EAS Journal of Anaesthesiology and Critical Care
Abbreviated Key Title: EAS J Anesthesiol Crit Care
ISSN: 2663-094X (Print) & ISSN: 2663-676X (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-2 | Issue-1 | Jan-Feb-2020 | DOI: 10.36349/easjacc.2020.v02i01.006

Research Article

The Effect of Combined Conventional and Modified Ultrafiltration on Mechanical Ventilation and Hemodynamic Changes in Paediatric Congenital Heart Surgery

Sanjeev Singh[*1], Isaac Okyere[2] and Deigheidy Ehab Mahrous[2]

[1]Department of Anaesthesiology and Intensive Care, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[1]Department of Cardiac Anaesthesia, NHIMS, Bangalore, India
[1]Department of Anaesthesia, Komfo Anokye Teaching Hospital, Kumasi, Ghana
[2]Department of Surgery, Komfo Anokye Teaching Hospital, Kumasi, Ghana
[2]Centre Chirurgical Marie Lannelongue, Universite Paris-Sud, France

Article History
Received: 19.01.2020
Accepted: 05.02.2020
Published: 18.02.2020

Journal homepage:
https://www.easpublisher.com/easjacc

Quick Response Code

Abstract: ***Background:*** Cardiopulmonary bypass (CPB) is associated with increased fluid accumulation in body and ultrafiltration is a method used to decrease body fluid volume and tissue oedema as the consequences of haemodilution after cardiac surgery with CPB. This study aimed to compare the effects of modified ultrafiltration (MUF) versus combined conventional ultrafiltration (CUF) and modified ultrafiltration on the duration of mechanical ventilation and hemodynamic status in paediatric patients undergoing congenital heart surgery. ***Materials and Methods:*** A simple randomised clinical trial was conducted on eighty paediatric patients undergoing congenital heart surgery on cardiopulmonary bypass. Patient management was standardised, and intensive care staff were blinded to group allocation. Preoperative Aristotle comprehensive complexity level, ultrafiltrate volumes, perioperative haemodynamic data, haematocrit, *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 and CUF plus MUF. ***Results:*** There was no operative mortality. Technical difficulties prevented completion of modified ultrafiltration in 3 patients of 40 in CUF+MUF. In this study there were 33.75% females and 66.25% males with a median age 441 days, mean weight 10.19 kg and Aristotle comprehensive complexity score level-2. CUF+MUF had greater ultrafiltrate volume (883 ± 82.7 ml; (p = 0.014). Duration of ventilatory support was 103.2±25.85 hours versus 61.4±13.74 hours in CUF and CUF+MUF respectively, (p= 0.004). Chest tube drainage in the first 48 hours was (107.63±23.83 and 79.31±47 ml) in CUF and CUF+MUF respectively, (p= 0.003). Inotropic infusion requirement was significantly less in CUF+MUF compared to CUF. EF and FAC were 10 % and 4 % higher at 45 minutes in CUF+MUF. Haemoglobin and systolic blood pressure were better maintained after CPB with CUF+MUF. ***Conclusions:*** The advantage of combining conventional and modified ultrafiltration over conventional ultrafiltration consists of the significant improvement in the haemodynamic status of patients, significantly decreases the duration of mechanical ventilation and inotrope requirement within 48 h after surgery.

Keywords: Cardiac surgery, Cardiopulmonary Bypass, Hemodynamics, Ventilation, Ultrafiltration (Source: Mesh, NLM).

1. INTRODUCTION

Cardiopulmonary bypass (CPB) is a double-edged sword without it, corrective cardiac surgery would not be possible in the majority of children with congenital heart disease. John Gibbon in 1953 performed the first successful open-heart surgery using a heart-lung machine in human beings. In the early 1950's blood requirements per cardiac case 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 (Singh, S., & Annamalai, A. 2017). 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 (Murkin, J. M. 2010, September; & Wan, S. *et al.*, 1997).

***Corresponding Author Sanjeev Singh** **Email**: drsanjeev73[at] rediffmail.com

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 haemodilution, as sufficient volume in the venous reservoir is necessary to ensure adequate arterial inflow (Depboylu, B. C. *et al.*, 2018).

