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Original article

Comparison between Crystalloid versus Colloid in ICU Patients After Open-Heart Surgery

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Abstract:

Background: Postoperative hemodynamic instability may lead to cardiovascular morbidity and requires prompt recognition and correction. Possible causes include blood loss, fluid deficit, or sepsis. This study aimed to assess the effect of using colloids versus crystalloids in postoperative cardiac patients requiring fluid volume replacement on mortality, need for blood transfusion or renal replacement therapy, and adverse events. **Methods:** This randomized, controlled clinical study enrolled 100 patients of cardiac ICU patients who underwent open-heart surgery. Patients were divided into two equal groups: Colloid group: cardiac ICU patients subjected to hypooncotic (e.g., starches, and 20 or 25% of albumin) solutions and crystalloids group: cardiac ICU patients subjected to isotonic or hypertonic saline and any buffered solutions. **Results:** SOFA (sequential organ failure assessment) scores ($p<0.001$) compared to the colloid group. Overall mortality rate was significantly higher in the crystalloid group (22%) compared to the colloid group (14%) ($p=0.265$). a higher percentage of patients in the crystalloid group had long mechanical statistically significant ($p=0.030$). **Conclusion:** The use of colloids for fluid volume replacement in postoperative cardiac patients in the ICU after open-heart surgery showed favorable outcomes compared to crystalloids. The colloid group had lower rates of complications, mortality, and requirements for catecholamines and mechanical ventilation. These findings suggest that colloids may be a more effective choice for fluid resuscitation in this patient population.

Keywords: Crystalloid; Colloid; ICU Patients; Open-heart Surgery.

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Introduction

Postoperative hemodynamic instability may lead to cardiovascular morbidity and requires prompt recognition and correction. Possible causes include blood loss, fluid deficit, or sepsis [1]. Fluid therapy is therefore a key component of the postoperative management of surgical patients [2].

Crystalloids, such as saline and Ringer's lactate, are solutions of salt, water and minerals, and are commonly used in the clinical setting. They have small molecules, and when used intravenously, they are effective as volume expanders. [3] They may have an isotonic or hypertonic composition, which could affect the distribution of fluid in the body; for example, because hypertonic crystalloids lower plasma osmolality they cause water movement from the intravascular to the extravascular space, and a lower volume may be required for fluid resuscitation. They are cheap and easy to use, with few side effects. However, because they move more easily into the extravascular space, their use may increase oedema. [4]

The composition of the crystalloid may not affect clinical outcomes; recent reviews have examined the possible effect of hypertonic solutions, and compared buffered with non-buffered fluids, but have not found important clinical differences. [5]

Broadly, 2 types of colloids are used in the postoperative period for cardiac surgical patients: albumin (human-derived) and hydroxyethyl starch (HES) solutions (synthetic). Crystalloid vehicles in which colloids are suspended may be isotonic 0.9%saline solution or buffered (lactated/acetated) electrolyte solutions. [6]

All colloids have a larger molecular weight than crystalloids and do not cross the endothelium into the interstitial fluid easily. This means that they stay in the intervascular space for longer than crystalloids, provide the benefit of rapid plasma expansion, and can correct colloidal osmotic pressure. Hemodynamic goals are reached by administrating smaller volumes of colloids than crystalloids. Colloids are a more expensive fluid replacement option, and they may have adverse effects such as allergic reactions,blood clotting disorders, and kidney failure [3].

The U.S. Food and Drug Administration also issued a warning about the increased risk of renal failure or death, as well as a risk of bleeding after cardiopulmonary bypass associated with starches. However, because these data do not derive exclusively from cardiac ICU patients, extrapolation of these findings to the perioperative period is questionable. Indeed, crystalloids are not devoid of side effects such as hyperchloremic metabolic acidosis, reduced renal blood flow, or impaired renal cortical perfusion [7]

Previous studies had shown that using starches, dextrans, albumin or FFP (moderate-certainty evidence), or gelatines (low-certainty evidence), versus crystalloids probably makes little or no difference to mortality. Starches probably slightly increase the need for blood transfusion and RRT (moderate-certainty evidence), and albumin or FFP may make little or no difference to the need for renal replacement therapy (low-certainty evidence) [8]

Therefore, the purpose of this study is to assess the effect of using colloids versus crystalloids in postoperative cardiac patients requiring fluid volume replacement on mortality, need for blood transfusion or renal replacement therapy, and other adverse events.

