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Research Article

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Conventional Ultrafiltration Versus Combined Conventional and Modified Ultrafiltration on Clinical Outcomes of Pediatric Cardiac Surgery

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Abstract

Background: Ultrafiltration is a method used to decrease body fluid volume and tissue oedema as the consequences of hemodilution after cardiac surgery with cardiopulmonary bypass (CPB). Combined conventional (CUF) and modified ultrafiltration (MUF) may offer advantages in comparison with conventional ultrafiltration. We conducted a prospective study to compare clinical outcomes between two groups.

Material and methods: A simple randomized clinical trial was conducted on eighty pediatric patients undergoing congenital heart surgery on cardiopulmonary bypass. Patient management was standardized, and intensive care staffs were blinded to group allocation. Preoperative Aristotle comprehensive complexity level, ultrafiltrate volumes, perioperative hemodynamic data, hematocrit, Transesophageal echocardiographically (TEE) determined ejection fraction (EF), fractional area change (FAC), temperature drift, arterial oxygenation, time of extubation, ventilation, comparison of inotropic drugs, postoperative chest tube drainage, intensive care unit (ICU) and hospital stay were recorded in CUF (group I) and CUF plus MUF (group II).

Results: There was no operative mortality. Technical difficulties prevented completion of modified ultrafiltration in 3 patients of 40 in group II. In this study there were 27 females (33.75%) and 53 males (66.25%) with median age 441 days, mean weight 10.19 kg and Aristotle comprehensive complexity score level-2. Group II had greater ultrafiltrate volume (883 ± 82.7 ml; (p=0.014). Duration of ventilatory support was 61.4 ± 13.74 hours versus 103.2 ± 25.85 hours in group II and I respectively, (p=0.004). Chest tube drainage in the first 48 hours was (79.31 ± 47 and 107.63 ± 23.83 ml) in group II and I respectively, (p=0.003). EF and FAC were 10% and 4% higher at 45 minutes in group II. Inotropic infusion requirement was significantly less in group II compared to group I. Group II maintained better systolic blood pressure and hemoglobin after CPB.

Conclusion: The advantage of combining conventional and modified ultrafiltration over conventional ultrafiltration consists of significant improvement of clinical conditions, as decreases the need for homologous blood transfusion, reduced requirement of inotropic drugs, and shortened duration of ventilatory support as well as average hospital length of stay.

Keywords: Cardiac surgery; Cardiopulmonary Bypass; Pediatric; Ultrafiltration

Introduction

In 1953, John Gibbon performed the first successful open-heart surgery using a heart-lung machine in human beings. Blood requirements per cardiac case in the early 1950's were quite higher. Cardiopulmonary bypass (CPB) is a double-edged sword. Without it, corrective cardiac surgery would not be possible in the majority of congenital heart diseases. The advantages of a motionless and bloodless field, however, are undermined by a large number of risks secondary to initiation of the systemic inflammatory response syndrome (SIRS) with significant accumulation of excess body water. However, much of the perioperative morbidity that occurs after cardiac surgery can be attributed to a large extent to pathophysiologic processes engendered by extracorporeal circulation [1].

In cardiac surgical practice conventional ultrafiltration (CUF) was introduced in the 1970's on CPB, usually during the rewarming phase. The volume of filtrate that can be removed during CUF is restricted by circuit volume and the volume of the venous reservoir, and thus CUF provides only a limited ability to remove excess water and reverse hemodilution, as sufficient volume in the venous reservoir is necessary to ensure adequate arterial inflow [2].

Over the past several years, a modified technique of ultrafiltration, commonly known as Modified ultrafiltration (MUF) was pioneered by Naik et al. performed after discontinuation from CPB but before administration of protamine. It has been used with increasing enthusiasm. Multiple studies have been undertaken to assess the effects of MUF on organ function and postoperative morbidity following repair of congenital heart defects [2,3]. In the literature, there is a large controversy about whether to use CUF or MUF or CUF+MUF. While numerous studies conducted in the past have shown that the use of MUF improves brain, lung, and heart functions post bypass after repair

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of congenital heart defects [2]. Many studies have reported no significant improvement in the clinical outcomes of patients, in which MUF has been implemented [4,5]. In this prospective randomized study, we aimed to compare CUF and CUF+MUF effects on ultrafiltrate volumes, perioperative hemodynamic data, hematocrit, transoesophaegeal echocardiographically determined Ejection Fraction (EF), Fractional Area Change (FAC), temperature drift, arterial oxygenation, time of extubation, ventilation, comparison of inotropic drugs, postoperative chest tube drainage, Intensive Care Unit (ICU) and hospital stay.

