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# Retrograde autologous priming RAP reduces deep hemodilution during cardiopulmonary bypass CPB

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**Abstract**

Immediate hemodilution and rapid decrease in osmotic pressure at the time of CBP onset are associated with the aforementioned organic dysfunctions.
Decreased osmotic pressure increases effective filtration pressure and microvascular filtration. Consequently, an increase in pulmonary interstitial fluid and myocardial edema is observed after discontinuation of CBP.
Retrograde autologous priming (RAP) is a means to effectively and safely restrict the hemodilution caused by the direct homologous blood transfusion and reduce the blood transfusion requirements during cardiac surgery.

**Materials and Methods**
The study included 40 patients scheduled to undergo coronary surgical revascularization, divided into two groups: the RAP group and the non-RAP group. The average age in both groups is 55 years (SD 5).

**Conclusion**
A significant benefit was observed between the two groups in the study regarding the amount of transfused blood (1.55 -SD 0.88) / (2.15 -SD 0.81). This is a very important fact in favor of using the RAP technique, taking into account the reduction of the risk for complications carried by heterologous transfusion. Also, a significant reduction in the use of donated blood at a time when the problems of blood insufficiency in the collection centers are known, is equally important.
The hospitalization (days of staying) in the ICU is also significantly lower in the RAP group (2.6 -SD 0.68) / (3.1-SD 0.64). This should be related to the faster activation of RAP in patients as a result of faster return to normal weight (with less fluid load), better ventilator function, and faster decline of cerebral edema.

**Keywords**: Retrograde autologous priming (RAP), hemodilution, cardiopulmonary bypassCPB)

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## 1. Introduction

Retrograde autologous priming (RAP) is a means to effectively and safely restrict the hemodilution caused by the direct homologous blood transfusion and reduce the blood transfusion requirements during cardiac surgery.[1] It is also generally considered a blood conservation method used in most patients during the cardiopulmonary bypass(CPB).[1] The processing of RAP includes three main steps, and the entire procedure of RAP (about 1L CPB prime volume) could be completed within 5 to 8 minutes.[2] This technique is proposed by Panico in 1960 for the first time and restated by Rosengart in 1998 to eliminate or reduce the risk of hemodilution during CPB.[2] More over, to precisely determine the clinical efficacy of RAP, many related studies were conducted. Most results of researches indicate that RAP is available to provide some benefits to reducing the requirements for red blood cell transfusion.[2] However, there are still some studies showing a failure of RAP to limit the hemodilution after the open heart operation.[3] The specific procedure of RAP was firstly described by Rosengart and DeBois to restrict the hemodilution during CPB.[4] When arterial cannulae and venous cannulae are prepared, the crystalloid prime (approximately 1L) is drained into a re-circulation bag.[4] Before the beginning of the CPB, the crystalloid priming fluid is displaced by the autologous blood.[4] There are three key steps for RAP to have a role to play.[4] The first step is that crystalloid is flowing from the arterial line into the transfer bag.[4] And then autologous blood flows through the arterial line and filter after the placement of arterial cannulae.[4] The second step is crystalloid prime in the venous reservoir and oxygenator is replaced by blood through pressure gradients.[3] Lastly, the remaining

crystalloid priming fluid is collected and displaced from the venous line into the CPB bag on the onset of CPB.[5] In each step, about 300ml CPB crystalloid prime volume is replaced by blood into the transfer bag. The entire process could be commonly finished within 5 to 8 minutes.[4]

**2.Materials and Method:**

The aim of the study is to compare the two CBP techniques.The study included 80 patients scheduled to undergo coronary surgical revascularization, divided into two groups: the RAP group (40 patients) and the non-RAP group (40 patients). The average age in both groups is 55 years (SD 5).

Criteria for exclusion from the study were: age> 70, body weight > < ± 30% of ideal weight, ejection fraction <50%, preoperative hemodynamic instability or surgical emergencies for other reasons, concomitant valvular disease, previous conduction disorders, compromised renal function, obvious pulmonary pathology and hematocrit <35%.After determining the preliminary criteria, the patients were randomly assigned to the two study groups.Statistical analysis: The Student test was used, significant changes were accepted for p <0.05 values.

Anesthesia was induced and maintained with midazolam, propofol, fentanyl, and sevoflurane . All patients underwent in moderate hypothermia (32°–34°C) CPB. The perfusion set was Terumo Capiox NX19 Oxygenator with Ultra Prime. Perfusion was maintained at pump flow rates of 2–2.4 l/min/$m^2$ throughout CPB to maintain a mean arterial pressure at 50–80 mm Hg. The pump was primed with crystalloid and arterial blood gases were measured every 15–30 min to maintain arterial carbon dioxide partial pressures of 35–40 mm Hg, unadjusted for temperature , and oxygen partial pressures of 150–250 mm Hg.