Patients and Methods:

This randomized, controlled clinical study enrolled 100 patients of cardiac ICU patients who underwent open-heart surgery. The study was approved by the Local Ethics Committee on Research involving human subjects of (Benha) Faculty of Medicine and Nasser Institute for research and treatment from January 2022 to December 2022, study was conducted at the Benha University Hospital, written informed consent was taken from all participants.

Approval code: Ms.2-12-2020.

The patients were divided into two equal groups: **Colloid group**: cardiac ICU patients subjected to hypooncotic (e.g., gelatines, and 4 or 5% of albumin) and hyperoncotic (e.g., dextrans, hydroxyethyl starches, and 20 or 25% of albumin) solutions and **crystalloids group**: cardiac ICU patients subjected to isotonic or hypertonic saline and any buffered solutions.

Investigators were blinded about patients' allocation.

Inclusion criteria were

(postpostoperative)adult cardiac ICU patients who had not previously received any fluid, both sexes and cases who required fluid resuscitation for acute hypovolemia.

Exclusion criteria were known severe congestive heart failure (EF ≤35%), chronic renal, liver or pancreatic disease; TB, COPD, asthma, coagulopathy or bleeding tendency and allergy to any fluid used.

Within each treatment group, investigators could use whichever fluids are available at their institution. The amount of fluid and duration of treatment were left at the discretion of the investigators with the following restrictions: (1) the daily total dose of hydroxyethyl starch could not exceed 30 ml/kg of body weight and (2) investigators were required to follow any local regulatory agency recommendations governing use.

Patients had to be managed according to their randomization arm except for (1) maintenance fluids, which was isotonic crystalloids, regardless of treatment group, and (2) in instances in which physicians wished to administer albumin in response to demonstrated hypoalbuminemia (serum albumin concentration less than 20 g/dl).

In addition, because the intervention would be continued until intensive care unit discharge and could thus be highly variable, there was no practical way to stock sites with adequate supplies of masked fluid solutions. However, the mortality endpoints were collected and assessed by study members blinded to treatment assignment.

Methods:

All patients were subjected to the following: History Taking and demographic data collection, general examination, clinical examination ((MAP), central venous pressure (CVP), Sequential Organ Failure Assessment (SOFA) score, urine output (UOP),Arterial lactate), complication assessment (acute kidney injury, arrhythmia, AF, thrombocytopenia, infection, ischemic bowel, and respiratory failure), catecholamine use assessment, evaluation of mechanical ventilation use, and mortality evaluation.

Patients were followed up for 30 days

Primary Outcome were maintenance of hemodynamic stability according to an age specific, predetermined, minimal mean arterial blood pressure and number of patients with at least one postoperative complication. Secondary outcome measures were mortality at longest available follow-up (within 30),

postoperative lactate clearance, postoperative inotropic requirements, transfusion of blood products, establishment of adequate urine output, monitoring of cost difference as determined by total number of boluses, number of ventilator hours, incidence of AKI and adverse events.

Statistical analysis:

Data management and statistical analysis were done using SPSS Version 25.0.(Armonk, NY: IBM Corp.). Quantitative data were assessed for normality using the Shapiro-Wilk test and direct data visualization methods. According to normality, quantitative data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages. Quantitative data were compared between the studied groups using the independent t-test or Mann-Whitney U test for normally and non-normally distributed quantitative variables,
respectively. Categorical data were compared using the Chi-square or Fisher's exact significant.

Results:

This study was conducted on 100 patients of cardiac ICU patients who underwent open-heart surgery. The patients were divided into two equal groups: Colloid group: cardiac ICU patients subjected to hypooncotic (e.g., gelatines, and 4 or 5% of albumin) and hyperoncotic (e.g., dextrans, hydroxyethyl starches, and 20 or 25% of albumin) solutions and crystalloids group: cardiac ICU patients subjected to isotonic or hypertonic saline and any buffered solutions.

