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A Retrospective Observational Study to Study the Effect of Mean Arterial Pressure on Renal Function During Cardiopulmonary Bypass

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Abstract

Introduction: This study is aimed to study the effect of mean arterial pressure (MAP) on renal function of adult patients undergoing cardiac surgery with cardioplulmonary bypass (CPB). *Methods*: A retrospective observational study was conducted and included a total of 99 patients who had undergone cardiac surgery under CPB. Renal dysfunction was assessed using RIFLE criterion during early post operative period. Patients were divided into those whose MAP was <50mmHg second group of patients where MAP was more than 50 mmHg. Total CPB time & aortic cross time (ACC) were recorded during surgery and post-operatively renal parameters (creatinine & urine output), blood transfusions requirements, hospital stay and mortality associated with renal dysfunction and prolonged CPB & ACC were studied. statistical analysis of observed parameters was done with p-value <0.05 considered significant. *Results:* Pre-operative patient demographics were recorded. Coronary artery bypass surgery (CABG) were the maximum cases performed followed by valve replacement surgeries. There was significant association between MAP <50mmHg to renal dysfunction (p<0.001), and between mortality to renal dysfunction (p<0.001). It was observed that prolonged CPB time & ACC time was statistical significantly associated with renal dysfunction (p=0.019; 0.023), CSA-AKI (p=0.007; 0.021), blood transfusions (p=0.04; 0.283) & mortality (p<0.001; 0.005). *Conclusion*: MAP of more than 50 mmHg is desirable and recommended to prevent cardiac surgery associated acute renal injury during CPB and every effort should be made to shorten CPB time & ACC time to improve post-operative results.

Keywords: Mean Arterial Pressure; Renal Dysfunction; Cardiac Surgery; Cardiopulmonary Bypass.

Introduction

The kidneys are particularly susceptible to injury following cardiac surgery with cardiopulmonary bypass (CPB). Cardiac surgery associated acute renal injury (CSA-AKI) has been reported in upto 30% of patients undergoing various cardiac surgical procedures and around 1% patients these patients require hemodialysis [1]. The kidneys recieve around 20% of cardiac output [21] and renal blood flow begins to decline at mean arterial pressure of less than 50 to 60 mmHg [2,3]. CPB causes major changes in renal physiology with non-pulsatile blood flow, hemodilution, hypothermia, release of stress hormones, mediators of inflammation and activation of complement system and decreased mean arterial perfusion pressure, all contributing to renal injury from mild to severe levels [4-7]. Prevention of renal injury is therefore of paramount importance during CPB and every effort should be made to prevent CSA-AKI as no causal therapy for AKI is present. Accordingly, we conducted a study to evaluate the association between mean arterial perfusion pressure (MAP) and renal dysfunction during cardiopulmonary bypass in adult patients undergoing cardiac surgery at our centre.

Methods

We conducted a retrospective observational study from 01.01.2010 till 31.12.2012 (two years) and included all adult patients who had undergone cardiac surgery with cardiopulmonary bypass (CPB) at Cardiac Centre, PS Medical College And Shri Krishna Hospital, Karamsad, Gujarat. A total of 99 patients were enrolled for our study. Patient with pre-operative serum creatinine level more than 1.4% mg were excluded.

Data Recording: Typed proforma was used to register all patient variables from pre-operative patient demographics, pre op investigations, intraoperative parameters and post operative course. Mean Arterial/Perfusion pressure (MAP) during cardiopulmonary bypass was recorded from perfusion charts of patient. A mean of MAP was derived and recorded. In post operative course we used “Rifle criterion” (RIFLE - R-risk; I-injury; F-failure; L-loss of function & E-end stage renal disease) [8,9] to record renal dysfunction taking in consideration creatinine value and urine output.

