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Impact of Intraoperative Mean Arterial Pressure on Respiratory Recovery Following Coronary Artery Bypass Grafting

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ABSTRACT

Background: Coronary artery bypass graft (CABG) is a common surgery aimed at treating coronary artery disease. A vital aspect of CABG is managing hemodynamics during the cardiopulmonary bypass (CPB) phase, especially in terms of maintaining appropriate mean arterial pressure (MAP). Studies indicate that MAP levels during CPB can affect postoperative recovery, particularly regarding respiratory outcomes; however, the optimal MAP for enhanced recovery remains uncertain. This research examines the impact of two MAP targets (60 mmHg and 80 mmHg) on respiratory recovery after CABG surgery.

Methods: Eighty-six patients selected for elective on-pump CABG were grouped based on intraoperative MAP: 43 with a MAP of 60 mmHg and 43 with a MAP of 80 mmHg. We compared perioperative and postoperative metrics, such as mechanical ventilation duration, ICU stay, and re-intubation requirements. Statistical analysis used SPSS version 23, with a significance threshold of $p < 0.05$.

Results: Patients with a mean arterial pressure (MAP) of 80 mmHg experienced a significantly reduced duration of mechanical ventilation, averaging 8.23 ± 1.54 hours, in contrast to the 60 mmHg group, which averaged 10.02 ± 2.14 hours ($p = 0.001$). Additionally, the ICU stays were significantly shorter for the high MAP group, with a markedly lower re-intubation rate at 4.7%, compared to 27.9% in the lower MAP group ($p = 0.007$).

Conclusion: Sustaining a MAP of 80 mmHg during CPB enhances respiratory recovery after CABG. This is demonstrated by shorter mechanical ventilation durations and reduced ICU stays. These results indicate that effectively managing MAP during surgery could facilitate recovery by improving tissue perfusion and reducing ischemic injury, which in turn may lead to improved pulmonary outcomes.

Introduction

Coronary artery bypass graft, or CABG, is a common surgical procedure that relieves symptoms of coronary artery disease and enhances survival in patients with severely blocked coronary arteries [1]. Although it has a high probability of success, CABG comes with several complications that may arise after the procedure, including prolonged intubation for mechanical ventilation, extended ICU stays, and issues such as renal impairment, respiratory distress, or cardiovascular instability [2-3]. The management of hemodynamics during the

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cardiopulmonary bypass (CPB) phase of CABG is one of the key determinants of its success.

CPB is a component of CABG that temporarily takes over the heart and lung functions during surgical operations. Facilitating circulation and oxygenation enables surgeons to perform graft operations on both a beating and a non-beating heart. Maintaining an ideal mean arterial pressure (MAP) during CPB is essential for ensuring adequate tissue perfusion to vital organs, including the heart, brain, and kidneys, while also mitigating the risks of ischemia. However, the ideal MAP in CPB and its effects on postoperative recovery, particularly respiratory recovery, remain subjects of debate [4]. Several studies have explored the correlation between post-CPB complications and MAP. It has been found that intraoperative variability in MAP was linked to higher levels of inflammatory biomarkers and poorer outcomes, including longer ICU stays and extended days of mechanical ventilation [5]. Other studies have shown that low intraoperative MAP levels can impair tissue perfusion, leading to complications such as acute renal impairment, which indirectly affects respiratory recovery. Further research has indicated that maintaining adequate intraoperative MAP can positively impact lung oxygenation and compliance in the postoperative phase by reducing ICU stay and mechanical ventilation duration [6-7]. In this context, the current study investigates the effects of two differing MAP targets, 80 mmHg and 60 mmHg, on the postoperative recovery of CABG patients. By comparing ICU stays and ventilation duration between these two groups, it is assumed that higher MAP maintained during CPB will lead to shorter recovery periods.