Demographic data showed no statistically significant difference between the studied groups. There was no significant difference between the two groups according to distribution of cardiac operation type. Table 1

There were no significant differences in MAP, CVP, SOFA score, urine output, arterial lactate levels or creatinine between the two groups on day 1 after the cardiac operations. However, on day 5, the crystalloid group had significantly lower CVP levels ($p<0.001$) and significantly higher SOFA scores ($p<0.001$) compared to the colloid group. The colloid group also had a significantly lower arterial lactate level ($p=0.041$) on day 5compared to the crystalloid group. Table 2, Figure 1 and Figure 2

There were no significant differences between the two groups in terms of urine output or MAP on day 5. According to complications in the studied groups, a significantly higher percentage of patients in the crystalloid group experienced complications compared to the colloid group (52% vs 30%, $p=0.040$). Complications included: acute kidney injury, AF, thrombocytopenia, infection, ischemic bowel and respiratory failure were not significantly different in distribution between the two groups. Table 2

According to mortality, overall mortality rate was significantly higher in the crystalloid group (22%) compared to the colloid group (14%) ($p=0.265$). According to catecholamine use, a higher percentage of patients in the crystalloid group received catecholamines compared to the colloid group (28% vs 16%), but this difference was not statistically significant ($p=0.148$). However, the amount of catecholamines used was significantly higher in the crystalloid group compared to the colloid group ($p<0.001$). According to mechanical ventilation a higher percentage of patients in the crystalloid group received mechanical ventilation compared to the

colloid group (34%vs 18%), and this difference was statistically significant (p=0.030).However, there was no significant difference between the two groups in the mean number of ventilation days (14.6 days in the colloid group vs 15.9days in the crystalloid group, p=0.331).Postoperative mechanical ventilation was more common in the Colloid group for durations less than 6 hours (40%) and more than 24 hours (18%), while the Crystalloid group had a higher incidence of ventilation lasting less than 12 hours (46%). These differences reached statistical significance (p=0.030 for less than 6 hours, p=0.191 for 6-12 hours, and p=0.040 for more than 24 hours). Table 3 and Figure 3

Table 1: Demographic data in the studied groups

Variable	Colloid group	Crystalloid Group	p
Age(years)	63.0±8.6	62.4±8.6	0.727
Gender, (%) Male	32(64%)	31(62%)	0.836
Female	18(36%)	19(28%)	
BMI (kg/m^2)	27.5±2.7	27.4±2.7	0.972
Type of cardiac operation distribution			
CABG	21(42%)	19(38%)	0.918
Valve and coronary bypass	18(36%)	19(38%)	
Valve replacement	11(22%)	12(24%)	

Data were presented as mean ± standard deviation (SD), frequency (%), BMI: body mass index, CABG: Coronary artery bypass graft

Table 2: Clinical data and complications in the studied groups.

Variable	Colloid group	Crystalloid group	P
MAP day 1 (mmHg)	55.9±3.0	55.4±3.1	0.234
MAP day 5 (mmHg)	65.9±3.0	65.4±3.1	0.041*
CVP day 1 (mmHg)	6.2±2.5	5.7±2.5	0.124
CVP day 5 (mmHg)	7.3±1.2	5.3±1.2	<0.001*
SOFA day1	8.1±1.6	8±1.8	0.652
SOFA day5	4.9±1.7	6.5 ± 2.1	<0.001*
UOP day 1 (ml/hr)	42.3±17.3	37.4 ± 16.4	0.111
UOP day 5 (ml/hr)	47.3±17.3	42.4 ± 16.4	0.111
Arterial lactate day 1 (mmol/L)	6.0±2.3	6.3 ± 2.4	0.548
Arterial lactate day 5 (mmol/L)	2.0±0.9	2.4 ± 1.3	0.733
Creatinine day 1 (mg/dl)	1.4±0.9	1.3±0.7	0.318
Creatinine day 5 (mg/dl)	1.2±0.7	1.3±0.3	0.814
Complications	15(30%)	26(52%)	0.040*
Acute kidney injury	3(6%)	5(10%)	0.482
Arrythmia,AF	2(4%)	3(6%)	
Heparin induced thrombocytopenia	1(2%)	1(2%)	
Infection	4(8%)	7(14%)	
Ischemic bowel	1(2%)	1(2%)	
Respiratory failure	4(8%)	9(18%)	

Data were presented as mean ± standard deviation (SD), frequency (%), SOFA: sequential organ failure assessment, AF: Atrial fibrillation, *: Significant P-value,**MAP**:mean arterial blood pressure, CVP: central venous pressure, UOP: urine output.

