Ultrafiltration during Cardiac Surgery requiring Cardiopulmonary Bypass and its effect on Acute Kidney Injury

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Introduction

- Acute kidney injury (AKI) is a common complication of cardiac surgery procedures. AKI is associated with a significant increase in mortality, morbidities, and enhanced healthcare costs.
- Cardiopulmonary bypass (CPB) is the most common tool to provide an appropriate operative field during cardiac surgeries, but it is associated with isovolemic hemodilution. To mitigate these effects, we use Ultrafiltration along with CPB.
- Ultrafiltration (UF) involves blood filtration through a semipermeable membrane to remove plasma water.
- It remains debatable whether the hemodilution impacts renal function and whether UF implementation further worsens renal function.
- This study aimed to assess the weight-adjusted volume of ultrafiltration on the risk of AKI following CBP surgeries.

Methods and Materials

- All adult patients (≥ 18 years old) who underwent cardiac surgery with CBP were included.
- We excluded patients with a) known pregnancy, b) cirrhosis, c) presumed or confirmed infection, d) preoperative hemodynamic instability (i.e., arterial hypotension or vasopressor infusion), e) emergency cardiac surgeries, f) implantation of mechanical circulatory support devices, g) transplant surgery, and h) vulnerable adult.
- These were divided into four groups based on the weight-adjusted UF volume, including 1) no volume removal, 2) 0.1-17.9, 3) 18-29.9, and 4) >30 ml per kg of body weight.
- Postoperative AKI status was defined based on Improving Global Outcomes (KDIGO) criteria, which uses preoperative serum Cr as baseline and compares this value with postoperative daily serum Cr for seven days after surgery; an increase in serum Cr (≥ 0.3 mg/dL) within 48 hours following surgery, increase in serum Cr concentration ≥ 1.5-fold baseline, or urine volume <0.5 mL/kg/h for seven days.

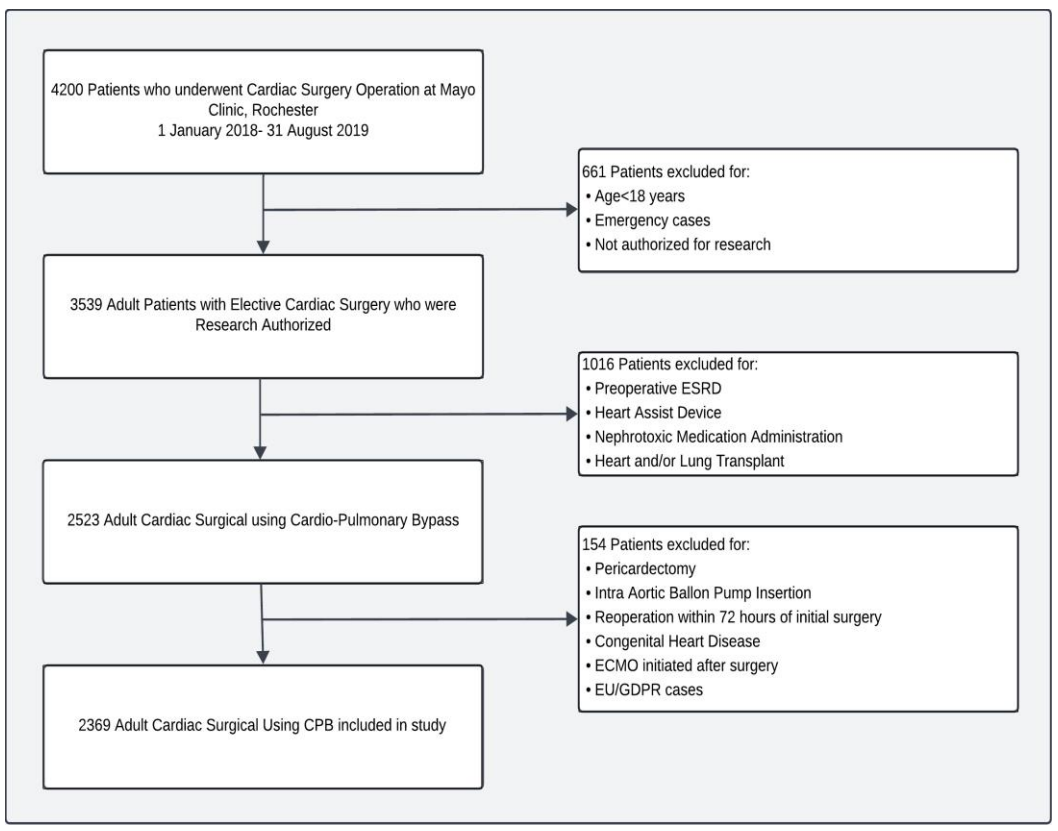
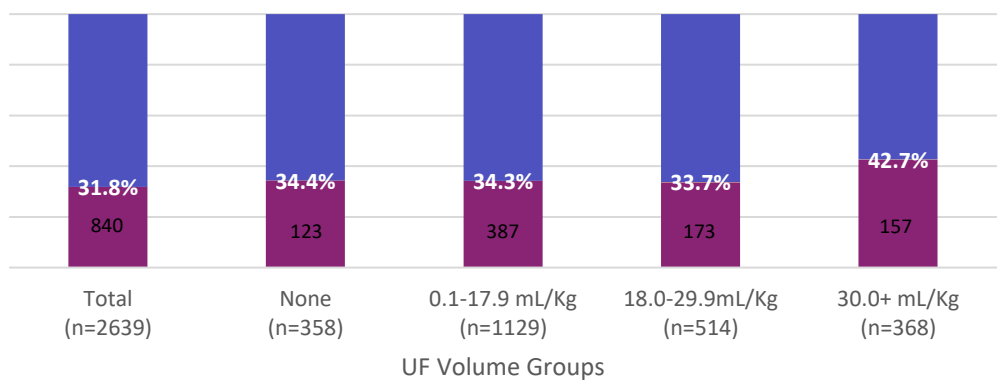