**3. Results**

Demographic data and operating parameters were at the same distribution in both groups. The postoperative levels of creatinine and urea together with the amount of diuretics administered were similar in both groups. Renal complications were not observed in any of the patients. None of the patients underwent surgical resection for hemorrhage in the postoperative period.

Hematocrit follow-up was performed at certain predetermined moments of the procedure, as follows:

Hct A1-hematocrit before the start of CBP ,Hct PC-hematocrit before clamping,Hct P1-hematocrit after first cardioplegia,Hct P2-hematocrit after second cardioplegia,Hct P3-hematocrit after third cardioplegia

Hct A2-hematocrit after detachment from CBP. The results obtained are presented in the table (Tab.1)

*Tab.1* The average value of Hct

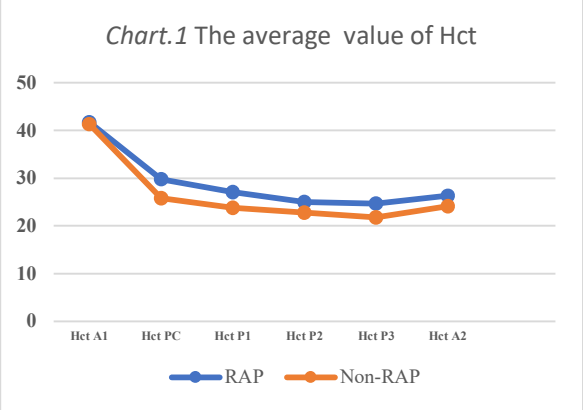
| | RAP | Non-RAP | Value p |
|---|---|---|---|
| Hct $A_1$ | 41,75(SD 2,4) | 41,3 (SD 4,1) | 0,351 NS |
| Hct PC | 29,8 (SD 3,8) | 25,8 (SD 3,4) | 0,002 |
| Hct $P_1$ | 27,1 (SD 3,3) | 23,8 (SD 3,4) | 0,005 |
| Hct $P_2$ | 25 (SD 3,5) | 22,8(SD 3,6) | 0,051 |
| Hct $P_3$ | 24,75 (SD 3,8) | 21,8 (SD 3,3) | 0,010 |
| Hct $A_2$ | 26,35 (SD 3,6 | 24,1 (SD 2,6) | 0,024 |
| Diuresis | 1825 (SD 747) | 1735 (SD 639) | 0,33 NS |

The average value of Hct A1 in both groups does not show significant differences, so the “starting point” is the same.The biggest change of Hct can be seen when the patient enters CBP marked PC. In the upper table can be seen that the Hct change is 4%. Must be noted that the used cardioplegia is sol crystalloid with the dose of 15ml/kg.The RAP technique has the highest efficiency after the third dose of cardioplegia, Hct P3 and can be seen that with the RAP technique, the Hct value is 3 % higher

In all the measured values of hct in the RAP technique are higher than the standard technique by decreasing in a significant way the hemodilution during CBP.

In the chart (chart.1) below it can be see the tendency of decreasing the Hct by comparing the two techniques.

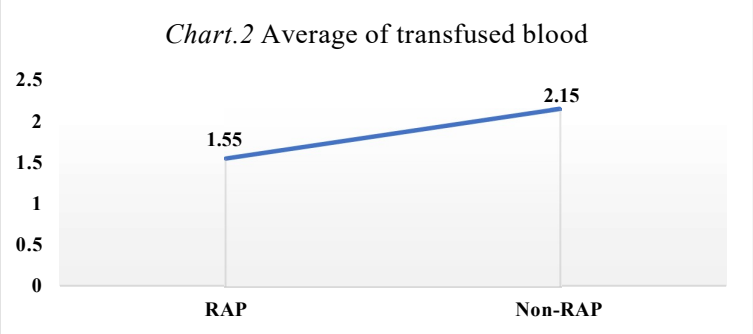



Changes in hematocrit values between the two groups studied throughout the intervention time are significant. The benefits of using RAP technique in maintaining hematocrit and implicating the latter in the postoperative physiology of the organism undergoing the intervention are clear. In the end the result of the technique significantly affects two very important variables taken into consideration; the amount of transfused blood and the days in ICU.

