The Effect of Retrograde Autologous Priming of the Cardiopulmonary Bypass Circuit on Cerebral Oxygenation

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Objective: **The aim of this study was to investigate the effect of retrograde autologous priming (RAP) of the cardiopulmonary bypass (CPB) circuit on cerebral oxygenation.**

Design: **A retrospective cohort study.**

Setting: **A university hospital.**

Participants: **Ninety-four patients undergoing CPB.**

Interventions: **CPB was primed with a RAP technique in the RAP group (n = 46) or with a conventional technique in the control group (n = 48).**

Measurement and Main Results: **Cerebral oxygenation was monitored by measuring the regional cerebral oxygen saturation (rSO_2). The rSO_2 and Hct values were compared between the groups during surgery. During the CPB period, the RAP group showed significantly higher values for rSO_2 (%) (immediately after the onset of CPB: 51.3 ± 8.4 and 56.3 ± 8.3; 30 minutes after the onset of CPB: 56.3 ± 5.1 and 59.7 ± 7.0; control group and RAP groups, respectively; $p < 0.01$ for each) and Hct (%) (immediately after the onset of CPB: 21.1 ± 3.7 and 23.1 ± 3.3; 30 minutes after the onset of CPB: 21.9 ± 3.7 and 23.3 ± 2.3; control group and RAP group, respectively; $p < 0.02$ for each). However, the 2 groups did not differ in rSO_2 (%) (67.2 ± 6.3 and 67.8 ± 6.4) or Hct (%) (27.8 ± 4.1 and 28.9 ± 3.6, control group and RAP group, respectively) at the end of the surgery.**

Conclusions: **The application of RAP to CPB limits the degree of hemodilution and improves cerebral oxygenation during CPB. The present findings suggest a potential benefit of RAP from a neurologic aspect.**

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KEY WORDS: cardiopulmonary bypass, cerebral oxygenation, retrograde autologous priming, hemodilution, neurologic outcomes

RETROGRADE AUTOLOGOUS PRIMING (RAP) of a cardiopulmonary bypass (CPB) circuit is a technique developed to minimize the hemodilution during CPB.[1] After arterial and venous cannulae are inserted, some of the primed circuit volume is displaced with the patient's own circulating blood volume immediately before the onset of CPB. The RAP of CPB has been reported to reduce the magnitude of hemodilution at the initiation of CPB and, thereafter, allow for a higher hematocrit (Hct) level during CPB.[1,2] The degree of hemodilution has been reported to be an important determinant of cerebral oxygenation during CPB.[3,4] Thus, the authors hypothesized that RAP of the CPB may improve cerebral oxygenation by limiting hemodilution.

To investigate the effect of RAP on cerebral oxygenation, the authors compared the value of regional cerebral oxygen saturation (rSO_2) in patients who underwent cardiac surgery with CPB. The rSO_2 was monitored using near-infrared spectroscopy (NIRS). NIRS measures the ratio of oxyhemoglobin to total hemoglobin in the area beneath the sensor, and it is expressed as a percentage value of rSO_2.[5,6] The monitoring of rSO_2 provides a noninvasive and continuous assessment of cerebral oxygenation during cardiac[3,7-10] and noncardiac surgery,[11-13] and the intraoperative rSO_2 value has been reported to be related to postoperative neurologic outcomes and major organ dysfunction.[9-12,14]

METHODS

With the approval of the authors' institutional review board, the medical records of patients who underwent coronary artery bypass graft (CABG) surgery with CPB from January 2006 to January 2009 were reviewed. The data reviewed were confined to 2 surgeons who share the same protocols for CPB management and surgical procedures. During the study period, the patients who had coronary lesions but did not have any additional problems that corresponded to the exclusion criteria were randomized to either conventional priming or RAP. These patients' data were reviewed retrospectively. The patients who met the exclusion criteria were not included in the data analysis. The exclusion criteria were as follows: (1) patients who required emergency surgery or repeat surgery (ie, patients who required surgical procedures other than CABG surgery); (2) patients >80 years of age with an ejection fraction <40%, a preoperative Hct <28%, a body weight <45 kg or >90 kg, or a preoperative creatinine >1.3 mg%; or (3) patients who had a preoperative neurologic problem including a history of stroke.

