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# PROSPECTIVE COMPARATIVE STUDY: USE OF PLASMALYTE (CRYSTALLOID) VS VOLULYTE (COLLOID) AS PRIMING SOLUTIONS ON CARDIAC BYPASS DURING CARDIAC SURGERY

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## ABSTRACT

**Background:** Cardiopulmonary bypass (CPB) is widely used to maintain systemic perfusion and oxygenation during cardiac surgery. The CPB circuit must be primed with fluid to achieve adequate flow rates without risk of air embolism. This study aimed to compare the effects of two different priming solutions – Plasmalyte (crystalloid) and Volulyte (colloid) – on acid-base balance, electrolytes, and hemodynamic parameters during cardiac surgery. **Methods:** This prospective, comparative observational study included 50 patients (25 per group) undergoing elective cardiac surgery with CPB. The primary outcome was pH measurement across different time points, while secondary outcomes included electrolyte changes and hemodynamic responses. Arterial blood gas analysis and hemodynamic parameters were recorded at multiple perioperative time points: pre-induction, post-induction, pre-bypass, during bypass (every 30 minutes), post-bypass, and after ICU transfer. **Results:** Demographics were comparable between groups. Plasmalyte showed better pH maintenance during bypass compared to Volulyte ($p<0.05$). No significant differences were observed in electrolyte levels between groups. Hemodynamic parameters, including heart rate, blood pressure, and blood glucose levels, remained comparable between groups without statistical significance. **Conclusion:** Plasmalyte is superior to Volulyte in maintaining physiological pH during cardiopulmonary bypass in patients undergoing cardiac surgery. Both solutions show comparable effects on electrolytes and hemodynamic parameters without significant differences. Plasmalyte may be preferred as a priming solution for cardiac bypass due to its better acid-base balance maintenance.

**KEYWORDS :** Cardiopulmonary bypass, Priming solution, Plasmalyte, Volulyte, pH, Acid-base balance, Cardiac surgery

## INTRODUCTION

The role of Cardiopulmonary bypass during cardiac surgery is well known. Most of the cardiac surgeries are done under cardiopulmonary bypass (CPB). Cardiopulmonary bypass is widely used to maintain systemic perfusion and oxygenation during open-heart surgery [1]. The CPB circuit must be primed with a fluid solution so that adequate flow rates can be rapidly achieved on initiation of CPB without risk of air embolism to the patient. Metabolic acidosis is frequently encountered in CPB. Acidosis can cause arrhythmias and decreased responsiveness to catecholamines, both leading to hypotension which affects cardiac contractility. Similarly, fall in pH in the intracellular fluid also reduces the contractility of the heart muscle [2,3].

Intravenous fluids and vasoactive infusions are commonly used in the early peri-operative period in the ICU to improve cardiac output, blood pressure, and organ perfusion. Compared to colloids, crystalloids are often the preferred solution for replacement or maintenance fluid therapy as they are relatively cheap, very commonly available, easy to transport, have a good shelf life, and minimal risk of allergy. Crystalloids are easy to manufacture, require no special compatibility testing, and are widely available even in developing countries [4]. Rapid crystalloid infusion has been shown to cause a large increase in plasma hyaluronic acid, presumably cleaving this polysaccharide from the endothelial glycocalyx. Increased right atrial pressure which results from large volume resuscitation and during right atrial cannulation during cardiac surgery increases the release of natriuretic peptide [5]. Owing to capillary leak, less than 5% of infused crystalloid remains in the intravascular space within 3 hours after infusion [6]. This results in increased tissue edema and compounds pre-existing myocardial dysfunction [7].