Materials and Methods

After obtaining approval from the hospital ethics committee, eighty children were enrolled for this study. Informed parental consent was obtained. Patients were divided into two groups of 40 each by using a random number table technique. Inclusion criteria were, children below 5 years of age undergoing cardiac surgery for congenital heart disease repair on CPB.

Exclusion criteria were patients with emergency surgeries, active non-cardiac disease that was expected to compromise the patient's postoperative recovery, those on preoperative ventilatory support, previous sternotomy/redo surgeries, which may influence blood loss (an outcome variable), weight greater than 15 kg, because of the need for a CPB oxygenator of greater flow capacity (to reduce CPB variables) and who did not give consent to participate in the study. The preoperative evaluation was performed by echocardiography and or cardiac catheterization. Patients fasted for a minimum of 4 hours. Patients were premedicated with injection (Inj.) midazolam 0.5 mg/kg, inj. ketamine 5 mg/kg and inj. glycopyrrolate by the oral route.

No child received intravenous fluids before entering the operating room, a continuous infusion of ringer lactate was initiated at a rate of 10 mL/kg/hr. Patients were monitored by electrocardiogram, pulse oximetry, and arterial pressure. The induction of anesthesia was performed with benzodiazepines (inj. Midazolam 0.1 mg/kg), inj. ketamine 0.5 mg/kg IV, and opioids (inj. fentanyl 10 ug/kg). Muscle relaxant inj. pancuronium (0.1 mg/kg) was used to intubate patients after adequate muscle relaxation. Sevoflurane/isoflurane, and inj fentanyl 2 ug/kg/hr were used to maintain anesthesia. In all children, additional monitoring included end-tidal carbon dioxide (CO_2), central venous pressure, arterial blood pressure, rectal and nasal temperatures and pediatric biplane transoesophageal echography.

After the injection of 300 IU/kg of unfractionated heparin to achieve an activated coagulation time (ACT) more than 480 seconds before going on CPB. Core cooling was used in all patients, monitored by rectal and oesophageal temperature. At the end of surgery after CPB, the reversal of heparin was accomplished with protamine sulfate (1.3 mg/1 mg heparin).

The pump was primed with crystalloid (ringer lactate) and packed red blood cells (PRBC). Also 1 meq/Kg of sodium bicarbonate, heparin 3 IU/ml of prime and 5 ml/Kg of 20% mannitol were added. PRBC were added, whenever the hematocrit decreased to <25% during CPB. A nonpulsatile flow (125-150 ml/Kg/min) was achieved during CPB using a twin roller pump and a fibre membrane oxygenator with a 40 arterial line filter. Myocardial preservation protocol included moderate systemic hypothermia (nasopharyngeal temperature 28-32°C), cold (4°C) antegrade hyperkalemic cardioplegia solution (Plegiocard, Samarth Pharma, India) with blood (1:4 proportions) and topical cooling of the myocardium with ice slush placed in the pericardial sac. The initial dose of cardioplegia was 20 ml/Kg, followed by half the initial dose every 20 minutes. Arterial blood gas measurements were performed every 30 minutes to maintain arterial oxygen partial pressure at 150 to 250 mm Hg and carbon dioxide partial pressure at 35-40 mm Hg. On completion of surgery patients were rewarmed to 36-37°C.

In group I Conventional ultrafiltration volume of 20-30 ml/Kg was removed during CPB. CUF was stopped if venous reservoir level fell low. In group II, CUF was performed during CPB as in group I and arteriovenous MUF performed after termination of CPB. During MUF blood taken from the aortic cannula and returned to the right atrium through the venous cannula after the end of CPB. Care was taken during MUF to avoid any air embolism. Systolic and diastolic arterial pressures were monitored during MUF and a decrease in systolic arterial pressure of 20% from the start of MUF treated with blood infusion through an aortic cannula to maintain CVP of 6-7 mm Hg. MUF removes 20-30 ml/Kg ultrafiltrate. After completion of modified ultrafiltration and removal of venous cannulae, 1 mg/kg of protamine sulphate was administered to reverse the anticoagulant effect of heparin and the next doses were prescribed if the ACT was not at the desired levels. Color of urine was monitored for hemolysis.