Methods

In this study, we enrolled a convenience sample of 43 patients with a low MAP (60 mmHg) and 43 patients with a high MAP (80 mmHg) who were candidates for elective CABG alone at the Tehran Heart Center. The inclusion criteria included an average age of 40 to 75 years, elective CABG, and consent to participate in the study. The exclusion criteria consisted of a history of previous cardiac surgery, a history of syncope or neurological diseases, and a previous cerebrovascular accident. The internal ethics committee's research board approved the study protocol (IR. TUMS.SPH.REC.1402.122), and all patients provided informed consent. The patient group underwent elective on-pump CABG performed by skilled cardiac surgeons at the Tehran Heart Center's operating rooms, adhering to current protocols. The patient's blood pressure was measured in the operating room before anesthesia induction using a brachial cuff while the patient was in a supine position. MAP was calculated using the standard formula. A venous blood sample was obtained at baseline to measure creatinine, urea, electrolytes, blood glucose, lipid profile, blood cell count, troponin, and lactate levels. A similar measurement was performed postoperatively after the patients were transferred to the ICU. Additionally, an arterial blood sample was taken before surgery and repeated postoperatively to measure arterial blood gas characteristics, including pH, PCO_2, PaO_2, and HCO_3. All the patients were monitored during surgery and their ICU stay. Heart rate and blood pressure were recorded at the beginning of the operation before anesthesia induction and at the time of ICU admission.

Categorical data were described as frequencies (percentages) and compared between the 2 study groups using the χ^2 test. Quantitative data were checked for normal distribution using the Kolmogorov-Smirnov test. Normally distributed data were described using mean and standard deviation, while non-normally distributed data were described using medians and interquartile ranges. Variables with normal distribution were compared between the study groups using the Student t-test, while non-normally distributed data were compared using analysis of variance. All the statistical analyses were performed using SPSS, version 23.0 (IBM, NY, USA), with a P value <0.05 considered statistically significant.

Results

In this study, 86 patients were included. We compared 43 patients with a low MAP (60 mmHg) to 43 patients with a high MAP (80 mmHg). There were 39 (90.7%) male patients in the low MAP group and 35 (81.4%) male patients in the high MAP group. The operation was successful for all patients, with no complications or mortality. Perioperative and postoperative characteristics are shown in (Table 1). We found a significant difference in mechanical ventilation time and ICU stay. The need for re-intubation was 12 (27.9%) in the MAP 60 group and 2 (4.7%) in the MAP 80 group, respectively (P value = 0.007). The mean duration of mechanical ventilation was 8.23±1.54 hours for the MAP 80 group and 10.02±2.14 hours for the MAP 60 group, significantly lower in the MAP 80 group (P value = 0.001).

Table 1- The clinical characteristics of patients before and after the cardiopulmonary bypass

	Pre-CPB			**Post-CPB**		
	MAP 60	**MAP 80**	**P value**	**MAP 60**	**MAP 80**	**P value**
Heart rate	81.13+98.04	82.12+33.95	0.901	78.1+63.4	80.1+60.1	0.47
SBP	140.18+97.3	123.23+37.36	0.0001	122.14+88.7	107.3+73.9	0.007

DBP	84.9+86.49	79.7+0.017	0.002	73.1+7.84	70.1+65.5	0.422
Hemoglobin	14.1+5.66	17.2+86.74	0.366	11.0+12.6	8.1+.87.3	0.001
FBS	137.35+63.21	105.43+ 53.77	0.001	155.3+7.63	101.2+42.5	0.001
sodium	136.5+28.17	134.3+71.92	0.121	139.3+60.85	131.1+99.4	0.002
Potassium	4.0+45.75	4.0+ 10.44	0.001	5.0+83.45	5.0+0.6	0.477
Lactate	11.4+6.71	12.3+61.52	0.001	17.7+79.58	13.3+44.52	0.001
Troponin	7.1+ 36.74	2.1+28.56	0.087	7.7+4.36	1.1+87.15	0.001
CK-MB	7.4+56.56	5.1+37.25	0.056	10.3+65.41	6.1+32.5	0.001
Triglyceride	177.4+51.22	187.5+35.4	0.003	180.3+26.5	182.3+83.8	0.74
HLD	44.6+4.32	33.9+37.4	0.343	46.6+14.5	42.6+30.5	0.001
LDL	139.14+19.5	116.2+33.7	0.001	142.1+7.28	120.3+85.3	0.001
Cholesterol	201.37+67.2	177.3+30.8	0.001	194.3+19.7	188.5+33.7	0.53
BUN	37.10+0.49	30.1+73.4	0.002	39.1+81.5	29.9+17.43	0.001
Creatinine	1.0+4.21	1.0+5.2	0.757	1.0+18.19	1.0+8.23	0.043
PH	7.0+37.06	7.0+36.0	0.615	7.0+12.88	7.0+38.0	0.061
PCO2	38.3+37.24	39.4+29.2	0.264	39.5+4.32	38.3+61.6	0.666
HCO3	22.1+0.48	22.3+5.41	0.928	21.1+97.2	21.1+62.8	0.309
Urinary output	286.11+74.9	392.1+56.7	0.001	262.479.9	452.1+56.1	0.001
Blood loss	280.43+23.8	266.1+74.5	0.426	258.6+14.0	385.11+12.9	0.001

