nº. 36,523, June 13th 2012) in compliance with 196/96 National Health Council Resolution (Conselho Nacional de Saúde).

RESULTS

Patients' profile in both groups related to cardiovascular surgical risk factors, previous AMI, value of LV ejection fraction, as well as frequencies referred to blood typing, Rh factor and ASA classification may be seen in Table 1. The data are not only frequency-based, but also expressed through mean, standard deviation and significance level.

Table 1. Patients' profile stratified by group

	without-CS n = 44	with-CS n = 43	*P* value
Gender			0.264
male	29 (65.9%)	33 (76.7%)	
female	15 (34.1%)	10 (23.3%)	
Age (years-old)	62.25 ± 7.85	62.53 ± 11.94	0.895
Weight (kg)	75.34 ± 14.68	80,37 ± 14.64	0.112
BSA (m^2)	1.83 ± 0.18	1.90 ± 0.17	0.072
SAH			0.798
yes	37 (84.1%)	37 (86.0%)	
no	7 (15.9%)	6 (14.0%)	
Smoking			0.305
yes	34 (77.3%)	29 (67.4%)	
no	10 (22.7%)	14 (32.6%)	
DM			0.596
yes	25 (56.8%)	22 (51.2%)	
no	19 (43.2%)	21 (48.8%)	
COPD			0.144
yes	9 (20.4%)	4 (9.3%)	
no	35 (79.6%)	39 (90.7%)	
Renal disease			0.729
yes	6 (13.6%)	7 (16.3%)	
no	38 (86.4%)	36 (83.7%)	
Previous AMI			0.700
yes	29 (65.9%)	30 (69.8%)	
no	15 (34.1%)	13 (30.2%)	
LVEF			0.569
normal (≥55%)	35 (79.6%)	32 (74.4%)	
abnormal (<55%)	9 (20.4%)	11 (25.6%)	
ASA			0.353
III	37 (84.1%)	39 (90.7%)	
IV	7 (15.9%)	4 (9.3%)	
BT			0.081
A	14 (31.8%)	22 (51.2%)	
B	18 (40.9%)	17 (39.5%)	
AB	3 (6.8%)	0 (0.0%)	
O	9 (20.5%)	4 (9.3%)	
Rh			0.746
positive	36 (81.8%)	34 (79.1%)	
negative	8 (18.2%)	9 (20.9%)	
Number of grafts	3.00 ± 0.71	2.81 ± 0.85	0.272
Initial Ht (g/dL)	40.27 ± 4.54	39.43 ± 4.71	0.399
Initial Hb (g/dL)	13.45 ± 1.72	13.22 ± 1.63	0.535
Clamp T. (min)	72.02 ± 20.91	67.37 ± 21.21	0.306
CPB T. (min)	89.52 ± 20.23	86.58 ± 24.90	0.546

BSA: body surface area; SAH: systemic arterial hypertension; DM: diabetes mellitus; COPD: chronic obstructive pulmonary disease; AMI: acute myocardial infarction; LVEF: left ventricular ejection fraction; ASA: clinical classification of American Society of Anesthesiologists; BT: blood type; Rh: Rh factor; Ht: hematocrit; Hb: hemoglobin; Clamp T.: aortic clamp time; CPB T.: cardiopulmonary bypass time

There was no statistically significant difference between the two groups in relation to researched cardiovascular surgical risk factors. The values of hematocrit and early hemoglobin (presurgical) are also found in Table 1.

The groups without-CS and with-CS showed, respectively, mean values of 89.52±20.23min and 86.58±24.90min of CPB time and 72.02±20.91min and 67.37±21.21min aortic clamp time. The mean number of grafted blood vessels (distal anastomosis) was 3.00±0.71 in the group without-CS and 2.81±0.85 blood vessels in the group with-CS. There was not also a statistically significant difference between the groups for these variables, confirming the global sample homogeneity.

When we evaluated the use of intraoperative pRBC or not, there was a statistically significant difference between the two groups (*P*=0.00008). In the group without-CS, 21 patients (47.7%) received intraoperative pRBC, whereas in the group with-CS, only four patients (9.3%) received homologous pRBC besides the one processed by Cell Saver. Such results show that the pRBC volume processed by CS significantly decreased the necessity of homologous pRBC use in the group that made use of this system (Table 2).