Ejection Fraction (EF) was calculated using Simpson method and fractional area change (FAC) was calculated in transgastric short-axis midpapillary view by subtracting left ventricular end-systolic area from left ventricular end-diastolic area and dividing by left ventricular end-diastolic area. Readings were taken before sternotomy (PrC), immediately after the termination of CPB (0 min=PSC0), 30 min and 45 min after termination of CPB. Posterior wall thickness was measured at end-diastole and end-systole in transgastric short-axis view at papillary muscle level at similar time intervals to assess myocardial oedema. Heart rate, systolic and diastolic arterial pressures, hematocrit and temperature were recorded at corresponding time intervals. CPB time, aortic cross-clamp time, inotropic support required during weaning, the volume of conventional and modified ultrafiltrate removed, time to extubate and the length of intensive care unit (ICU) stay were also recorded. Patients were extubated when they were fully rewarmed, conscious, maintaining saturation with adequate respiratory efforts, hemodynamically stable and no significant mediastinal bleeding.

Statistical data analysis was performed using the SPSS software package (SPSS Inc, Chicago, IL). The descriptive statistics including indicators of central tendency and dispersion (mean and standard deviation) were used to describe the specifications in both groups. All variables were tested for normality; Chi-square test was used for comparing categorical variables such as gender, operation type, and inotrope drug administration. Comparison of demographic and operation data, duration of mechanical ventilation and ICU stay, and time of the consumption of inotrope drugs between groups were determined using the independent-samples t-test for paired data. $p<0.05$ considered statistically significant.

Results

Eighty pediatric patients were enrolled in this study. Three subjects were excluded from the data analysis for protocol violations. Of the remaining 77 patients, 40 received CUF only (group I), and 37 received both CUF+MUF (group II). Demographic characteristics of the two groups were similar and are presented in Table 1.

Parameter	Group I	Group II	p value
Number (n)	40	37	-
Age (days; mean ± SD)	447 ± 7.82	435 ± 7.64	0.515
Weight (Kg; mean ± SD)	10.53 ± 4.64	9.87 ± 5.39.	0.727
BSA (m^2)	0.45 (0.18)	0.47 (0.19)	0.642
Sex F:M	1:2.64	01:01.5	0.249
ACC Level (mean ± SD)	7.7 ± 5.32	7.8 ± 8.64	0.472
Data are presented as means ± standard deviation (SD), ratio and percentages. Group I=conventional ultrafiltration (CUF), Group II=CUF+MUF (modified ultrafiltration), ACC Level: Aristotle comprehensive Complexity Level, Kg=Kilogram, M=Male, F=Female, P is significant <0.05			

Table 1: Distribution of patient's demographic profile.

Preoperative diagnosis and Aristotle comprehensive complexity (ACC) level are shown in Table 2. There were no significant differences in the complexity of cardiac operations performed as both the groups belong to ACC level 2 (represents 6.0-7.9).

Pre-operative diagnosis	Group I	Group II	Total
Ventricular septal defect	10	23 (1)*	34 (42.5%)
Tetralogy of Fallot	18	7 (2)*	27 (33.7%)
Atrioventricular septal defect	4	2	6 (7.5%)
Double-outlet right ventricle	4	1	5 (6.2%)
Transposition of the great arteries	2	1	3 (3.7%)
Total anomalous pulmonary venous return	1	0	1 (1.3%)
Truncus arteriosus	1	1	2 (2.5%)
Anomalous origin of coronary artery for pulmonary artery	0	1	1 (1.3%)
Cardiac tumor	0	1	1 (1.3%)
Total (n)	40	37 (3)*	80
NYHA/Ross pre-operative functional class			
I	3 (7.5%)	5 (12.5%)	8 (10%)
II	28 (70%)	27 (67.5%)	55 (68.7%)
III	9 (22.5%)	8 (20%)	17 (21.3%)
ACC Level (mean ± SD)	7.7 ± 5.32	7.8 ± 8.64	7.7 ± 9.51
New York Heart Association (NYHA) /Ross pre-operative functional class; ACC: Aristotle comprehensive Complexity; Level-1 (1.5-5.9); Level-2 (6.0-7.9); Level-3 (8.0-9.9); Level-4 (10.0-15); standard deviation (SD), *: Technical difficulties prevented completion of modified ultrafiltration in 3 of 40 patients in group II			

Table 2: Pre-Operative diagnosis.