Over the past several years, a modified technique of ultrafiltration, commonly known as Modified ultrafiltration (MUF) was pioneered by Naik and colleagues in 1991, is 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 (Naik, S. K. *et al.*, 1991).

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 of congenital heart defects (Sever, K. *et al.*, 2004). Many studies have reported no significant improvement in the clinical outcomes of patients, in which MUF has been implemented (Mohanlall, R. e al 2014; & Williams, G. D. *et al.*, 2006).

In this prospective randomized study, we aimed to compare CUF and CUF+MUF effects on ultrafiltrate volumes, perioperative haemodynamic data, haematocrit, 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 length of stay (LOS).

2. MATERIAL AND METHODS

This study was undertaken after an institutional 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.

2.1 Inclusion criteria

Inclusion criteria were, children below 5 years of age undergoing elective cardiac surgery for congenital heart disease repair on CPB under general anaesthesia.

2.2 Exclusion criteria

Exclusion criteria were patients with emergency surgeries, redo surgery, active noncardiac 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.

2.3 Anaesthesia protocol

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 anaesthesia was performed with benzodiazepines (inj. Midazolam 0.1mg/kg), inj. ketamine 0.5 mg/kg IV, and opioids (inj. fentanyl 10ug/kg). Muscle relaxant inj. pancuronium (0.1mg /kg) was used to intubate patients after adequate muscle relaxation. Sevoflurane or isoflurane, and inj fentanyl 2 ug/kg/hr were used to maintain anaesthesia. In all children, additional monitoring included end-tidal carbon dioxide (CO2), central venous pressure, arterial blood pressure, rectal and nasal temperatures and paediatric 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).

2.4 Ultrafiltration protocol

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 haematocrit 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 the CUF group, conventional ultrafiltration volume of 20-30 ml/Kg was removed during CPB. CUF was stopped if venous reservoir level fell low. In CUF+MUF group, CUF was performed during CPB as in group CUF 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, 1mg/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. Colour of urine was monitored for haemolysis.

2.5 Parameters Analysis

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), 30min and 45min after the 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, haematocrit 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, haemodynamically stable and no significant mediastinal bleeding.

2.6 *Statistical Analysis*

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, operation data, duration of mechanical ventilation, ICU LOS, hospital LOS and time of the consumption of inotrope drugs between groups were determined using the independent-samples *t*-test for paired data. *P*-value < 0.05 considered statistically significant.

3. RESULTS

In this study eighty patients were enrolled and three subjects were excluded from the data analysis for protocol violations. Of the remaining seventy-seven patients, only forty received CUF, and thirty-seven received both CUF+MUF. Demographic characteristics of the two groups were similar (P is insignificant >0.05) and are presented in table 1.

Table 1: Distribution of patient's demographic profile:

Parameter	CUF	CUF+MUF	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 (m2)	0.45 (0.18)	0.47 (0.19)	0.642
Sex F: M	1:2.64	1:1.5	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. CUF=conventional ultrafiltration, MUF=modified ultrafiltration, ACC Level=Aristotle comprehensive Complexity Level, Kg = Kilogram, M = Male, F = Female, P is significant <0.05

Preoperative diagnosis and Aristotle comprehensive complexity (ACC) level are shown in table2 & 3 respectively. 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).

Table2: Pre-Operative diagnosis:

Pre-Operative diagnosis	CUF	CUF+MUF	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 from pulmonary artery	0	1	1 (1.3%)
Cardiac tumor	0	1	1 (1.3%)
Total (n=)	40	37 (3)*	80

* -Technical difficulties prevented completion of modified ultrafiltration in 3 of 40 patients in group CUF+MUF.