The pRBC mean volume processed by Cell Saver in the patients that used it was 503.34±148.90ml, ranging from 183ml to 872ml. Considering that the mean pRBC volume which is processed by each unit and recommended by the Brazilian Ministry of Health is 220-280ml, it is possible to infer that CS was able to avoid, on average, the transfusion of approximately two homologous pRBC units in each patient.

When homologous pRBC volumes used in the intraoperative period were evaluated, the patients from the group without-CS showed significantly higher volumes (198.65±258.65ml) than the homologous pRBC ones used in the patients from the group with-CS (35.06±125.67ml) (*P*=0.000117).

The mean values of postoperative hematocrit and hemoglobin of both groups may be seen in Table 3. In relation to the hemoglobin variable, there was positive correlation between the groups of a 5% significance level (*P*=0.016), showing that the patients from the group that used the blood volume processed by CS had superior mean values of hemoglobin compared to the mean values of patients from the group without-CS. The postoperative mean values of hematocrit were also superior in the group with-CS, but not reaching statistical significance (*P*=0.057).

Upon analyzing the postoperative data, there was no statistically significant difference in the absolute use of pRBC in the immediate postoperative period (up to 24h) (*P*=0.739), not even in the pRBC volumes used (*P*=0.642401) between the two groups.

Such results show that Cell Saver is efficient in the reduction of absolute use and in the reduction of pRBC mean volume used in intraoperative coronary artery bypass grafting surgery, when associated with miniCPB.

Table 2. Necessity of intra and postoperative packed red blood cells in both groups

	without-CS n = 44	with-CS n = 43	*P* value
Use of intraoperative pRBC			0.00008
yes	21 (47.7%)	4 (9.3%)	
no	23 (52.3%)	39 (90.7%)	
pRBC volume (ml)	198.65±258.65	35.06±125.67	0.000117
Use of postoperative pRBC			0.739
yes	7 (15.9%)	8 (18.6%)	
no	37 (84.1%)	35 (81.4%)	
pRBC volume (ml)	56.36±139.13	99.76±240.82	0.642

pRBC: pack of red blood cells

Table 3. Postoperative mean values of hematocrit and hemoglobin in both groups

	without-CS n = 44	with-CS n = 43	*P* value
PO Ht (g/dL)	32.37 ± 4.77	34.51 ± 5.55	0.057
PO Hb (g/dL)	10.66 ± 1.62	11.63 ± 2.08	0.016

PO: postoperative; Ht: hematocrit; Hb: hemoglobin

DISCUSSION

The use of hemotransfusions in patients undergoing cardiac surgeries is frequent, due to higher morbidity of this population and the complexity of the procedure itself. It is estimated that 20% of all blood transfusions in the United States are linked to cardiac surgeries [3]. For this reason, there is great interest in developing mechanisms and techniques which are able to reduce this great necessity.

CPB has a considerable impact on the systemic inflammatory response and on the induction of circulatory diseases [9], which may be attenuatted through miniaturization of its circuit (miniCPB). With miniCPB, it was possible to diminish the patient's hemodilution, as well as reducing the blood contact surface with non-endothelial structures, resulting in a lower necessity of hemocomponents transfusion compared to the conventional use of CPB, with significant impact on cardiac surgeries outcome [10].

Autotransfusion through devices which can process intraoperative bleeding and promotes hemoconcentration, with posterior reinfusion to the patient, has been the most used method currently in elective cardiac surgeries [11,12]. The benefits in using this kind of system are considerable, as they diffuse in different steps of the global process of hemotransfusion. Perhaps the best characteristic of this system is the elimination of all steps of processing, storage and later distribution of pRBC in blood banks, since the final pRBC volume is processed and reinfused in the patient inside the surgical environment. Thus, it is possible to avoid a bag switch, contamination in processing, and other potential errors while managing the product. Another benefit is a better proven viability of processed red blood cells due to the absence of the storage process, which causes a decrease in 2.3-DPG levels, besides morphological alterations in the erythrocyte cytoskeleton [13,14]. CS is also safer in terms of transmission of external infectious agents [15], besides significantly diminishing all the other risks and immunological complications or not related to blood transfusion therapy [16].

Since the 1970s, studies have been carried out to evaluate the CS performance related to the necessity of blood transfusion, especially in surgeries with a high risk of bleeding, for instance, cardiac surgeries. The use of CS in cardiac surgeries has already been compared to the use of associated cardiopulmonary bypass or not, showing that, regardless of CPB use, there was a lower necessity of homologous blood transfusion in relation to the group who did not use it [17]. In our study, we chose to include only patients who underwent CABG with miniCPB because of advantages previously discussed.