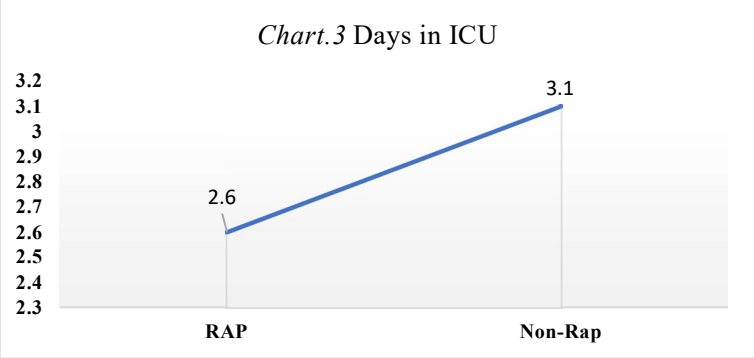
*Tab.2* Transfused blood and days in ICU

| | RAP | Non-RAP | Value p |
|---|---|---|---|
| Transfused blood | 1,55 (SD 0,88) | 2,15 (SD 0,81) | 0,007 |
| Days in ICU | 2,6 (SD 0,68) | 3,1(SD 0,64) | 0,004 |

At the group where the technique RAP was applied the blood transfusion was lower in comparison with the group where the RAP technique was not applied. The patients of the RAP group did a better postoperative rehabilitation and the days on the ICU were less.






With the use of the hematic cardioplegia, its value has decreased, but in clinics that use crystalloid cardioplegia this technique is very valuable, especially in the elders.

## 4. Discussion

Hemodilution is an important component of CPB practice which has allowed safe and effective tissue perfusion without the need for blood products. The quest to determine the optimal level of hemodilution for patients has been difficult owing to the large variability in the tolerance of both patients and specific tissues to hemodilution. Although many factors determine the tolerance to hemodilution, microvascular function is probably the defining determinant. Microvascular function determines the amount of blood flow, and thus oxygen delivery to, and waste removal from a given tissue.

Experimental models of hemodilution have demonstrated that several factors, working in concert, are required to sustain adequate levels of microvascular blood flow. These factors include capillary perfusion pressure, RBC properties and viscosity. Maintaining plasma viscosity at or near normal levels may offer one approach to extending the level of hemodilution and/ or to improving microvascular blood flow to tissues vulnerable to ischemic or hypoxic injury. Further clinical research is required to determine the optimal level of hemodilution for individual patients. Although the optimal level of hemodilution has not been defined, reducing the levels of hemodilution may be an effective strategy to attenuate the pathophysiology associated with CPB.

Karkouti et all[6] ,studying 10,949 patients undergoing cardiac surgery with CPB, reported a 10% increase in the odds of experiencing a perioperative stroke with each percent decrease in hematocrit. When acute renal failure was examined, these same investigators reported a 23% increase in the odds of developing acute postoperative renal failure for those with a CPB nadir hematocrit less than 21%[7]. Interestingly, the odds of developing renal failure was also increased in those with a hematocrit greater than 25%, suggesting that an “optimal” hematocrit to manage this outcome might be somewhere between 21% and 25%.

The lowest hematocrit on CPB has also been associated with greater in-hospital mortality and reduced survival up to 6 yr after surgery[8].A single prospective randomized trial in infants confirms the deleterious effects of extreme hemodilution. In that study, 147 infants were randomized to a hematocrit of 20% or 30% at the onset of low-flow CPB using a pH-stat strategy[9]. The lower hematocrit group had lower nadirs of cardiac index, higher serum lactate levels 60 min after CPB, and at age 1 yr, worse scores on a psychomotor development index. In contrast, a single retrospective study found no correlation between cognitive performance and hematocrit levels preoperatively, 30 min after CPB, 10 min after the end of CPB, or on the first postoperative day[10]. However, only 1 of 111 patients in that study had a hematocrit on CPB less than 20%.

## 5. Conclusions

The data obtained from the study shows that the use of RAP technique reduces the amount of fluids used during CBP and consequently reduces the decrease in osmotic plasma pressure throughout the CBP period. Deep hemodilution, as explained in theory , leads to the accumulation of fluids in the body caused by an imbalance between microvascular filtration and lymphatic drainage. Minimization of changes in the physiology of the organism as a result of CBP is expected to affect the early postoperative course of the operated patient. A significant benefit was observed between the two groups in the study regarding the amount of transfused blood (1.55 -SD 0.88) / (2.15 -SD 0.81). This is a very important fact in favor of using the RAP technique, taking into account the reduction of the risk for complications carried by heterologous transfusion. Also, a significant reduction in the use of donated blood at a time when the problems of blood insufficiency in the collection centers are known, is equally important.

The hospitalization (days of staying) in the ICU is also significantly lower in the RAP group (2.6 -SD 0.68) / (3.1-SD 0.64). This should be related to the faster activation of RAP in patients as a result of faster return to normal weight (with less fluid load), better ventilator function, and faster decline of cerebral edema.
Continuation of the study by expanding the group of patients both quantitatively and the inclusion in the study of patients with other preoperative characteristics, emerges as an obligation to confirm the benefit of RAP technique in cardiac surgery patients. Based on the results obtained, it is logical to propose the routine use of this technique towards its perfection, in order to reduce the level of hemodilution and in parallelly its known side effects.

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