There were no significant differences in the prevalence of preoperative medication use or the need for preoperative mechanical ventilation. Study groups did not differ significantly with respect to preoperative hematocrit, white blood cell count, electrolyte levels, renal and coagulation laboratory test values.

There were no significant differences between groups for CPB prime, duration of CPB, cross-clamping time, minimum core temperature during CPB, total heparin dose, total urine output, and Average Intraoperative whole blood administered as presented in Table 3. Total volumes of ultrafiltrate obtained was 527.6 ± 79.3 and 883 ± 82.7 ml in group I and II respectively which is significantly higher in group II ($p<0.05$).

Characteristic	Group I	Group II	p value
CPB prime (mL, mean ± SD)	687 ± 46.6	621 ± 48.2	0.357
CPB duration (min, mean ± SD)	116 ± 41.5	121 ± 43.6	0.521
Aortic cross clamp time (min, mean ± SD)	86 ± 25.3	78 ± 33.4	0.383
Minimum core temperature (°C, mean ± SD)	25.8 ± 3.21	25.1 ± 4.57	0.537
Ultrafiltrate volume (ml mean ± SD)	527.6 ± 79.3	883 ± 82.7	0.014
Total heparin (units, mean ± SD)	5741 ± 783	5823 ± 739	0.485
Urine output during CPB (ml, mean ± SD)	67.4 ± 8.2	42.7 ± 5.8	0.135
Average Intraoperative whole blood administration (ml, mean ± SD)	349 ± 31.6	353 ± 36.2	0.412
Data are presented as means ± standard deviation (SD), Group I=CUF, Group II=CUF+MUF, ml=Millilitres, p is significant<0.05			

Table 3: Intraoperative characteristics of the patient population.

Laboratory variables such as hemoglobin, hematocrit and Oxygen saturation were not changed significantly in postoperative period for groups I to II, as shown in Table 4.

Variables	Group I	Group II	p value
Hemoglobin	10.9 ± 1.74	11.0 ± 27	0.512
Hematocrit	36.9 ± 5.35	37.5 ± 5.92	0.516
Ph	7.4 ± 0.13	7.4 ± 0.04	0.837
PaO_2	146 ± 6.74	283 ± 5.26	0.163
$PaCO_2$	37.4 ± 4.38	39 ± 3.72	0.731
HCO_3	23.1 ± 2.35	22.8 ± 2.58	0.283
O_2 Saturation	95.5 ± 11.48	94.47 ± 11.83	0.418
Data are presented as means ± standard deviation (SD), Group I=CUF, Group II=CUF+MUF, p is significant<0.05			

Table 4: Postoperative laboratory variables at 10 min post-CPB.

Comparison of post-operative systolic blood pressure in the group II showed slight improvement in an Intensive Care Unit (ICU) and after 2 hours in ICU (Figure 1). Hemodynamic variables as heart rate, systolic blood pressure, diastolic blood pressure, rate pressure product, mean arterial pressure, central venous pressure were improved after 48 hours but did not change significantly from the group I to II (Table 5).

Postoperative percentage of patients extubated in the operating room was 19 and 21 in groups I and II (p>0.05). The duration of postoperative mechanical ventilator support in hours, average ICU Length Of Stay (LOS) in days, Chest tube drain in first 48 hours in ml and average hospital LOS in days were (103.2 ± 25.85 and 61.4 ±13.74), (5.8 ± 3.53 and 3.3 ± 2.65), (107.63 ± 23.83 and 79.31 ± 47) and (8.2 ± 4.32 and 6.9 ± 3.74) in groups I and II respectively. These differences were statistically significant (Table 6).