Another study evaluated the new hemoconcentration technique, which is used in CS, in the necessity of hemocomponents transfusion in patients undergoing coronary artery bypass grafting surgery [18]. This study evaluated two groups of patients, one using the hemoconcentrator and the other not using it, investigating the quantity of blood used during CPB and in the immediate postoperative period. The group that used the hemoconcentrator showed a lower necessity of blood transfusions during CPB, as well as lower mean volumes of used blood in the intraoperative period.

In 2009, an important meta-analysis evaluated the efficiency of CS use in cardiac surgeries, showing that it reduces the necessity of exposure to hemocomponents and pRBC in this population when compared to the non-use of CS, indicating the benefit of applying this system in bleeding throughout the intraoperative period [19].

Another study comparing the use of CS in immediate postoperative outcomes of 288 patients who underwent cardiac surgeries with CPB showed advantages in the use of CS, especially in an increase of postoperative hemoglobin levels and no hospitalization time in ICU [20]. The same study also evaluated the blood volume which was reinfused in each patient by CS, resulting in a mean of 426ml pRBC, a slightly inferior value in relation to the one found in our study (mean of 503.34ml). However, the former study evaluated cardiac surgeries with conventional CPB, not with miniCPB as in our study. The use of miniCPB may have highly contributed to obtain more significant results, showing that it may provide more favorable outcomes.

On the other hand, other authors reported that the use of CS may not have clinical benefits in certain groups of patients. They state that with the proper control of intraoperative hemostasis in patients with low risk of bleeding during cardiac surgeries, the use of CS may not have a reasonable cost-benefit [8], not reducing the use of homologous transfusion [21]. Nevertheless, the technical complexity, which is inherent in cardiac surgeries, associated with a higher morbidity of patients undergoing such procedure per se would be potential indicators of the necessity of pRBC homologous transfusion.

Our study showed an important reduction in the use of pRBC in the intraoperative period of coronary artery bypass grafting surgery with miniCPB associated with CS. With the reinfusion of autologous pRBC processed by the system during the intraoperative period, there was a lower necessity of homologous pRBC in these patients. The mean volume of pRBC processed by CS was 503.34±148.90ml, corresponding approximately to two homologous pRBC units. This pRBC volume, which was reinfused, avoided the use and, consequently, specific risks related to homologous hemotransfusion, which have already been previously discussed. The analysis of such risks was not the objective of the present study, but they are important variables which deserve attention and must be evaluated in further studies. The postoperative values of hemoglobin and hematocrit in the patients who used CS were also higher in relation to the other group. In addition, the population of patients

who received autotransfusion benefited from a pRBC with superior viability in relation to the stored homologous pRBC.

Taking in consideration that it was a cross-sectional study, our research shows a range of methodological limitations, which were, to some extent, minimized throughout its development. However, we were able to show that the use of CS led to an important impact in terms of reducing homologous pRBC use in CABG with miniCPB, possibly being as basis for new investigations related to cost-effectiveness, cost-benefit, mortality, long-term risks and complications by using this system in such surgical procedures.

CONCLUSION

The use of Cell Saver was efficient in reducing the necessity of intraoperative use of homologous packed red blood cells in patients undergoing coronary artery bypass grafting surgery associated with miniCPB. When it was necessary, the homologous pRBC volume used was significantly greater than the group of patients who did not use CS, showing that the autologous pRBC volume processed by CS and reinfused in the patient was also efficient in reducing this necessity.

REFERENCES

1. Lopez AD. Assessing the burden of mortality from cardiovascular diseases. World Health Stat Q. 1993;46(2):91-6.

2. Chor D, Fonseca MJ, de Andrade CR. Cardiovascular diseases. Comments on early mortality in Brazil. Arq Bras Cardiol. 1995;64(1):15-9.

3. Stover EP, Siegel LC, Parks R, Levin J, Body SC, Maddi R, et al. Variability in transfusion practice for coronary artery bypass surgery persists despite national consensus guidelines: a 24-institution study. Institutions of the Multicenter Study of Perioperative Ischemia Research Group. Anesthesiology. 1998;88(2):327-33.

4. Arora RC, Légaré JF, Buth KJ, Sullivan JA, Hirsch GM. Identifying patients at risk of intraoperative and postoperative transfusion in isolated CABG: toward selective conservation strategies. Ann Thorac Surg. 2004;78(5):1547-54.