Table3. Complexity Level:

NYHA) /Ross pre-operative functional class	CUF	CUF+MUF	Total
I	3 (7.5%)	5 (12.5%)	8 (10%)
II	28 (70%)	27 (67.5%)	55 (68.7%)
III	9 (22.5%)	8 (20%)	55 (68.7%)
ACC Level (mean ±SD)	7.7 ±5.32	7.8±8.64	7.7 ±9.51

NYHA=New York Heart Association; 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)

Table4. Intraoperative characteristics of the patient population:

Characteristic	CUF	CUF+MUF	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 crossclamp 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), CPB= Cardiopulmonary bypass, °C = Celsius, ml= Millilitre, P is significant <0.0

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 concerning to preoperative haematocrit, 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.4. Total volumes of ultrafiltrate obtained was 527.6 ±79.3 and 883 ±82.7 ml in group CUF and CUF+MUF respectively which is significantly higher in group CUF+MUF ($p< 0.05$).

Laboratory variables such as haemoglobin, haematocrit and Oxygen saturation were not changed significantly in the postoperative period for both the groups, as shown in table 5.

Table5. Postoperative laboratory variables at 10 min post-CPB:

Variables	CUF	CUF+MUF	p-value
Haemoglobin	10.9 ±1.74	11.0 ±27	0.512
Haematocrit	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), P is significant < 0.05

Comparison of postoperative systolic blood pressure ***in the CUF+MUF group showed a slight improvement in an*** Intensive care unit (ICU) ***and after*** 2 hours in ICU (Figure. 1). Haemodynamic 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 CUF to CUF+MUF (table 6).

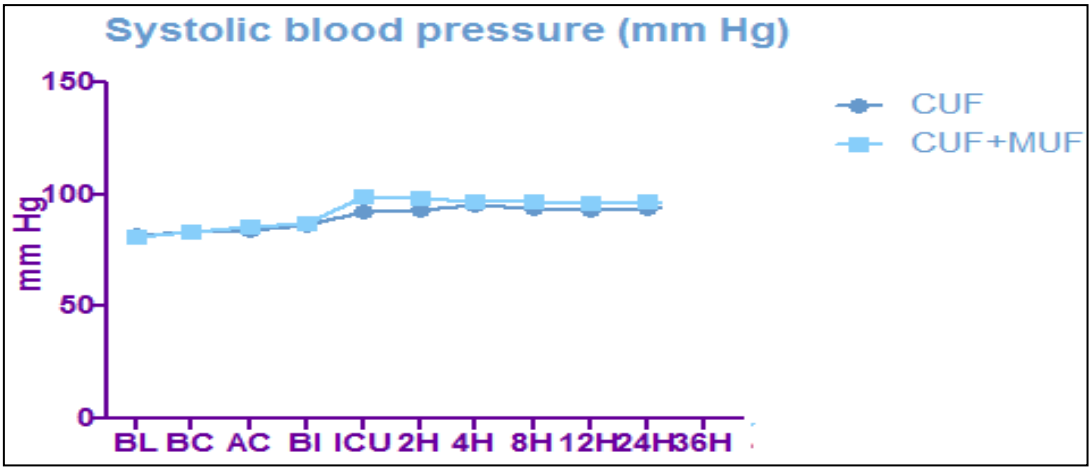

Figure 1. Systolic blood pressure in millimetre of mercury (mmHg) at (BL)- base line, (BC)- before cardiopulmonary bypass, (AC)- after cardiopulmonary bypass, (BI)- before shifting to ICU, (ICU) - at ICU, 2h- after 2 hours in ICU, 4h, 8h, 12h, 24h,and 36h- after 4, 8, 12, 24, and 36 hours respectively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