Anesthesia was induced with etomidate and alfentanil by an intravenous bolus injection and was maintained with sevoflurane supplemented with a continuous infusion of fentanyl. The bilateral rSO_2 was monitored continuously with NIRS (INVOS 5100, Somanetics, Troy, MI) for every patient according to the center's protocol. Standardized CPB techniques were applied to all patients. The extracorporeal circuit consisted of a centrifugal pump, a heparin-coated membrane oxygenator (Trillium Affinity NT; Medtronics, Minneapolis, MN), an arterial filter (Affinity; Medtronics, Minneapolis, MN), and a hard-shelled reservoir (Affinity CVR, Medtronics). The CPB circuit was primed with 1,000 mL of lactated Ringer solution and either 500 mL of 6% hydroxyethyl starch (Voluven; Fresenius Kabi, Bad Homburg, Germany) or 500 mL of 10% pentastarch (Pentaspan; Jeil, Seoul, Korea). Pump flow was maintained between 2.0 and 2.4 L/min/m^2, and the mean arterial pressure (MAP) was maintained between 55 and 75 mmHg. Patients were not actively cooled during CPB, but rectal temperature was allowed to drift between 32° and 35°C. Before separating the patient from CPB, patients were warmed to a rectal temperature of 37°C. A hemoconcentrator (Hemocor HPH 400; Minntech, Minneapolis, MN) was used to perform ultrafiltration. Conventional ultrafiltration was performed during the CPB period. After weaning from CPB, modified ultrafiltration (MUF) was performed for 5 to 10 minutes depending on the patient's hemodynamic state.

In patients who underwent RAP, a recirculation line was diverted from the arterial outlet of the oxygenator, and this line was attached to

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Supported by the SNUBH research fund (grant no. 022005-030).

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1053-0770/2506-0015$36.00/0
doi:10.1053/j.jvca.2011.02.017

a 1,000-mL blood transfer bag. The RAP protocol was conducted in 3 stages before the initiation of CPB. First, priming solution was displaced from the arterial tubing. Arterial blood was allowed to flow from the aorta to the arterial tubing, displacing the priming solution into a blood transfer bag. Next, venous blood was allowed to flow into venous tubing, and the priming solution was displaced into the blood transfer bag. Finally, the priming solution in the venous reservoir and oxygenator were displaced to the transfer bag. Approximately 400 to 600 mL of priming solution in the CPB circuit was displaced with the patient's own blood during the RAP process; the systolic blood pressure was maintained at a pressure >90 mmHg using small bolus doses of phenylephrine (100-300 μg total) and crystalloid (100-200 mL). Standardized blood conservation methods were used during the surgery. In patients with an initial Hct >35%, autologous blood was collected after the induction of anesthesia, and, simultaneously, the same volume of colloid, either 6% hydroxyethyl starch or 10% pentastarch, was replaced. The blood was then transfused after weaning from CPB. Intraoperative cell salvage was performed for all patients, and the salvaged red cells were reinfused after weaning from CPB. Packed red blood cells (PRBCs) were transfused for an Hct below 20% during CPB. After weaning from CPB, PRBC transfusion was performed for Hct values between 25% and 28% depending on the patient's hemodynamic state.

In all patients, the preoperative and intraoperative bilateral rSO_2 values were obtained from the anesthesia record and were averaged. The preoperative rSO_2 value was measured before the induction of anesthesia when the patient arrived in the operating room (preinduction). The intraoperative rSO_2 values were obtained at the following time points: (1) after the induction of general anesthesia when vital signs were stable (baseline), (2) 5 minutes after the initiation of CPB (CPB-on), (3) 30 minutes after the initiation of CPB (or when a stable body temperature was obtained) (CPB-mid), (4) after the termination of MUF (CPB-off), and (5) at the end of the surgery (end-OP).