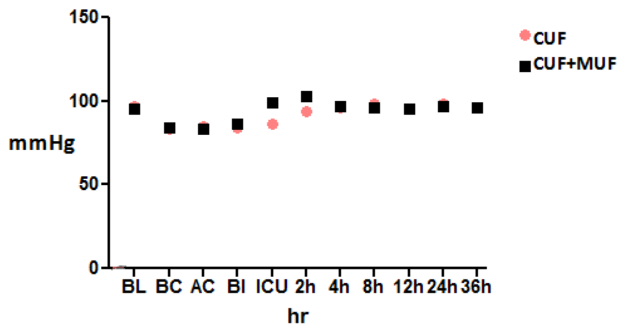

Figure 1: Systolic blood pressure in milli metre of mercury (mmHg) at (BL)-base line, (BC)-before cardiopulmonary bypass, (AC)-after cardiopulmonary bypass, (BI)-before shifting to ICU, (ICU)-at ICU, 2 h-after 2 hours in ICU, 4 h, 8 h, 12 h, 24 h and 36 h-after 4, 8, 12, 24 and 36 hours respectively in ICU.

Hemodynamic data	Group I	Group II	p value
Heart rate	112.30 ± 8.47	109.80 ± 8.36	0.318
Systolic blood pressure (mmHg)	94.63 ± 4.79	95.72 ± 4.90	0.489
Diastolic blood pressure (mmHg)	55.70 ± 6.73	56.31 ± 6.27	0.575
RPP	10,626 ± 1327	10,524 ± 1196	0.253
MAP (mm Hg)	68,67 ± 4.73	69.45 ± 4.9	0.462
CVP (mmHg)	9 ± 4.61	8 ± 4.21	0.528
Data are presented as means ± standard deviation (SD), RPP=Rate pressure product, MAP=Mean arterial pressure, CVP=Central venous pressure. Group I=CUF, Group II=CUF+MUF, mmHg=millimetre of mercury, p is significant<0.05			

Table 5: Hemodynamic data after 48 hours.

Variable	Group I	Group II	p value
% of patients extubated in OR	19%	21%	0.386
Duration of mechanical ventilation (hr, mean ± SD)	103.2 ± 25.85	61.4 ± 13.74	0.004^{*}
Average ICU LOS (days, mean ± SD)	5.8 ± 3.53	3.3 ± 2.65	0.007^{*}
Chest tube drain in first 48 hours (ml)	107.63 ± 23.83	79.31 ± 47	0.003^{*}
Average Hospital LOS (days, mean ± SD)	8.2 ± 4.32	6.9 ± 3.74	0.021^{*}
Data are presented as means ± standard deviation (SD), and percentages. Group-I=CUF, Group-II=CUF+MUF, LOS=Length of Stay; OR=Operating room; hr=hours, p=*is significant <0.05			

Table 6: Comparison of mechanical ventilation and Length of Stay (LOS).

The number and duration of inotropes administered in both groups shown in Table 7. Adrenaline was the most commonly used and dobutamine the least commonly used inotropes in the two groups. However, the amounts of inotropes required were significantly lesser in group II (p<0.05).

Variable	Group I (n=40)	Group II (n=38)	p value
Adrenaline	105.7 ± 15.3 hrs (n=38)	51.2 ± 9.7 hrs (n=36)	0.002^{*}
Dopamine	57.2 ± 11.5 hrs (n=18)	30.5 ± 5.2 hrs (n=14)	0.005^{*}
Dobutamine	92.3 ± 13.4 hrs (n=12)	43.8 ± 7.3 hrs (n=11)	0.003^{*}
Data are presented as means ± standard deviation (SD), hrs=Hours; p<0.05 is significant for number of hours			

Table 7: Comparison of inotropic drugs infused in two groups.

From the Pearson correlation analysis in the Intensive Care Unit after 30 minutes of extubation, there was significant positive Correlation seen in the Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and Heart Rate (HR) with the adrenaline. DBP and HR had strong strength but reduced correlation significance (Figure 2).

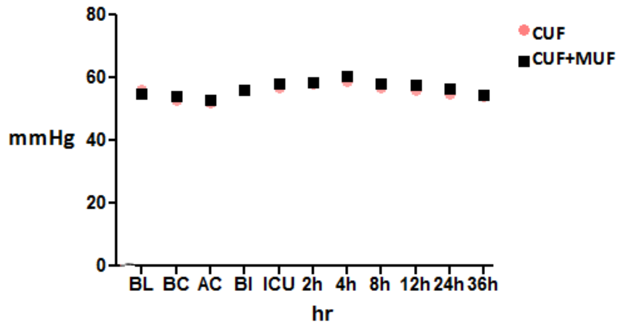

Figure 2: Diastolic blood pressure in millimetre of mercury (mmHg) at (BL)-base line, (BC)-before cardiopulmonary bypass, (AC)-after cardiopulmonary bypass, (BI)-before shifting to ICU, (ICU)-at ICU, 2 h-after 2 hours in ICU, 4 h, 8 h, 12 h, 24 h and 36 h-after 4, 8, 12, 24, and 36 hours respectively in ICU.