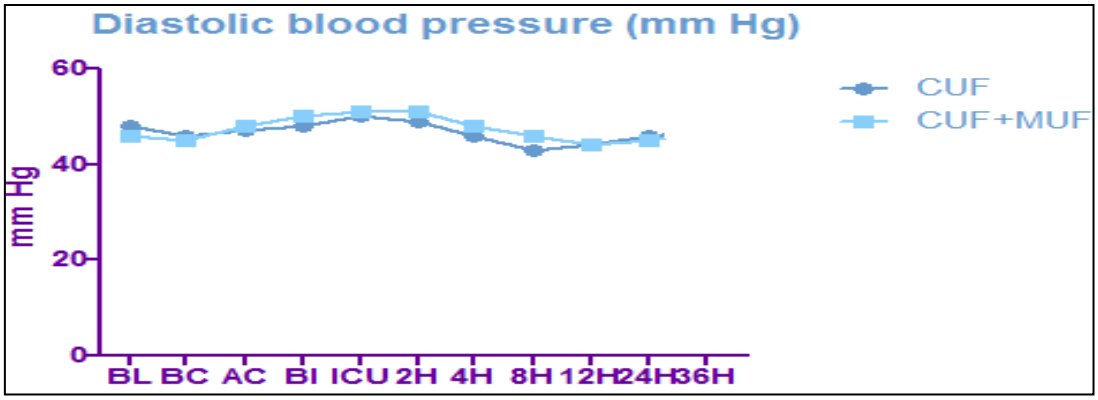

Figure 2. Diastolic blood pressure in millimetre of mercury (mmHg) at (BL)- base line, (BC)- before cardiopulmonary bypass, (AC)- after cardiopulmonary bypass, (BI)- before shifting to ICU, (ICU) - at ICU, 2h- after 2 hours in ICU, 4h, 8h, 12h, 24h,and 36h- after 4, 8, 12, 24, and 36 hours respectively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

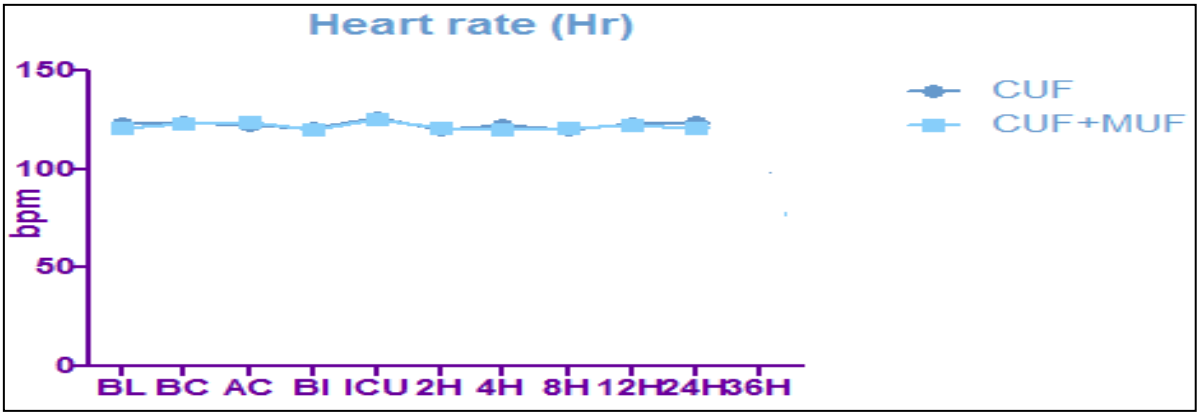

Figure 3. Heart rate at (BL)- base line, (BC)- before cardiopulmonary bypass, (AC)- after cardiopulmonary bypass, (BI)- before shifting to ICU, (ICU) - at ICU, 2h- after 2 hours in ICU, 4h, 8h, 12h, 24h,and 36h- after 4, 8, 12, 24, and 36 hours respectively in ICU.

Table6. Haemodynamic data after 48 hours:

Haemodynamic data	CUF	CUF+MUF	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. mmHg= millimetre of mercury, P is significant < 0.05.

Postoperative percentage of patients extubated in the operating room was 19 and 21 in groups CUF and CUF+MUF (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 CUF and CUF+MUF respectively. These differences were statistically significant (table 7).

Table7. Comparison of mechanical ventilation and Length of Stay (LOS):

Variable	CUF	CUF+MUF	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, LOS= Length of Stay; OR- operating room; hr= hours, P =* is significant <0.05.

The number and duration of inotropes administered in both groups shown in table 8. 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 CUF+MUF ($p < 0.05$).