Table 3: Mortality rate, catecholamine use, mechanical ventilation and post operative MV in the studied groups.

Variable	Colloid group	Crystalloid group		p
Mortality				
Death within 30 days	7(14%)	11(22%)		0.265
Catecholamine use	8(16%)	14(28%)		0.148
Catecholamine amount (mg)	10.07±1.8	21.5±5.1		<0.001 *
Mechanical ventilation	9(18%)	17(34%)		0.030*
Number of ventilation days	14.6±3.1	15.9±3.3		0.331
Post operative Mechanical ventilation	Less than6 hours	30(60%)	10(20)	<0.001 *
	6-12 hours	11(22%)	23(46%)	0.191
	More than 24 h	9(18%)	17(34%)	0.040*

Data were presented as mean ± standard deviation (SD), frequency (%),*:Significant P-value.

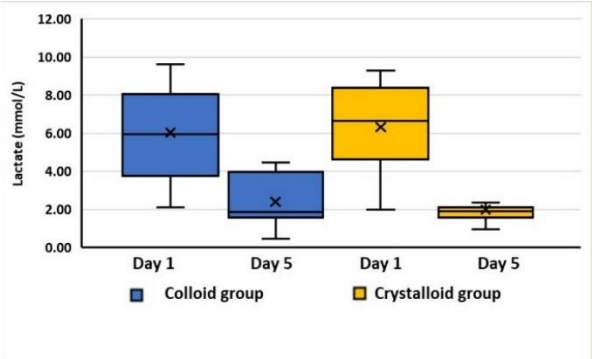

Figure 1: Arterial lactate in the studied groups.

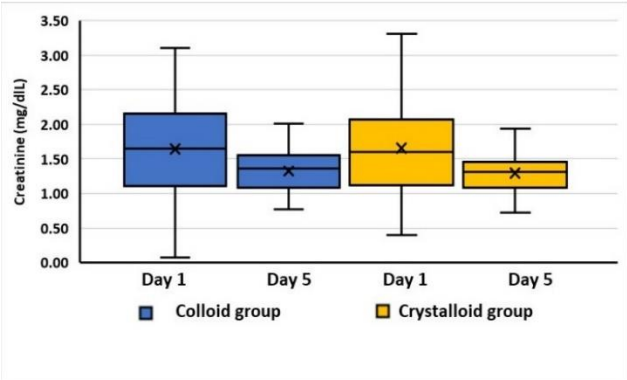

Figure 2: Serum creatinine in the studied groups.

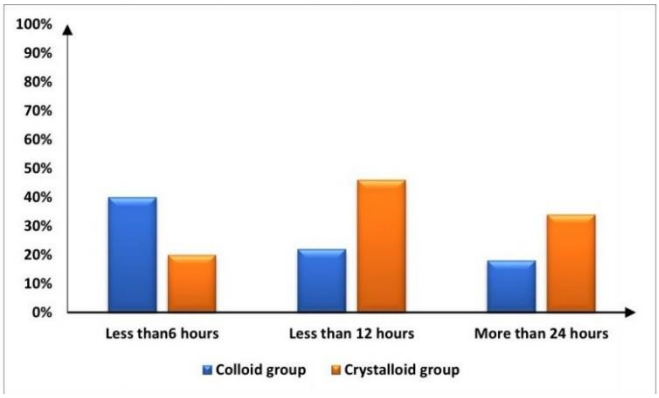

Figure 3: Post operative MV in the studied groups

Discussion:

In our study all patients in both groups were critically ill patients post open heart surgery and required fluid resuscitation for acute hypovolemia.

In terms of clinical assessment of the studied groups, the previous table shows the mean and standard deviation difference for (mean arterial blood pressure, CVP, SOFA score, UOP, arterial lactate and creatinine) in each group day 1 and day 5 post operation. There were no significant differences in MAP, CVP, SOFA score, urine output, arterial lactate levels or creatinine between the two groups on day 1 after the cardiac operations. However, on day 5, the crystalloid group had significantly lower CVP levels ($p<0.001$), and significantly higher SOFA scores ($p<0.001$) compared to the colloid group. The colloid group also had a significantly lower arterial lactate level ($p=0.041$) on day 5compared to the crystalloid group. There were no significant differences between the two groups in terms of urine output or MAP on day 5.