Discussion

This study explored how mean arterial pressure (MAP) during cardiopulmonary bypass (CPB) affects respiratory recovery, specifically examining the duration of mechanical ventilation and ICU stay in patients undergoing coronary artery bypass grafting (CABG). Our findings indicated that maintaining a higher MAP of 80 mmHg during CPB significantly decreased both the time required for mechanical ventilation and the length of ICU stay compared to the 60 mmHg group. This result supports the hypothesis that optimizing hemodynamic management during surgery enhances postoperative recovery, especially regarding respiratory outcomes.

During cardiopulmonary bypass (CPB), it is essential to maintain an adequate mean arterial pressure (MAP) to ensure sufficient organ perfusion and avoid ischemia. The CPB procedure momentarily takes over the roles of the heart and lungs, which are deliberately stopped for the surgery. In this condition, it is crucial to uphold adequate perfusion pressure so that vital organs, especially the brain, heart, and kidneys, receive enough blood flow [8]. The connection between MAP and organ perfusion during CPB has been extensively studied, indicating that sustaining higher MAP levels may enhance perfusion and mitigate ischemic injury to various tissues [9].

This study's outcomes are consistent with the findings of Gumus et al., which state that elevated mean arterial pressure (MAP) during cardiopulmonary bypass (CPB) improves myocardial perfusion and reduces ischemic heart damage, potentially resulting in better overall outcomes. Optimal perfusion through higher MAP can lessen the likelihood of postoperative issues, like low cardiac output syndrome, which may hinder respiratory recovery [10]. The length of mechanical ventilation and the duration of ICU stays are linked to the body's capacity to recover from ischemic and inflammatory injuries incurred during surgery [11]. Therefore, managing MAP effectively is vital for speeding up recovery after surgery. Our results corroborate this, as patients with higher MAP during CPB showed significantly shorter recovery times than those with lower MAP.

This study's key finding reveals that the duration of mechanical ventilation is reduced in the high MAP group. This shorter duration is likely due to enhanced tissue perfusion and oxygenation resulting from elevated MAP, which supports quicker recovery of respiratory function. A vital mechanism contributing to this improvement is the influence of MAP on lung compliance and oxygenation following surgery. Studies show that adequate MAP maintenance during cardiopulmonary bypass (CPB) optimizes oxygen delivery to tissues, including the lungs, which can substantially affect respiratory recovery post-CABG [12].

Research by Zhang et al. indicated that keeping a stable mean arterial pressure (MAP) throughout cardiopulmonary bypass (CPB) leads to better oxygenation and fewer pulmonary complications after surgery. This improvement in oxygenation likely explains why our high MAP group had a reduced need for mechanical ventilation, as enhanced perfusion and oxygen delivery to the lungs can enable faster weaning from the ventilator [13]. Furthermore, it has been reported that ventilation strategies during CPB, especially MAP management, can affect postoperative oxygenation and the rate of respiratory complications. By optimizing MAP, we might mitigate pulmonary issues such as atelectasis and pulmonary edema, which often contribute to extended mechanical ventilation [14].