Table8. Comparison of inotropic drugs infused in two groups:

Variable	CUF (n=40)	CUF+MUF (n=38)	p-value
Adrenaline	105.7±15.3hrs (n=38)	51.2±9.7hrs(n=36)	0.002*
Dopamine	57.2±11.5hrs (n=18)	30.5±5.2hrs(n=14)	0.005*
Dobutamine	92.3±13.4hrs(n=12)	43.8±7.3hrs(n=11)	0.003*

Data are presented as means ± standard deviation (SD), hrs= Hours; p < 0.05 is significant for number of hours.

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. 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.

Table9: Pearson product (r) correlation between vital signs and inotropic drugs in ICU

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.

Transesophageal echocardiography (TEE) derived fractional area change (FAC%) increase was observed in post CPB. In group CUF and CUF+MUF, 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).

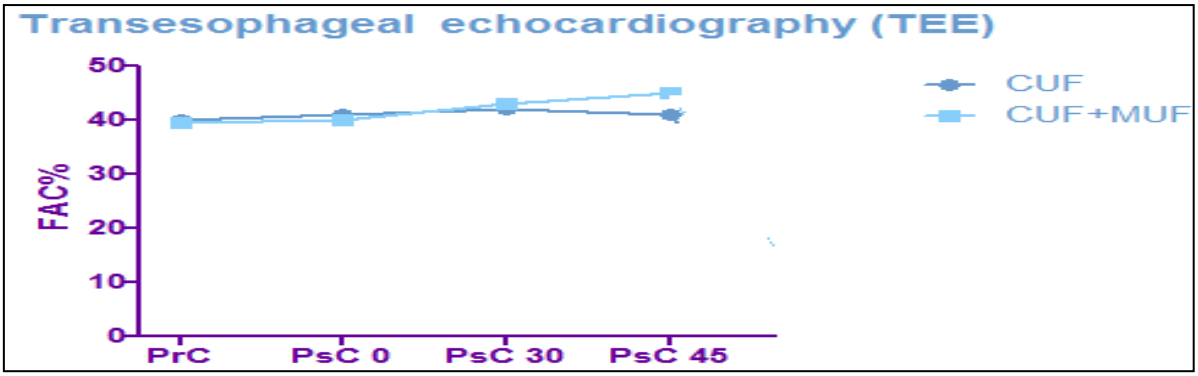

Figure 4. *Transesophageal* echocardiography (TEE) derived fractional area change (FAC%) in CUF and CUF + MUF groups at PrC-Pre CPB, PsC 0m- Post CPB at O minutes, PsC 30m- Post CPB at 3O minutes, and PsC 45m- Post CPB at 45 minutes.

Transesophageal echocardiography (TEE) derived ejection fraction (Ef%) improved post cardiopulmonary bypass (CPB) in both the groups. In group CUF+MUF 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 ($p< 0.05$).