Rifle criteria for acute kidney injury- Determines five levels of renal injury-

1. *risk*–serum creatinine rises to more than 1.5 mg% or urine output less than 0.5 ml/kg/hour for 6 hours.
2. *injury*–serum creatinine more than 2.0 mg% or urine output less than 0.5 ml/kg/hour for 12 hours.
3. *failure*–serum creatinine more than 3.0 mg% or urine output less than 0.3 ml/kg/hour for 24 hours or anuria for 12 hours.
4. *Loss of function.*
5. *End stage renal disease.*

Technique of cardiopulmonary bypass: All surgeries performed via midline sternotomy. Cardio pulmonary bypass (CPB) was instituted via aortic cannulation and venous drainage achieved via bi-caval venous cannulation after heparinisation @ 400IU/ kg body weight and activated clotting time achieved of more thn 480 seconds. Hollow fiber polypropylene membrane oxygenator and roller pump was used in all patients and mild hypothermia was implemented. Blood cardioplegia with ratio of 4:1 with high potassium (24mmol/l) was infused after cross clamping aorta and low potassium (12mmol/l) cardioplegia for maintenance was used for myocardial protection. After surrgery, heparin action was reversed with protamine and patients were transferred to the post-operative cardiothoracic intensive care unit. Continuous Intra-arterial blood pressure monitoring was done throughout the surgery and mean arterial/perfusion pressure recorded.

Statistical Analysis: Patient data recorded on Microsoft EXCEL data sheet in rows & columns. Data was analyzed using Statistical Package for Social Sciences (SPSS) version 15.0. Chi-square and Independent samples ‘t’-tests were used to compare the data. The confidence level of the study was kept at 95%, hence a “p” value less than 0.05 indicated a statistically significant association.

Results

The present study was carried out with an aim to evaluate the association of mean arterial perfusion pressure during cardiopulmonary bypass surgery with renal derangement. A total of 99 patients were enrolled in the study. The patients pre-operative demographics were recorded as shown in Table 1.

For various cardiac diseases diagnosed, the patients underwent the following procedures as depicted in Figure 1.

Table 1: Demographic and anthropometric profile of patients enrolled in the study

S. N.	Characteristic	Statistic
1.	Mean Age±SD (Range) in years	50.26±15.43 (16-75)
2.	Gender	
	Male	69 (69.7%)
	Female	30 (30.3%)
3.	Mean body weight±SD (Range) in kg	63.0±13.9 (27-100)
4.	Mean height±SD (Range) in cm	161.6±9.0 (115-183)
5.	Mean BSA±SD (Range) in m^2	1.65±0.21 (1.05-2.04)

Follow up for evaluating renal derangement was done on postoperative Day 1, 2, 3, 4, 5 & 7 respectively with maximum number of renal derangements observed on Day 2 (n=29; 29.3%) as shown in Figure 1.

Mean MAP values of patients having renal derangement (49.56±6.52 mm Hg) were lower as compared to those of patients not having renal

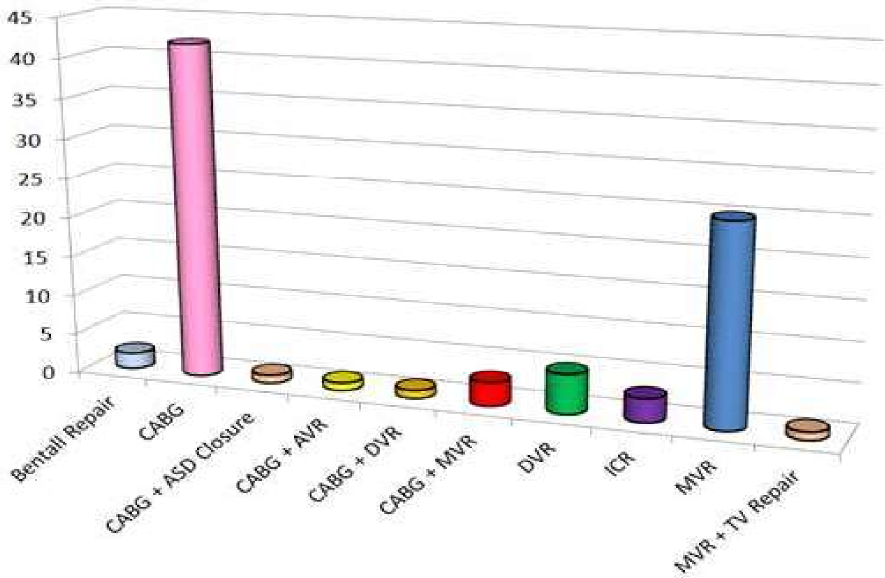

Fig. 1: Distribution of operations performed for various diagnosis. (CABG-coronary artery bypass surgery; ASD-atrial septal defect closure; AVR/MVR/DVR-aortic/mitral/double valve replacement; ICR-intra cardiac repair; TV-tricuspid valve repair)