Cardiac surgeries such as coronary artery bypass graft, valve replacements, and aortic surgery are major procedures performed under general anesthesia. To maintain hemodynamic stability and adequate perfusion, patients often require treatment with fluids and vasopressors. Often, patients receive large amounts of fluids including crystalloids, colloids, and blood products intra-operatively as well as postoperatively. Many pathophysiological changes occur during CPB surgery [8]. When selecting a solution for priming the cardiopulmonary bypass circuit, three major factors should be considered: osmolality (iso-osmotic or slightly hypertonic to minimize tissue edema), electrolyte balance (normal electrolyte balance to prevent post-CPB abnormalities), and dilution (avoid <21% Hct). Volulyte contains 6% Hydroxyethyl starch (HES) 130/0.4 in a balanced electrolyte solution, with the carrier solution physiologically more similar to plasma than saline, while Plasmalyte is a balanced crystalloid solution that closely mimics human plasma in its content of electrolytes, osmolality, and pH [9]. This study aims to understand various physiological changes that occur when two different priming solutions are used.

## MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Anesthesiology at DY Patil University School of Medicine & Hospital, Nerul, Navi Mumbai over a period of 2 years. After obtaining ethical committee approval and informed written consent, 50 patients undergoing elective cardiac surgery with cardiopulmonary bypass (CPB) were included and allocated into two groups containing 25 patients each using the sealed envelope technique: Group P (Plasmalyte) and Group V (Volulyte).

Inclusion criteria were patients > 22 years and < 80 years of age giving consent for surgery, while exclusion criteria included lactating & pregnant women and critically ill patients (ASA-4 and emergency cases). All standard

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demographic data, history, previous diagnoses, comorbidities, and routine biochemistry investigations were documented. Pre-operative assessments including airway examination and investigations like complete blood count, glucose, BUN, creatinine, electrolytes, kidney function tests, liver function tests, X-ray chest, ECG, and other relevant tests were performed.

All patients received standard monitoring, and hemodynamic parameters (heart rate, blood pressure, oxygen saturation, $EtCO_2$, urine output, CVP), along with blood sugars and electrolytes were recorded at multiple time points: pre-induction, post-induction, pre-bypass, during pump (at 30-minute intervals), post-bypass, and after shifting to ICU. Arterial blood gas analysis including pH, $PO_2$, $PCO_2$, $HCO_3$, base deficit, electrolytes, and lactate was performed at the same time points using an ABL 800 Blood Gas Analyzer.

General anesthesia was standardized for all patients using propofol (0.5-1 mg/kg), fentanyl (5-10  g/kg), and a non-depolarizing muscle relaxant for induction, with sevoflurane in equal mixtures of air and oxygen for maintenance. Anticoagulation was achieved with heparin 300 units/kg before CPB establishment, maintaining activated clotting time above 480 seconds. For Group P, the CPB circuit was primed with Plasmalyte, and for Group V with Volulyte, with approximately 1500-1700 mL of fluid used for an average adult patient weighing about 60 kg. The cardioplegia solution was prepared using 500 mL of the respective priming solution.

CPB was performed using a membrane oxygenator with non-pulsatile flow (2.2-2.4 L/min/m²) under alpha-stat management. Moderate hypothermia (33-34°C) and cold cardioplegia were used in all cases. After CPB termination, heparin was neutralized with protamine. All patients were transferred to the ICU postoperatively and monitored for up to 30 days for signs of complications.

Data analysis was performed using MedCalc Statistical Software version 19.0.6. The mean values between the two groups were compared using a two-sample mean test. Two-way ANOVA was used for comparison of mean values at different time periods. All testing was conducted using two-sided tests with alpha 0.05.

## RESULTS AND OBSERVATIONS

**Methodology For Laboratory Analysis:** Blood samples were obtained at predefined time points (pre-induction, post-induction, pre-bypass, on pump at 30-minute intervals, post-bypass, and after ICU transfer) for all patients. Arterial blood gas analysis was performed using an ABL 800 Blood Gas Analyzer. pH, arterial oxygen and carbon dioxide tensions, bicarbonate levels, base excess/deficit, electrolytes ($Na^+$, $K^+$, $Cl^-$), and lactate were measured. Simultaneously, hemodynamic parameters including heart rate, blood pressure, and blood glucose levels were recorded at the same time points.