The inflammatory response following surgery greatly influences the length of mechanical ventilation and the stay in the ICU. Maintaining a higher mean arterial pressure (MAP) during cardiopulmonary bypass (CPB) may mitigate the systemic inflammatory reaction typically initiated by surgical stress [15]. Research conducted by Hsu et al. shows that inflammatory markers, such as cytokines, are less pronounced in patients who receive optimal hemodynamic support during CPB, potentially resulting in fewer complications post-surgery. A reduced inflammatory response might alleviate respiratory distress and enable a faster recovery from mechanical ventilation, thus reducing ICU duration [16].

Our study contributes to the expanding body of literature examining the relationship between MAP during CPB and postoperative recovery, particularly regarding respiratory outcomes. Previous research has shown that maintaining an optimal MAP during CPB can enhance not only cardiac but also pulmonary recovery. For instance, it has been demonstrated that suboptimal MAP was associated with longer durations of mechanical ventilation and ICU stays in patients undergoing cardiovascular surgeries [17]. Our findings align with these studies, emphasizing the significance of MAP in enhancing respiratory recovery after cardiac surgery.

Bignami et al. conducted a randomized controlled trial that examined different mechanical ventilation strategies during CPB and their impact on postoperative outcomes, further supporting our findings. While their research focused more on ventilation strategies than mean arterial pressure (MAP), they determined that optimized mechanical ventilation parameters and hemodynamic stability during CPB are essential in reducing postoperative respiratory complications. This indicates that enhancing both ventilation and hemodynamics can collaboratively improve recovery results [16].

Conversely, maintaining a lower MAP during CPB, as seen in the 60 mmHg cohort, can result in hypoperfusion. This condition has been associated with multiple complications, including low cardiac output syndrome and renal dysfunction, which may extend the duration of mechanical ventilation. Elhaddad et al. highlighted that interrupting mechanical ventilation during CPB while also having suboptimal MAP can lead to worse outcomes, particularly affecting lung oxygenation and ventilation. Inadequate levels of MAP during CPB can diminish lung perfusion, thereby hampering gas exchange and prolonging the need for mechanical ventilation [18]. Moreover, a decreased MAP can intensify the inflammatory reaction, further hindering recovery [19]. Coleman et al. (2019) noted that inadequate hemodynamic management during CPB elevates systemic inflammation, potentially lengthening hospital stays and recovery durations. This aligns with our study's findings, which indicated that patients with lower MAP values experienced extended ICU stays, likely due to the combined impact of reduced oxygenation and inflammation [20].

This study highlights the crucial role of maintaining an optimal Mean Arterial Pressure (MAP) during Cardiopulmonary Bypass (CPB) to enhance postoperative recovery, especially concerning respiratory outcomes. By ensuring sufficient organ perfusion, a higher MAP during CPB can prevent ischemic damage and lower the chances of complications like low cardiac output and respiratory failure. This indicates that focused MAP management might serve as a straightforward yet powerful approach for accelerating recovery in CABG patients.

Future research should investigate the lasting effects of MAP management during CPB on overall patient outcomes, such as survival rates and quality of life. Moreover, studies aimed at identifying the ideal MAP range for various CABG patient subgroups (like those with conditions such as diabetes or hypertension) could facilitate more personalized interventions. Implementing advanced monitoring methods, such as tailored hemodynamic optimization and ongoing MAP monitoring, may further enhance patient outcomes while decreasing complication rates.

Conclusion

In conclusion, this study emphasizes the significant impact of maintaining an optimal Mean Arterial Pressure (MAP) during cardiopulmonary bypass (CPB) on the postoperative recovery of patients undergoing coronary artery bypass grafting (CABG). The findings suggest that a higher MAP of 80 mmHg during CPB is associated with shorter durations of mechanical ventilation and ICU stays, indicating better respiratory recovery. This outcome supports the notion that optimal hemodynamic management during surgery, particularly maintaining adequate MAP, is crucial in enhancing organ perfusion, reducing ischemic damage, and minimizing complications. The study aligns with previous research that highlights the importance of MAP in improving not only cardiac but also pulmonary recovery, offering valuable insights for clinical practice in optimizing CABG patient outcomes. Further research is necessary to explore the long-term effects of MAP management on overall survival and quality of life, as well as to refine personalized MAP targets based on patient characteristics.

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