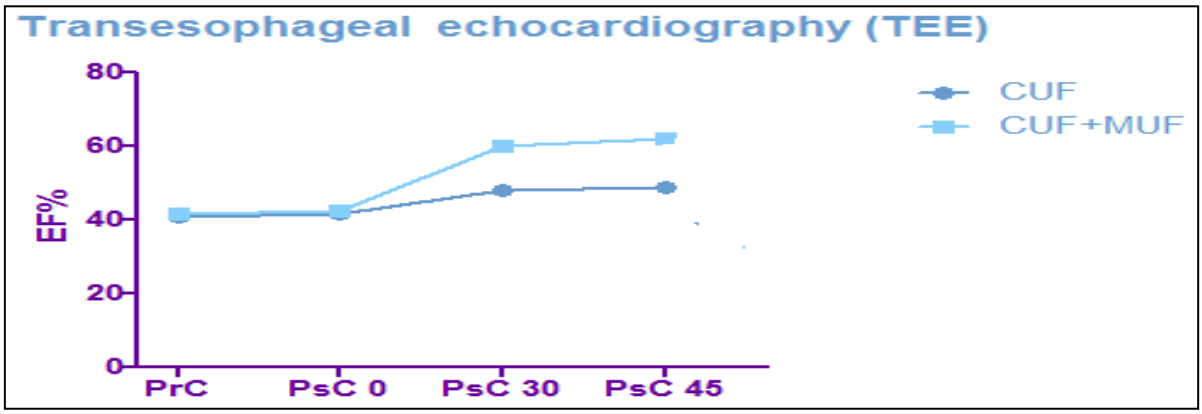

Figure 5. *Transesophageal* echocardiography (TEE) derived ejection fraction (Ef %) in CUF and CUF + MUF groups at PrC-Pre CPB, PsC 0- Post CPB at 0 minute, PsC 30- Post CPB at 30 minutes, and PsC 45- Post CPB at 45 minutes.

4. DISCUSSION

One of the common problems encountered in cardiac surgery is the use of cardiopulmonary bypass (CPB). CPB in cardiac surgery is associated with the accumulation of water, tissue oedema and subsequently organ dysfunction (Williams, G. D. *et al.*, 2006; & Singh, S., & Mahrous, D.E. 2019). Previous studies have shown various advantages of CUF after CPB in decreases body water, improved haemodynamics, and decreases transfusion requirements (Singh, S., & Annamalai, A. 2017; & Sever, K. *et al.*, 2004). 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 (Naik, S. K. *et al.*, 1991). As per Singh *et al.*, Interleukins (IL) were better removed by (CUF), while tumoral necrosis factor (TNF) was better removed by MUF with poliarilетersulfonate filters. MUF removes pro-inflammatory agents more effectively and resulting in an improved haemodynamic status of patients (Singh, S., & Mahrous, D.E. 2019). MUF has become the standard practice in the vast majority of cardiac centres and demonstrated that MUF can be effective in improving clinical outcomes as significantly decreases the duration of mechanical ventilation and inotrope requirement (Naik, S. K. *et al.*, 1991; Sever, K. *et al.*, 2004; & Singh, S., & Mahrous, D.E. 2019). 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 (Kuratani, N. *et al.*, 2011; Torina, A. G. *et al.*, 2012). 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 paediatric 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 (Torina, A. G. *et al.,* 2012). 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 (Kotani, Y. *et al.,* 2008). 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 (Sahoo, T. K. *et al.,* 2007). The difference in the results obtained in contrast to Torina *et al.,* suggests the beneficial effect of using CUF + MUF in paediatric patients.

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.,* (39ml/kg) (Maluf, M. A., *et al.,* 2001), but not as aggressive as of Thompson *et al.,* (95ml/kg) in CUF+MUF (Thompson, L. D. *et al.,* 2001).

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 (Chaturvedi, R. R. *et al.,* 1999).

Paediatric cardiac surgery revealed that MUF augmented haemoconcentration 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 (Javadpour, H. *et al.,* 2009). 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(Sahoo, T. K. *et al.,* 2007; Thompson, L. D. *et al.,* 2001). As Sahoo *et al.,* study were in adult patients scheduled for coronary artery bypass grafting (CABG) surgery, but this study was in paediatric patients for corrective cardiac surgery (Sahoo, T. K. *et al.,* 2007).

Inotropes may improve haemodynamics, but there is a potential risk for increased myocardial oxygen and energy consumption. It has been suggested that an increase in contractility of the hibernating but viable myocardium by low doses of inotropes can lead to a perfusion contraction mismatch with activation of anaerobe glycolysis and eventually myocardial necrosis (Singh, S. *et al.,* 2020). Thus the use of inotropes has been associated with adverse clinical outcomes as shown in a few studies (Fellahi, J. L., *et al.,* 2008; Shahin, J. *et al.,* 2011). Depboylu *et al.,* ultrafiltration reduces inotropes requirement in the postoperative period, but not significantly (Depboylu, B. C. *et al.,* 2008). In a similar study Ziyaeifard *et al.,*, using CUF + MUF significantly reduced inotropes requirement in the postoperative period (Ziyaeifard, M. *et al.,* 2016). They used milrinone, adrenaline, and dobutamine but in our study adrenaline, dopamine and dobutamine were used. Thus, clinical practice in inotrope management is highly dependent on patient requirement (Singh, S. 2020). The risks must be weighed against potential benefits on a per-patient basis. The difference in types of inotropes used is due to the different hospital routines. In our study CUF+MUF significantly reduced the requirement of adrenaline, dopamine and dobutamine in terms of the number of patients and hours. We must, however, take into account clinical and methodological variations in his study from our study.