**Table 1: Demographic Characteristics Of Patients**

| Characteristic | Group P (n=25) | Group V (n=25) | P Value |
|---|---|---|---|
| Age (years) | 60.32 ± 11.81 | 58.9 ± 11 | 0.6620 |
| Gender n (%) | | | |
| Male | 21 (84%) | 18 (72%) | 0.3697 |
| Female | 4 (16%) | 7 (28%) | 0.6657 |
| BMI (kg/m²) | 24.88 ± 3.38 | 25.34 ± 3.56 | 0.6415 |
| Heart Rate (bpm) | | | |
| 60-80 | 17 (68%) | 16 (64%) | 0.8618 |
| Mean Blood Pressure (mmHg) | | | |
| SBP | 117 ± 17.8 | 118 ± 16.68 | 0.8385 |
| DBP | 72.4 ± 11.89 | 73.6 ± 12.05 | 0.7252 |

Table 1 shows the demographic characteristics of the study population. The mean age was 60.32 ± 11.81 years in Group P and 58.9 ± 11 years in Group V (p=0.6620). Males predominated in both groups (84% in Group P and 72% in Group V). The mean BMI was comparable between both groups (24.88 ± 3.38 kg/m² in Group P and 25.34 ± 3.56 kg/m² in Group V; p=0.6415). Baseline vital parameters including heart rate and blood pressure were also similar between groups with no statistically significant differences.

**Table 2: Baseline Laboratory Parameters**

| Parameter | Group P | Group V | P Value |
|---|---|---|---|
| Serum Electrolytes | | | |
| $Na^+$ (mEq/L) | 133 ± 3.54 | 133 ± 2.5 | 1.0000 |
| $K^+$ (mEq/L) | 3.76 ± 0.48 | 3.8 ± 0.5 | 0.7742 |
| $Cl^-$ (mEq/L) | 104 ± 4.62 | 104 ± 4.7 | 1.0000 |
| Liver Function Tests | | | |
| Total Bilirubin (mg/dL) | 1.18 ± 0.2 | 1.14 ± 0.19 | 0.4720 |
| SGOT (U/L) | 34.1 ± 7.22 | 33 ± 6.5 | 0.5739 |
| SGPT (U/L) | 34.97 ± 8.18 | 35 ± 8.2 | 0.9657 |
| ALP (U/L) | 65.4 ± 18.5 | 66.23 ± 18.52 | 0.8493 |

Table 2 shows baseline laboratory parameters in both groups. Serum electrolytes ($Na^+$, $K^+$, $Cl^-$) were comparable between both groups. The mean sodium and chloride levels were identical in both groups ($Na^+$: 133 mEq/L; $Cl^-$: 104 mEq/L), while potassium levels showed minimal difference (3.76 mEq/L in Group P vs 3.8 mEq/L in Group V; p=0.7742). Liver function tests were also similar with no significant differences between groups.

**Table 3: Hemodynamic Parameters During Different Time Periods**

| Parameter | Group P | Group V | P Value |
|---|---|---|---|
| Heart Rate (bpm) | | | |
| Pre-Induction | 79.32 ± 13.26 | 81.55 ± 13.02 | 0.5531 |
| Post Induction | 82.64 ± 12.45 | 82.09 ± 12.45 | 0.8765 |
| Pre-Bypass | 81.16 ± 11.67 | 80.73 ± 11.67 | 0.8945 |
| On Pump to Post Bypass | 90.36 ± 14.78 | 90.68 ± 15.04 | 0.9398 |
| After Shifting to ICU | 82.92 ± 14.20 | 82.27 ± 14.29 | 0.8725 |
| Systolic Blood Pressure (mmHg) | | | |
| Pre-Induction | 123.44 ± 17.86 | 121.95 ± 18.02 | 0.7703 |
| Post Induction | 125.64 ± 8.10 | 125.9 ± 8.102 | 0.9101 |
| On pump - First 30 minutes | 86.84 ± 11.71 | 86.09 ± 9.73 | 0.8065 |
| Post Bypass | 122.2 ± 16.19 | 121.9 ± 16.19 | 0.9480 |
| Blood Sugar (mg/dL) | | | |
| Pre-Induction | 135.52 ± 32.27 | 133.14 ± 32.28 | 0.7855 |
| Post Induction | 171.52 ± 40.28 | 168.22 ± 40.92 | 0.7654 |
| Pre-Bypass | 215.32 ± 38.29 | 212.41 ± 41.87 | 0.7900 |
| Post Bypass | 159 ± 26.50 | 154.59 ± 26.5 | 0.5415 |