Table 2: Distribution of patients according to occurrence of renal derangement at different post-operative follow-up intervals

Time	Cases followed up	No. of cases with renal derangement (Cr>1.5)	% Derangement
Day 1	99	25	25.3
Day 2	99	29	29.3
Day 3	99	21	21.2
Day 5	99	17	17.2
Day 7	24	6	25.0

derangement (54.01±5.34 mm Hg) and difference was significant ($p<0.001$). A total of 75 patients had MAP >50 mm Hg, out of these only 12 (16%) had post-operative renal derangement. However, out of 24 patients having MAP<50 mm Hg, a total of 20 (83.3%) had renal derangement. Statistically, the proportion of patients having post-operative renal derangement was significantly higher among cases with MAP <50 mm Hg as compared to those having MAP >50 mm Hg ($p<0.001$) (Table 3).

Mean CPB time (min) and aortic cross clamp (ACC) time (min) were significantly higher among those having post-operative renal derangement as

Table 3: Association between low MAP (<50 mm of Hg) and event of post-operative renal derangement (χ^2=37.68; $p<0.001$)

S. N.	Renal Derangement	MAP≥50 (n=75)		MAP <50 (n=24)	
		No.	%	No.	%
1.	No	63	84.0	4	16.7
2.	Yes	12	16.0	20	83.3

Table 4: Association of length of CPB and ACC with renal dysfunction.

S. N.	Variable	No Renal dysfunction (n=67)		Renal dysfunction (n=32)		Statistical significance	
		Mean	SD	Mean	SD	't'	'p
1.	CPB Time (min)	148.64	55.75	179.91	70.83	2.386	0.019
2.	ACC Time (min)	98.22	41.72	121.28	54.98	2.314	0.023

Table 5: Association between length of CPB and ACC and different post-operative outcomes

S. N.	Outcome	CPB≤180 min (n=65)		CPB>180 min (n=34)		Statistical significance		ACC≤120 min (n=68)		ACC>120 min (n=31)		Statistical significance	
		No.	%	No.	%	χ^2	P	No.	%	No.	%	χ^2	P
1.	CSA-AKI												
	No	50	76.9	17	50.0	7.39	0.007	51	75.0	16	51.6	5.324	0.021
	Yes	15	23.1	17	50.0			17	25.0	15	48.4		
2.	>2 PCV												
	No	61	93.8	27	79.4	4.70	0.030	62	91.2	26	83.9	1.151	0.283
	Yes	4	6.2	7	20.6			6	8.8	5	16.1		
3.	Hosp. ≥7												
	No	52	80.0	23	67.6	1.85	0.173	54	79.4	21	67.7	1.579	0.209
	Yes	13	20.0	11	32.4			14	20.6	10	32.3		
4.	Mortality												
	No	65	100.0	28	82.4	12.2	<0.001	67	98.5	26	83.9	8.036	0.005
	Yes	0	0	6	17.6			1	1.5	5	16.1		