Table 1 – Selection of the Study Population.

Results

- A total of 2369 patients were included in the study with an average age of 65.6 years (IQR = 56.2 – 72.9 years). 66.5% (N=1575) were male.
- There was no significant difference between the age (p = 0.819) and sex (p = 0.104) of the patients across the four groups. The average BMI and BSA differed significantly between UF volume groups(p<0.001). The history of CHF, CAD, hypertension, AF, hypercholesterolemia, elevated triglyceride, use of statin, and hydrochlorothiazide use significantly differed between UF volume groups. (P<0.05)
- Among the Operative Variables: Preoperative Hemoglobin, CPB duration, Aortic cross-clamp duration, Anesthesia duration, Lowest MAP during CPB, Lowest intraoperative Hb significantly differed between UF volume groups. (P<0.05)

AKI incidence according to Weight adjusted UF Volume groups
p-value=0.019



	Model 1		Model 2		Model 3	
	OR (95% CI)	p-Value	OR (95% CI)	p-Value	OR (95% CI)	p-Value
Ultrafilteration and AKI	1.12 (1.06, 1.17)	**<.001**	1.14 (1.07, 1.20)	**<.001**	1.07 (0.99, 1.16)	0.076
Interaction analysis, association between UF and AKI according to nadir hemoglobin						
UF @ nadir Hb= 6 g/dL	1.33 (1.19, 1.49)	**<.001**	1.31 (1.16, 1.47)	**<.001**	1.22 (1.03, 1.44)	**0.024**
UF @ nadir Hb= 8 g/dL	1.18 (1.10, 1.27)	**<.001**	1.19 (1.10, 1.29)	**<.001**	1.14 (1.02, 1.28)	**0.018**
UF @ nadir Hb= 10 g/dL	1.05 (1.00, 1.12)	0.073	1.09 (1.02, 1.16)	**0.009**	1.08 (0.99, 1.17)	0.080
UF @ nadir Hb= 12 g/dL	0.94 (0.86, 1.02)	0.151	0.99 (0.91, 1.09)	0.876	1.01 (0.91, 1.13)	0.808
Interaction analysis, association between UF and AKI according to OR RBC transfusion requirement						
UF @ RBC volume = 0	1.08 (1.01, 1.14)	**0.020**	1.09 (1.02, 1.17)	**0.014**	1.07 (0.98, 1.17)	0.143
UF @ RBC volume = 330 mL	1.07 (1.01, 1.13)	**0.019**	1.09 (1.03, 1.16)	**0.006**	1.07 (0.99, 1.16)	0.101
UF @ RBC volume = 660 mL	1.06 (1.00, 1.12)	0.054	1.09 (1.02, 1.16)	**0.008**	1.07 (0.98, 1.17)	0.149
UF @ RBC volume = 990 mL	1.05 (0.98, 1.13)	0.172	1.09 (1.01, 1.18)	**0.024**	1.07 (0.95, 1.21)	0.263

Abbreviations: OR=Odds ratio; CPB=cardio-pulmonary bypass; g/dL=grams per deciliter; BMI=body mass index; RBC = red blood cells.

Table 2 – Estimated association between ultrafiltration volume and acute kidney injury
*Odds ratios correspond to the increased odds of developing acute kidney injury associated with the variable of interest. Estimates for the effect of UF are per 10 mL/kg increase. - **Model 1** is unadjusted. - **Model 2** is adjusted for covariates known before surgery (age, BMI, chronic kidney disease stage, history of congestive heart failure, myocardial infarction, atrial fibrillation or flutter, diabetes, hypertension, hypercholesterolemia, coronary artery disease, and peripheral vascular disease). - **Model 3** is adjusted for both covariates known before surgery and the duration of aortic cross-clamp and CPB. Interaction models include the main effects of the specified variables and the UF-by-variable interaction term.

Conclusion

This study underscores the importance of carefully considering ultrafiltration strategies during cardiac surgeries to potentially mitigate the risk of AKI. It also highlights the necessity for comprehensive intraoperative monitoring and assessment for blood product transfusion to reduce the risk of AKI.