5. CONCLUSION

Ultrafiltration technology is a method to effectively concentrate blood and remove excess water from the body. The application of ultrafiltration technology during or after CPB can attain a rather satisfactory balance liquid intake and output volume during operation. Type of ultrafiltration in paediatric cardiac surgery is still controversial. As a result of this study, use of CUF+MUF is recommended. Besides the improving haematocrit levels, surgical blood loss, and need for transfusion of blood products. Furthermore, reduces the duration of mechanical ventilation and 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 at multiple centres with a larger patient population would yield more statistically significant results.

Conflict of Interest:

All the authors do not have any possible conflicts of interest.

Acknowledgements:
Thanks to Dr. Sharad Kumar Govil and Mithlesh Govil for their moral support.

REFERENCES

1. Singh, S., & Annamalai, A. (2017). The Efficacy of Tranexamic Acid Versus Epsilon Amino Caproic Acid in Decreasing Blood Loss in Patients Undergoing Mitral Valve Replacement Surgery. *Journal of Anesthesiology*, *5*(2), 11-18.
2. Wan, S., LeClerc, J. L., & Vincent, J. L. (1997). Inflammatory response to cardiopulmonary bypass: mechanisms involved and possible therapeutic strategies. *Chest*, *112*(3), 676-692.
3. Depboylu, B. C., Yazman, S., & Harmandar, B. (2018). Use of Conventional Ultrafiltration in Patients with Pulmonary Hypertensive Mitral Valve Disease Undergoing Valve Surgery. *Cardiology and Cardiovascular Research*, *2*(2), 23.
4. Naik, S. K., Knight, A., & Elliott, M. J. (1991). A successful modification of ultrafiltration for cardiopulmonary bypass in children. *Perfusion*, *6*(1), 41-50.
5. Sever, K., Tansel, T., Basaran, M., Kafalı, E., Ugurlucan, M., Ali Sayın, O., ... & Onursal, E. (2004). The benefits of continuous ultrafiltration in pediatric cardiac surgery. *Scandinavian Cardiovascular Journal*, *38*(5), 307-311.
6. Mohanlall, R., Adam, J., & Nemlander, A. (2014). Venoarterial modified ultrafiltration versus conventional arteriovenous modified ultrafiltration during cardiopulmonary bypass surgery. *Annals of Saudi medicine*, *34*(1), 18-30.
7. Williams, G. D., Ramamoorthy, C., Chu, L., Hammer, G. B., Kamra, K., Boltz, M. G., ... & Reddy, V. M. (2006). Modified and conventional ultrafiltration during pediatric cardiac surgery: clinical outcomes compared. *The Journal of thoracic and cardiovascular surgery*, *132*(6), 1291-1298.
8. Singh, S., & Mahrous, D.E. (2019). Conventional Ultrafiltration versus Combined Conventional and Modified Ultrafiltration on Clinical Outcomes of Pediatric Cardiac Surgery. J Anesth Clin Res, 10,12;1-6.
9. Kuratani, N., Bunsangjaroen, P., Srimueang, T., Masaki, E., Suzuki, T., & Katogi, T. (2011). Modified versus conventional ultrafiltration in pediatric cardiac surgery: A meta-analysis of randomized controlled trials comparing clinical outcome parameters. *The Journal of thoracic and cardiovascular surgery*, *142*(4), 861-867.
10. Milovanovic, V., Bisenic, D., Mimic, B., Ali, B., Cantinotti, M., Soldatovic, I., ... & Ilic, S. (2018). Reevaluating the importance of modified ultrafiltration in contemporary pediatric cardiac surgery. *Journal of clinical medicine*, *7*(12), 498.