Came in agreement with our study, [9]. documented that the average creatinine was the same in both groups over the course of the hospital stay. The number of patients with an increase in creatinine over the course of their hospital stay of 50% (equals RIFLE risk category) (24) was similar in the two groups [9]

According to complications in the studied groups, a significantly higher percentage of patients in the crystalloid group experienced complications compared to the colloid group (52% vs 30%, $p=0.040$). Complications included: acute kidney injury, AF, thrombocytopenia, infection, ischemic bowel and respiratory failure were not significantly different in distribution between the two groups.

In several retrospective studies, renal injury was increased in cardiac surgery patients who received HES [10,11]. Although attempts were made to adjust for baseline differences in one of these studies [11], these studies are limited by their retrospective design and the lack of a fixed protocol for the use of the HES. Further support for our argument that colloids must be administered with a careful protocol, which is based on the identification of a flow response, comes from the analysis of all patients who received starch, whether they should have or not, based on the protocol.

According to mortality, overall mortality rate was significantly higher in the crystalloid group (22%) compared to the colloid group (14%) ($p=0.265$). The difference in mortality rates within 30 days was not statistically significant between the two groups (14% in the colloid group vs 22% in the crystalloid group, $p=0.265$).

In consistent with our findings, [12]. conducted a multicenter, randomized clinical trial stratified by case mix (sepsis, trauma, or hypovolemic shock without sepsis or trauma) to test whether use of colloids compared with crystalloids for fluid resuscitation alters mortality in patients admitted to the ICU with hypovolemic shock. Colloids (n=1414; gelatines, dextrans, hydroxyethyl starches, or 4% or 20% of albumin) or crystalloids (n =1443; isotonic or hypertonic saline or Ringer lactate solution) for all fluid interventions other than fluid maintenance throughout the ICU stay.

According to catecholamine use, a higher percentage of patients in the crystalloid group received catecholamines compared to the colloid group (28% vs 16%), but this difference was not statistically significant ($p=0.148$). However, the amount of catecholamines used was significantly higher in the crystalloid group compared to the colloid group ($p<0.001$).

Difference (p-value<0.05) between studied groups 45% of patients in crystalloid group, and 15% of patients in colloid regarding requirement of Ephedrine for treatment of hypotension. Also, the total dose of Ephedrine given for

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treatment of hypotension was statistically significant higher in Crystalloid when compared to colloid group (p-value <0.05) [13]

According to mechanical ventilation, a higher percentage of patients in the crystalloid group received mechanical ventilation compared to the colloid group (34% vs 18%), significant difference between the two groups in the mean number of ventilation days (14.6 days in the colloid group vs 15.9 days in the crystalloid group, p=0.331).

Along with our study, [12]. reported that there were more days alive without mechanical ventilation in the colloids group vs the crystalloids group by 7 days (mean: 2.1 vs 1.828 days (mean: 14.6 vs 13.5 days; mean difference, 1.10 [95% CI,0.14 to 2.06] days; P=.01)and alive without vasopressor therapy by 7 days (mean: 5.0 vs 4.7 days; mean 15.2 days; mean difference, 1.04 [95% CI,-0.04 to 2.10] days; P=.03) [12].

Finally, this study had some limitations as it included a single-center study with a relatively small sample size of 100 patients. Therefore, the follow-up period was limited to 30 days and the study allowed the use of different types and amounts of fluids within standardized fluid protocols could introduce variability in the treatment and outcomes.

Conclusions:

The use of colloids for fluid volume replacement in postoperative cardiac patients in the ICU after open-heart surgery showed favorable outcomes compared to crystalloids. The colloid group had lower rates of complications, mortality, and requirements for catecholamines and mechanical ventilation. Additionally, the colloid group demonstrated improved hemodynamic stability and lower arterial lactate levels on day 5 post-operation. These findings suggest that colloids may be a more effective choice for fluid resuscitation in this patient population.

Conflict of interest:

Authors declare no conflict of interest.

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