5. Snyder-Ramos SA, Möhnle P, Weng YS, Böttiger BW, Kulier A, Levin J, et al. The ongoing variability in blood transfusion practices in cardiac surgery. Transfusion. 2008;48(7):1284-99.

6. Engoren MC, Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ. Effect of blood transfusion on long-term survival after cardiac operation. Ann Thorac Surg. 2002;74(4):1180-6.

7. American Society of Anesthesiologists Task Force on Perioperative Blood Transfusion and Adjuvant Therapies. Practice guidelines for perioperative blood transfusion and adjuvant therapies: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Transfusion and Adjuvant Therapies. Anesthesiology. 2006;105(1):198-208.

8. Society of Thoracic Surgeons Blood Conservation Guideline Task Force, Ferraris VA, Ferraris SP, Saha SP, Hessel EA 2nd, Haan CK, Royston BD, et al; Society of Cardiovascular Anesthesiologists Special Task Force on Blood Transfusion. Perioperative blood transfusion and blood conservation in cardiac surgery: the Society of Thoracic Surgeons and The Society of Cardiovascular Anesthesiologists clinical practice guideline. Ann Thorac Surg. 2007;83(5 Suppl):S27-86.

9. Mulholland JW, Anderson JR, Yarham GJ, Tuladhur S, Saed I, Oliver MD. Miniature cardiopulmonary bypass: the Hammersmith experience. Perfusion. 2007;22(3):161-6.

10. Gunaydin S, Sari T, McCusker K, Schonrock U, Zorlutuna Y. Clinical evaluation of minimized extracorporeal circulation in high-risk coronary revascularization: impact on air handling, inflammation, hemodilution and myocardial function. Perfusion. 2009;24(3):153-62.

11. Henry DA, Henderson KM, Fryer JL, Treloar CJ, McGrath KM, Deveridge SF. Use of interventions to minimise perioperative allogeneic blood transfusion in Australia. A survey by the International Study of Perioperative Transfusion (ISPOT) Study Group. Med J Aust. 2000;172(8):365-9.

12. McGill N, O'Shaughnessy D, Pickering R, Herbertson M, Gill R. Mechanical methods of reducing blood transfusion in cardiac surgery: randomized controlled trial. BMJ. 2002;324(7349):1299.

13. Simchon S, Jan KM, Chien S. Influence of reduced red cell deformability on regional blood flow. Am J Physiol. 1987;253(4 Pt 2): H898-903.

14. Surgenor SD, DeFoe GR, Fillinger MP, Likosky DS, Groom RC, Clark C, et al. Intraoperative red blood cell transfusion during coronary artery bypass graft surgery increases the risk of postoperative low-output heart failure. Circulation. 2006;114(1 Suppl):I43-8.

15. Carless PA, Henry DA, Moxey AJ, O'Connell DL, Fergusson DA. Cell salvage for minimising perioperative allogeneic blood transfusion. Cochrane Database Syst Rev. 2003;(4):CD001888.

16. Klein HG, Spahn DR, Carson JL. Red blood cell transfusion in clinical practice. Lancet. 2007;370(9585):415-26.

17. Niranjan G, Asimakopoulos G, Karagounis A, Cockerill G, Thompson M, Chandrasekaran V. Effects of cell saver autologous blood transfusion on blood loss and homologous blood transfusion requirements in patients undergoing cardiac surgery on- versus off-cardiopulmonary bypass: a randomised trial. Eur J Cardiothorac Surg. 2006;30(2):271-7.

18. Souza DD, Braile DM. Avaliação de nova técnica de hemoconcentração e da necessidade de transfusão de hemoderivados em pacientes submetidos à cirurgia cardíaca com circulação extracorpórea. Rev Bras Cir Cardiovasc. 2004;19(3):287-94.

19. Wang G, Bainbridge D, Martin J, Cheng D. The efficacy of an intraoperative cell saver during cardiac surgery: a meta-analysis of randomized trials. Anesth Analg. 2009;109(2):320-30.

20. Marcoux J, Rosin M, McNair E, Smith G, Lim H, Mycyk T. A comparison of intra-operative cell-saving strategies upon immediate post-operative outcomes after CPB-assisted cardiac procedures. Perfusion. 2008;23(3):157-64.

21. Klein AA, Nashef SA, Sharples L, Bottrill F, Dyer M, Armstrong J, et al. A randomized controlled trial of cell salvage in routine cardiac surgery. Anesth Analg. 2008;107(5):1487-95.