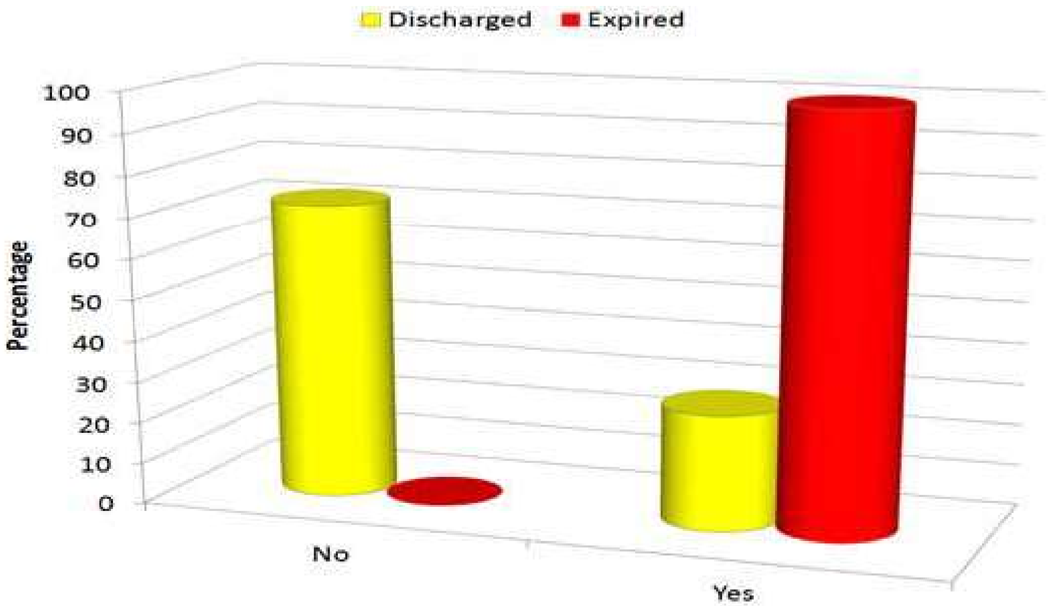

Fig. 2: Association of renal dysfunction to mortality (χ^2=13.373; p<0.001)

compared to those not having post-operative renal derangement (p<0.05) (Table 4).

Additional findings during post operative period in our study showed that CSA-AKI and mortality was significantly higher (p<0.05) in patients requiring prolonged CPB support (>180 mins) and had prolonged ACC time (>120 mins). Need for more than two packed red blood cell (PCV) transfusion was significantly higher (p<0.05) in patients on prolonged CPB. Hospital stay, although more than normal, but was not found to be statistically significant (p>0.05)(Table 5).

Among those who were discharged, only 28% had some renal dysfunction, however, all the cases who expired had renal dysfunction. Statistically, a significant association between renal dysfunction and mortality was observed (p<0.001).

Discussion

The kidneys recieve 20% of total cardiac output and studies have reported that renal blood flow reduced by even 40% has lead to various degrees of renal cell injury. As many as 30% patients develop some sort of renal dysfunction post cardiac surgery with CPB and of these around 1% require renal replacement therapy in form of hemodialysis [1,10]. These cardiac surgery associated acute kidney injury (CSA-AKI) lead to higher morbidity and mortality post operatively. The thick ascending loop of henle (mTAT) situated in renal medulla is highly susceptible to ischemia / hypoperfusion as the medulla recieves 10% whereas cortex receives 90% of total renal blood flow [3,9]. During CPB major changes take place in renal physiology as mentioned earlier with mean arterial perfusion pressure being one of the most important factors for renal blood flow. Ascione et al., identified this injury with hypoperfusion as well as loss of pulsatile perfusion [7]. Mean arterial pressure is a result of total blood flow rate and arterial resistance which in turn is dependent on blood viscosity and hematocrit and hypothermia. Therefore, an intricate set of events have to be taken into consideration to prevent acute renal injury.

In our study we did a retrospective observational analysis to study the effect of mean arterial pressure (MAP) during CPB to assess the development of early post-operative cardiac surgery associated –acute kidney injury (CSA-AKI) on ninety nine consecutive adult patients undergoing cardiac surgery at our center. We assessed renal injury post CPB using RIFLE criterion [8,9], although glomerular filtration rate (GFR) and creatinine clearance rate are more precise indicators of renal injury, their measurement requires more resources.

The patient demographics in our study population are depicted in Table-1 and the age of patients ranged from 16 to 75 years with a mean value of 50.26±15.43 years. Male to female ratio in our study subjects was 2.3:1 (table 1). Coronary artery disease was the most common diagnostic entity (n=41; 41.4%) followed by rheumatic valvular heart diseases and coronary artery bypass surgery (CABG) followed by valve replacement surgery remained most commonly performed surgeries respectively as shown in Figure 1.