Table 3 shows hemodynamic parameters across different time periods. Heart rate in both groups followed a similar pattern throughout the procedure, with a slight increase during bypass and returning to baseline after ICU transfer. No significant differences were observed between groups at any time point. Systolic blood pressure showed an expected decrease during bypass in both groups but returned to pre-induction levels after bypass, with no significant between-group differences. Blood glucose levels increased during the procedure in both groups, with peak values observed pre-bypass, followed by a gradual decline. The pattern was similar in both groups without statistical significance.

**Table 4: Arterial Blood Gas Analysis During Different Time Periods**

| Parameter | Group P | Group V | P Value |
|---|---|---|---|
| pH | | | |
| Pre-Induction | 7.40 ± 0.04 | 7.39 ± 0.06 | 0.4914 |

| | | | |
|---|---|---|---|
| Post Induction | 7.41 ± 0.05 | 7.41 ± 0.06 | 0.4871 |
| Pre-Bypass | 7.42 ± 0.04 | 7.42 ± 0.04 | 0.0835 |
| On Pump - First 30 minutes | 7.44 ± 0.05 | 7.43 ± 0.05 | 0.0608 |
| On pump - Next 30 minutes | 7.41 ± 0.04 | 7.40 ± 0.04 | 0.0100* |
| Post bypass | 7.44 ± 0.04 | 7.45 ± 0.05 | 0.0430* |
| After Shifting to ICU | 7.44 ± 0.039 | 7.43 ± 0.06 | 0.0835 |
| Electrolytes | | | |
| $Na^+$ (mEq/L) | | | |
| Pre-Induction | 132.24 ± 3.39 | 131.54 ± 3.39 | 0.4689 |
| On Pump - Next 30 minutes | 132.87 ± 4.29 | 132.64 ± 3.91 | 0.8505 |
| After Shifting to ICU | 130.84 ± 2.5 | 130.7 ± 2.56 | 0.8457 |
| $K^+$ (mEq/L) | | | |
| Pre-Induction | 4.07 ± 0.43 | 4.05 ± 0.43 | 0.8816 |
| On Pump - Next 30 minutes | 3.27 ± 0.40 | 3.28 ± 0.40 | 0.9299 |
| After Shifting to ICU | 4.03 ± 0.297 | 3.99 ± 0.30 | 0.6378 |
| $Cl^-$ (mEq/L) | | | |
| Pre-Induction | 104.92 ± 3.752 | 104.73 ± 3.75 | 0.8512 |
| On Pump - Next 30 minutes | 103.88 ± 3.49 | 103.91 ± 3.49 | 0.9759 |
| After Shifting to ICU | 106.12 ± 4.146 | 106.31 ± 4.15 | 0.9178 |

*Statistically significant

Table 4 presents the arterial blood gas analysis across different time points. pH values were comparable between groups at most time points but showed significant differences during the second 30-minute period on pump (7.41 ± 0.04 in Group P vs 7.40 ± 0.04 in Group V; p=0.0100) and post-bypass (7.44 ± 0.04 in Group P vs 7.45 ± 0.05 in Group V; p=0.0430). This indicates better pH maintenance in the Plasmalyte group during these critical periods. Electrolyte levels ($Na^+$, $K^+$, $Cl^-$) remained relatively stable throughout the procedure in both groups, with no significant differences observed at any time point.