Dopamine had a significant correlation with SBP and HR. However, the association between DBP and dopamine was not significant. The association of SBP, DBP, HR and dobutamine were found to be positive but not significant (Table 8).

Parameter	Adrenaline	Dopamine	Dobutamine
SBP (mmHg)	0.61^{***}	0.46^{**}	0.12
DBP (mmHg)	0.42^{**}	0.13	0.28
HR (per min)	0.47^{**}	0.41^{**}	0.25

Data is presented as (r) the correlation coefficient of the Pearson product. ICU=Intensive Care Unit, SBP: Systolic blood pressure, DBP-Diastolic blood pressure, and *Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level, ***Correlation is significant at the 0.001 level

Table 8: Pearson product (r) correlation between vital signs and inotropic drugs in ICU.

Transesophageal echocardiography (TEE) derived ejection fraction (Ef%) improved post cardiopulmonary bypass (CPB) in both the groups. In group II there was a significant improvement in EF at 30 min (60%) and 45 min (62%) after CPB compared with 0 min after CPB (41%) value after bypass (p<0.05) (Figure 3).

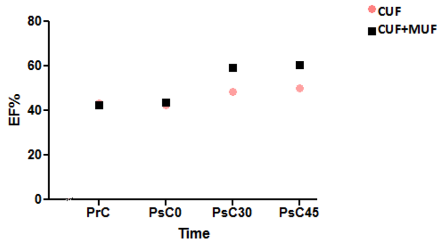

Figure 3: *Transesophageal* echocardiography (TEE) derived ejection fraction (Ef%) in CUF and CUF+MUF groups at PrC-Pre CPB, PsC 0-Post CPB at 0 minute, PsC 30-Post CPB at 30 minutes, and PsC 45-Post CPB at 45 minutes.

Transesophageal echocardiography (TEE) derived fractional area change (FAC%) increase was observed in post CPB. In group I and II there was no significant change in FAC% at 30 min (42% and 43%) and 45 min (41% and 45%) after CPB compared with 0 min after CPB (41% and 40%) respectively (p>0.05) (Figure 4).

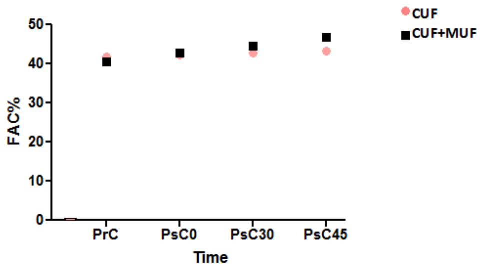

Figure 4: *Transesophageal* echocardiography (TEE) derived fractional area change (FAC%) in CUF and CUF+MUF groups at PrC-Pre CPB, PsC 0 m-Post CPB at O minutes, PsC 30 m-Post CPB at 3O minutes, and PsC 45 m-Post CPB at 45 minutes.

Discussion

Cardiopulmonary bypass in cardiac surgery is associated with the accumulation of water and an increase in total body water is associated with tissue oedema and subsequently organ dysfunction [5,6]. Previous studies have shown various advantages of CUF after CPB in decreases body water, improved hemodynamics, and decreases transfusion requirements [1,2]. Over time the improvement in ultrafiltration techniques resulted in a significant increase in their efficiency. After Naik et al. described MUF in 1991 the basis of his approach was the removal of the greater volume of fluid than what had been able to achieve with CUF [3]. As per Curi-Curi et al. Interleukins (IL) were better removed by (CUF), while tumoral necrosis factor (TNF) was better removed by MUF with poliariletersulfonate filters. MUF removes pro-inflammatory agents more effectively and resulting in an improved hemodynamic status of patients [6]. MUF has become the standard practice in the vast majority of cardiac centers and demonstrated that MUF can be effective in improving clinical outcomes as significantly decreases the duration of mechanical ventilation and inotrope requirement [2,3,6]. MUF has become controversial as shown in some studies, that MUF does not provide postoperative outcome benefits over CUF by improving the inflammatory response, decreasing the ICU and hospitalization periods [7-9]. It is still controversial whether to use MUF, CUF or both together to achieve best results. At the present CPB management without any ultrafiltration is unthinkable. The major problem with the interpretation of findings was different techniques and protocols that have been used for ultrafiltration. The present study aimed to evaluate the importance of combined conventional and modified ultrafiltration on postoperative outcomes in pediatric patients undergoing on-pump cardiac surgery.