The data for the MAP and nasopharyngeal temperatures were also obtained from the anesthesia record at the same time points. The Hct values at time point 1 through 5 were obtained from the anesthesia record, and the postoperative Hct value for day 3 was obtained from a laboratory report sheet. The intraoperative and postoperative use of PRBCs was determined by reviewing the anesthesia record, the CPB record, and the ICU records. The data regarding any postoperative major neurologic complications including seizures, delirium, or strokes were determined by reviewing ICU records and surgeons' medical records.

Data were expressed as the number of patients (percentile), median (interquartile range), or mean (standard deviation). Nominal data were compared between groups using the chi-square test or Fisher exact test. For numeric data, a t test was used for between-group comparisons at each time point. The changes in rSO_2 values during the operation were analyzed using a repeated-measures analysis of variance. The post hoc analysis was performed using paired t tests with a Bonferroni correction. Significance was defined at $p < 0.05$.

RESULTS

Data from 94 patients were analyzed. Forty-six patients underwent RAP (RAP group), and the other 48 patients did not (control group). Table 1 shows patient characteristics and intraoperative data. The groups were similar with respect to their demographic data and operative profiles. The volume of administered fluid and the volume of autologous blood donation were not different between the groups. Although there was a trend for more units of PRBC transfusion for the RAP group, the 2 groups did not show any difference in the number of units of transfused PRBC or the number of the patients who received PRBC transfusion.

Table 1. Patient Characteristics and Intraoperative Data

	Control Group (n = 48)	RAP Group (n = 46)	*p* Value
Age (y)	63.8 ± 6.7	64.6 ± 7.1	0.56
Sex (M/F)	36/12	31/15	0.50
Body weight (kg)	64.8 ± 9.9	64.3 ± 11.5	0.83
CPB time (min)	111.3 ± 32.8	116.7 ± 44.3	0.50
RAP volume (mL)	—	401.5 ± 105.5	—
MUF volume (mL)	696.9 ± 213.7	671.7 ± 228.2	0.58
No. of patients of IAD (%)	33/48 (68.8)	33/46 (71.7)	0.82
IAD volume (mL)	150.3 ± 44.1	147.0 ± 54.4	0.79
Administered crystalloid (mL)			
Before CPB	1185.4 ± 321.6	1202.2 ± 355.6	0.81
After CPB	727.1 ± 463.0	639.1 ± 422.4	0.34
Administered colloid (mL)			
Before CPB	155.2 ± 127.3	149.3 ± 113.4	0.81
After CPB	213.5 ± 159.0	223.5 ± 182.8	0.78
Colloid used (HES/pentastarch)	39/9	39/7	0.79
No. of patients transfused with PRBC	33/48 (68.8 %)	35/46 (76.1%)	0.76
No. of units of transfused PRBC	2.3 ± 1.9	1.7 ± 2.0	0.16
Before CPB	0	0	—
During CPB	1.0 ± 1.2	0.7 ± 0.8	0.10
After CPB	1.3 ± 1.3	1.0 ± 1.5	0.47

NOTE. Data are represented as a mean (standard deviation) or number of patients (%). The 2 groups were similar in their demographic and operative characteristics. No differences were observed in the volume of infused fluid, in the number of patients who received PRBCs, or in the number of units of PRBC transfused. The control group consisted of patients whose CPB circuit was primed with the conventional method, and the RAP group consisted of patients whose CPB circuit was primed with retrograde autologous priming. Abbreviations: M, male; F, female; MUF, modified ultrafiltration; IAD, intraoperative autologous donation; HES, 6% hydroxyethyl starch; pentastarch, 10% pentastarch.

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