## DISCUSSION

The current study examined the effects of two different priming solutions – Plasmalyte (crystalloid) and Volulyte (colloid) – on acid-base balance, electrolytes, and hemodynamic parameters during cardiopulmonary bypass (CPB) in patients undergoing cardiac surgery. Demographic data showed no significant differences between groups in age, gender, BMI, or baseline hemodynamic parameters, ensuring that both groups were comparable at baseline. The mean age of the patients in Group P was 60.32 ± 11.81 years and in Group V was 58.9 ± 11 years, with a male predominance in both groups, similar to findings by Greener et al. (2021) [10] who reported 70.1% male patients with a mean age of 63.4 ± 22.1 years in their cardiac surgery cohort. Most patients had normal BMI range (18.5-24.9 kg/m²) in both groups, consistent with observations by Weinberg et al. (2017) [11] and Base et al. (2011) [12]. The baseline laboratory parameters including serum electrolytes and liver function tests were also comparable between groups, indicating proper randomization.

The primary finding of our study was the significant difference in pH values between the two groups at specific time points during and after CPB. Plasmalyte demonstrated superior pH maintenance during the procedure, particularly during the second 30-minute period on pump (p=0.0100) and post-bypass (p=0.0430). This aligns with findings by Vashisth et al. (2022) [13] who reported that Plasmalyte-A maintained satisfactory metabolic parameters with less metabolic acidosis during cardiac surgeries compared to Ringer lactate. Similarly, Surabhi and Kumar (2021) [14] concluded that Plasmalyte-A is the preferred cardiopulmonary bypass prime in adult patients undergoing valve replacement surgeries due to less metabolic acidosis development. The pH maintenance in Plasmalyte group can be attributed to its balanced composition that closely resembles plasma and the presence of metabolizable anions (acetate and gluconate) that convert to bicarbonate, providing buffer capacity. In contrast, Volulyte, despite having a balanced carrier solution, didn't show equivalent buffering capacity in our study population. Hemodynamic parameters including heart rate, blood pressure, and blood glucose levels showed expected physiological changes during the procedure but without significant differences between groups. Heart rate increased during bypass in both groups, while blood pressure decreased during bypass and returned to baseline afterward. Blood glucose levels peaked pre-bypass and gradually decreased in both groups, consistent with the stress response to surgery and CPB as noted by Maurya et al. (2018) [15].

Electrolyte changes were minimal in both groups, with sodium, potassium, and chloride levels remaining within physiological ranges throughout the procedure. This differs slightly from observations by Morgan et al. (2008) [16] who noted hyperchloremia with bicarbonate-balanced solutions compared to Plasmalyte. In our study, both solutions maintained stable electrolyte profiles, possibly due to their balanced compositions. Neither solution caused significant electrolyte disturbances, suggesting both are safe choices from an electrolyte perspective. The absence of significant differences in hemodynamic parameters and electrolyte levels between groups, despite the pH differences, suggests that Plasmalyte's advantage lies primarily in acid-base balance management rather than in hemodynamic stability or electrolyte control. This makes Plasmalyte potentially preferable in situations where acid-base balance is critical, such as in patients with pre-existing acidosis or those at risk for prolonged CPB. Our findings contribute to the growing body of evidence supporting the use of balanced crystalloid solutions like Plasmalyte in cardiac surgery, particularly for CPB prime, due to their favorable effects on acid-base balance while maintaining hemodynamic stability and electrolyte homeostasis.

## CONCLUSION

Based on the observations and results obtained in this study comparing Plasmalyte (crystalloid) and Volulyte (colloid) as priming solutions during cardiopulmonary bypass in cardiac surgery, the following conclusions can be drawn:

1. Plasmalyte is superior to Volulyte in terms of maintaining physiological pH during cardiopulmonary bypass. The difference is statistically significant during critical periods of bypass and post-bypass, making Plasmalyte the preferred choice for maintaining acid-base balance.
2. Changes in electrolytes (sodium, potassium, chloride) are comparable in both groups with no statistically significant differences, indicating that both solutions provide adequate electrolyte stability during cardiac bypass.
3. Hemodynamic parameters and stress response (as measured by blood glucose levels) are similar between both groups, suggesting that the choice between these priming solutions does not significantly impact hemodynamic stability during cardiac surgery.

In summary, Plasmalyte may be considered the preferred priming solution for cardiopulmonary bypass during cardiac surgery due to its superior ability to maintain physiological pH while providing comparable electrolyte stability and hemodynamic response to Volulyte.

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