In our study, patients in group CUF+MUF showed an improvement in the systolic blood pressure (SBP), diastolic blood pressure (DBP) and central venous pressure (CVP) compared to the CUF alone. Torina et al. studied the effects of MUF in adult patients scheduled for coronary artery bypass grafting (CABG) surgery and showed that using MUF had no significant effect on the hemodynamic status of patients [9]. Kotani et al. in a study on infants with congenital heart disease showed that the use of MUF improves the SBP and DBP as found in our study with CUF+MUF [9]. Sahoo et al. reported combined CUF and MUF are associated with improved stability in heart rate and reduced CVP of patients in the 48-hours postoperative period, which is in line with the results obtained from our study [10]. The difference in the results obtained in contrast to Torina et al. suggests the beneficial effect of using CUF+MUF in pediatric patients.

Transoesophageal echocardiography (TEE) determined ejection fraction (EF) and fractional area change (FAC) were also used in our study to assess the systolic function of the heart, although these are load-sensitive indices. There was a significant improvement in EF and FAC at 30 and 45 minutes post-CPB in CUF+MUF group, which suggests improved systolic function. These findings were consistent with Chaturvedi et al. who had shown significant improvement in global left ventricle function after MUF [11].

In our study, the volume of ultrafiltrate removed during CUF+MUF was based on body weight. The volume of ultrafiltration obtained was as expected significantly greater in the combined conventional and modified ultrafiltration (89.4 ml/kg) than the conventional ultrafiltration (50.1 ml/kg). When compared to other relevant studies our extent of ultrafiltration is higher than Maluf et al. (39 ml/kg) [12],

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but not as aggressive as of Thompson et al. (95 ml/kg) in CUF+MUF [13].

Pediatric cardiac surgery revealed that MUF augmented hemoconcentration and facilitated the restoration of circulation, as compared with CUF. Beneficial effects of using MUF in reducing the duration of mechanical ventilation, length of stay (LOS) in the Intensive Care Unit (ICU) and hospital have been pointed out in the study of Javadpour et al., which is similar to the present study, have used CUF and MUF together [14]. In CUF+MUF group reduction in the duration of mechanical ventilation was due to the removal of excess water from the body, especially the lungs, which improved their function more quickly. Nonetheless, only a few studies using CUF +MUF failed to report a significant change in the duration of mechanical ventilation, LOS in the ICU and hospital may be due to variation in study protocol and population [11,14]. Sahoo et al. study was in adult patients scheduled for coronary artery bypass grafting (CABG) surgery, but this study was in pediatric patients for corrective cardiac surgery.

In our study CUF+MUF significantly reduced the requirement of adrenaline, dopamine and dobutamine in terms of the number of patients and hours. Depboylu et al. ultrafiltration reduces inotropes requirement in the postoperative period, but not significantly [15]. We must, however, take into account clinical and methodological variations in his study from our study. In a similar study Ziyaeifard et al., using CUF+MUF significantly reduced inotropes requirement in the postoperative period [16]. They used milrinone, adrenaline, and dobutamine but in our study adrenaline, dopamine and dobutamine were used. The difference in types of inotropes used in the two studies is due to the different hospital routines.

Conclusion

Type of ultrafiltration in pediatric cardiac surgery is still controversial. As a result of this study, use of CUF+MUF is recommended. Besides the improving hematocrit levels, surgical blood loss, and need for transfusion of blood products. Furthermore, reduces the duration of mechanical ventilation, the requirement of inotropic agents, LOS in ICU and hospital by using CUF+MUF. The insignificant results of this study might be caused due to the small cohort of patients included in the study. Designing a new study with a larger patient population would yield more statistically significant results.

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