In our study we observed that MAP ranged from 42 to 83 mm of Hg with a mean value of 52.58±6.09 mm of Hg. A total of 24 (24.2%) patients had MAP values <50 mm of Hg whereas75 patients had MAP >50 mm Hg. Follow up for evaluating renal derangement done on postoperative-day 1,2,3,4,5 & 7 tabulated in Table 2. We observed that the proportion of patients having post-operative renal derangement was statistically significantly higher among cases with MAP <50 mm Hg as compared to those having MAP >50 mm Hg (p<0.001) as depicted in table 3. Jinu Joseph et al. [11] reported that higher mean arterial pressures help to maintain sufficient glomerular filtration pressures, whereas lower MAP could not be defined. Nuzat et al. [9], concluded in their study that MAP less than 50mm Hg and low flow during CPB is one of the risk factors for acute kidney injury with significant association between low MAP and CSA-AKI. At many cardiac centers, clinicians maintain MAP of 50–60 mm Hg during CPB in the majority of adult patients undergoing bypass. Other data support higher MAPs (>70 mm Hg) during CPB [12-15].

Murphy GS et al.,(16) in their study found that the optimal MAP to ensure adequate tissue perfusion during CPB has not been established. In particular, the lower limit of safe renal perfusion pressure is uncertain and higher MAP >70-80mmHg leads to autoregulation . At many cardiac centers, clinicians maintain MAP of 50–60 mm Hg during CPB in the majority of adult patients undergoing bypass. In a study of 511 patients undergoing CPB by Slogoff S et al. [17], MAPs 50 mmHg (expressed as absolute values or intensity-duration units) were not predictors of postoperative renal or neurologic dysfunction. In contrast, Reich et al. [18], identified hypotension during bypass (defined as a MAP <50 mm Hg) as a significant predictor of mortality in a cohort of 2149 CABG patients. Gold et al. [15], compared two strategies of blood pressure management during CPB and concluded that high MAP may improve outcomes, but this finding could not be subsequently validated either.

In our analysis, we tried to study other variables also which have been reported to get affected during cardiopulmonary bypass while undergoing cardiac surgery. In our study, the CPB time ranged from 58 to 324 min with a mean value of 158.75±62.42 minutes & ACC time ranged from 31 to 250 min with a mean value of 105.68±47.39 minutes. Prolonged CPB time (>180 minutes) and ACC time (>120 minutes) had adverse effects on renal function and association with CSA-AKI was found to be statistically significant ($p<0.05$) as shown in Table 4. Fisher et al. [19], observed that patients who developed acute renal failure had longer periods of bypass at pressures <60 mm Hg than control patients with normal postoperative renal function. Nuzat et al. [9], reported that ACC time >40 mins, CPB time > 60 mins, low flow during CPB and age above 50 years had significant adverse renal effects after CPB. Additional findings during post operative period in our study (Table 5) showed that CSA-AKI and mortality was significantly higher ($p<0.05$) in patients requiring prolonged CPB support (>180 mins) and had prolonged ACC time (>120 mins). Higher red blood cell (PCV) transfusion was significantly higher ($p<0.05$) in patients on prolonged CPB. Length of hospital stay, although more, was not found to be statistically significant ($p>0.05$).

Stefano S, et al. [20] evaluated relation of prolonged CPB time and Nael AN, et al. [21], had studied effects of ACC on post-operative morbidity and mortality and both found deleterious effects of prolonged CPB time and prolonged ACC time on post-operative prognosis.

At discharge, 28% patients had some renal dysfunction; however, all the cases who expired had renal dysfunction. Statistically, a significant association between renal dysfunction and mortality was observed ($p<0.001$) in our study (Figure 2).

Conclusion

MAP of less than 50 mmHg has strong association to post operative renal dysfunction and patients with CSI-AKI has higher incidence of morbidity and mortality making it desirable to have MAP more than 50mmHg during CPB. It is also recommended to have shorter CPB time and ACC time for better post-operative recovery.

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