11. Torina, A. G., Silveira-Filho, L. M., Vilarinho, K. A., Eghtesady, P., Oliveira, P. P., Sposito, A. C., & Petrucci, O. (2012). Use of modified ultrafiltration in adults undergoing coronary artery bypass grafting is associated with inflammatory modulation and less postoperative blood loss: a randomized and controlled study. *The Journal of thoracic and cardiovascular surgery*, *144*(3), 663-670.
12. Kotani, Y., Honjo, O., Osaki, S., Kawabata, T., Ugaki, S., Fujii, Y., ... & Sano, S. (2008). Effect of modified ultrafiltration on postoperative course in neonates with complete transposition of the great arteries undergoing arterial switch operation. *Circulation Journal*, *72*(9), 1476-1480.
13. Sahoo, T. K., Kiran, U., Kapoor, P. M., Choudhary, S. K., & Choudhury, M. (2007). Effects of combined conventional ultrafiltration and a simplified modified ultrafiltration in adult cardiac surgery. *Indian Journal of Thoracic and Cardiovascular Surgery*, *23*(2), 116-124.
14. Maluf, M. A., Mangia, C., Silva, C., & Carvalho, W. B. D. (2001). Conentional and conventional plus modified ultrafiltration during cardiac surgery in high-risk congenital heart disease. *Journal Of Cardiovascular Surgery*, *42*(4), 465.
15. Thompson, L. D., McElhinney, D. B., Findlay, P., Miller-Hance, W., Chen, M. J., Minami, M., ... & Hanley, F. L. (2001). A prospective randomized study comparing volume-standardized modified and conventional ultrafiltration in pediatric cardiac surgery. *The Journal of thoracic and cardiovascular surgery*, *122*(2), 220-228.
16. Chaturvedi, R. R., Shore, D. F., White, P. A., Scallan, M. H., Gothard, J. W., Redington, A. N., & Lincoln, C. (1999). Modified ultrafiltration improves global left ventricular systolic function after open-heart surgery in infants and children. *European journal of cardio-thoracic surgery*, *15*(6), 742-746.
17. Javadpour, H., Siddiah, V., & Redmond, M. (2009). Effects of modified ultrafiltration in children undergoing repair of complete atrioventricular canal defect. *J Cardiovasc Thorac Res. 1*:1–4.
18. Singh, S., Okyere, I., & Singh, A. (2020). A Team-Based Approach to Surgical and Anaesthetic Care for Children with Congenital Heart Disease in a Low Resource Setting in Ghana West Africa. *RAJAR*, *6* (1), 2610-2615
19. Fellahi, J. L., Parienti, J. J., Hanouz, J. L., Plaud, B., Riou, B., & Ouattara, A. (2008). Perioperative Use of Dobutamine in Cardiac Surgery and Adverse Cardiac OutcomePropensity-adjusted Analyses. *Anesthesiology: The Journal of the American Society of Anesthesiologists*, *108*(6), 979-987.
20. Shahin, J., deVarennes, B., Tse, C. W., Amarica, D. A., & Dial, S. (2011). The relationship between inotrope exposure, six-hour postoperative physiological variables, hospital mortality and

renal dysfunction in patients undergoing cardiac surgery. *Critical Care*, *15*(4), R162.

21. Ziyaeifard, M., Alizadehasl, A., Aghdaii, N., Rahimzadeh, P., Masoumi, G., Golzari, S. E., ... & Gorjipur, F. (2016). The effect of combined conventional and modified ultrafiltration on mechanical ventilation and hemodynamic changes in congenital heart surgery. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, *21*.
22. Singh, S. (2020). A Comparative Clinical Study of Oral Clonidine Versus Intravenous Clonidine on Haemodynamic Changes due to Laryngoscopy and Endotracheal Intubation. *Pharmaceutical Science and Technology*, *3*(2), 34.
23. Murkin, J. M. (2010, September). Panvascular inflammation and mechanisms of injury in perioperative CNS outcomes. *Seminars in Cardiothoracic and Vascular Anesthesia*. *14* (3), 190–95.