Original Article

Effects of Advanced Hemodynamic Monitoring on the Postoperative Intubation Time in Patients With Moderate-to-Severe Left Ventricular Dysfunction Undergoing Cardiac Surgery

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ABSTRACT

Background: Advanced monitoring can lead to the early recovery of patients in complicated and high-risk surgical operations. The aim of this study was to evaluate the effects of advanced monitoring on the hemodynamics of patients undergoing cardiac surgery.

Methods: In this study, patients undergoing cardiac surgery were divided into 2 groups of control and advanced monitoring. In each group, 25 patients were examined. The patients had moderate-to-severe left ventricular dysfunction (ejection fraction < 35%). The patients in the case group were placed on the FloTrac cardiac output monitor, which is used as a therapeutic guide in the operating room and the intensive care unit (ICU).

Results: Upon ICU admission, the average stroke volume variation and the mean cardiac index in the advanced monitoring group in the first 6 hours were 10 and 2.7, respectively, and in the second 6 hours were 11 and 2.8, correspondingly. The mean serum level administered was 1000 cc in the first 6 hours and 500 cc in the second 6 hours. In the control group, the mean serum level administered was 2000 cc in the first 6 hours and 500 cc in the second 6 hours, which had a significant relationship between the 2 groups in the first 6 hours (P = 0.01). Additionally, 84% of the patients with advanced monitoring were extubated in the first 6 hours (P = 0.0).

Conclusions: This study showed that cardiac surgery in patients with moderate-to-severe left ventricular dysfunction using advanced monitoring and goal-directed hemodynamic therapy based on the cardiac index, the stroke volume variation, and the stroke volume index reduced the duration of intubation after surgery. ***(Iranian Heart Journal 2020; 21(4): 14-21)***

KEYWORDS: Advanced monitoring, Cardiac surgery

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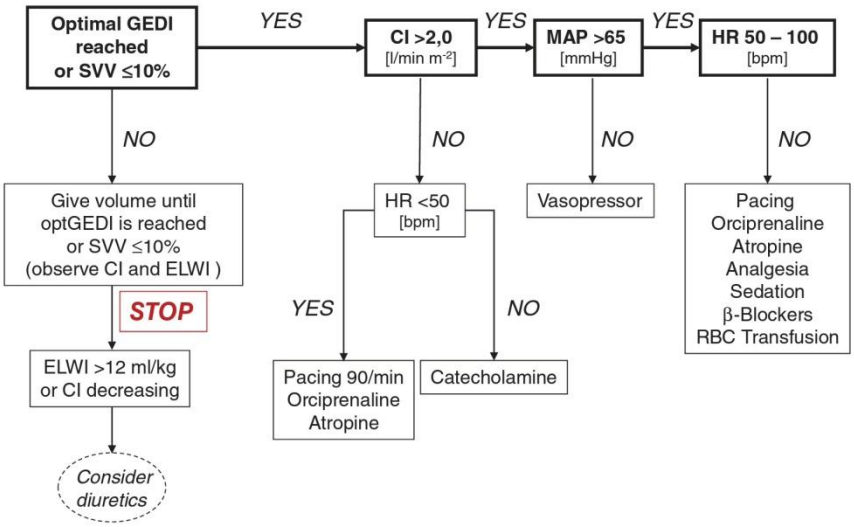
Advanced hemodynamics can confer early recovery to patients in complicated and high-risk surgical operations. Perioperative cardiocirculatory dysfunction is associated with increased morbidity. [1] The early diagnosis of cardiocirculatory dysfunction with advanced monitoring is done via the method of goal-directed therapy. It is essential for early diagnosis, timely action, and the prevention of ischemia and tissue damage, which has an impact on the clinical outcome. Studies have shown that the optimization of hemodynamics in high-risk patients (ie, those moderate-to-severe left ventricular dysfunction based on echocardiography) maintains and improves tissue oxygenation, reduces the need for mechanical ventilation, and improves the outcome. The low cardiac output syndrome is described as a part of this dysfunction. The most common definitions of the low cardiac output syndrome also include decreases in the cardiac index (< 2.0 L/min/m^2), systolic blood pressures of less than 90 mm Hg, and signs of tissue hypoperfusion (eg, cold periphery, clammy skin, confusion, oliguria, and increased lactate levels) without hypovolemia. The use of inotropic agents or mechanical circulatory support is always required to improve patients' hemodynamics. [2,3] Acute renal failure, neurological and pulmonary complications, and atrial fibrillation are the most common outcomes of the low cardiac output syndrome. [4,5] The goal of perioperative hemodynamic management in cardiac surgery should be the establishment of an equilibrium between oxygen delivery and oxygen consumption, which is especially important in patients with a low cardiac output. The choice of perioperative advanced monitoring depends on the type of surgery and patient-related risks. [6]

METHODS

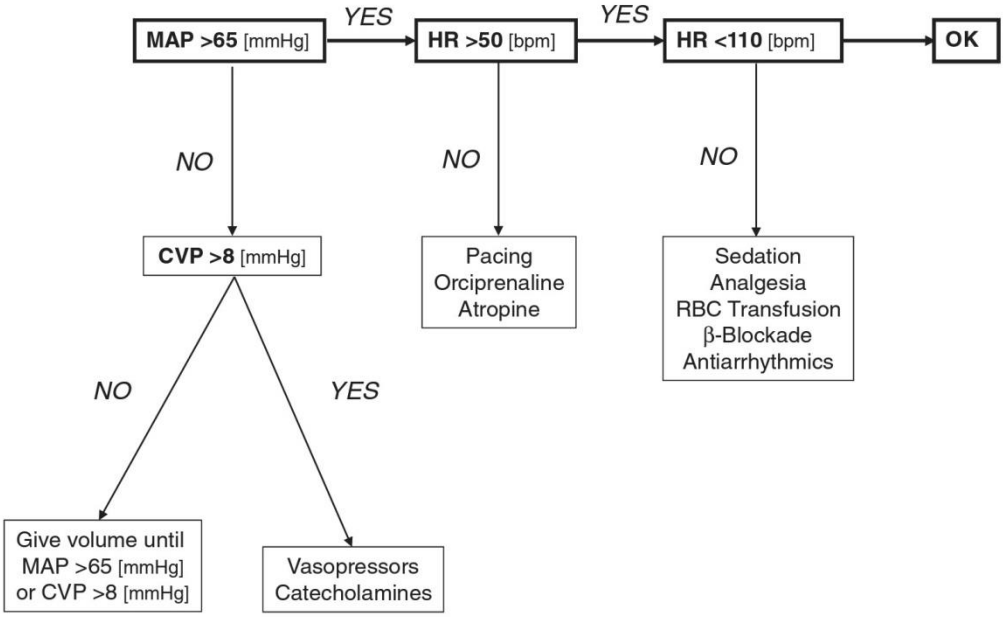
The present cross-sectional descriptive study assessed patients undergoing coronary artery bypass grafting surgery (CABG) with cardiopulmonary bypass (CPB) or cardiac valve surgery or a combination of CABG and valve surgery. The study population was divided into 2 groups of control and advanced monitoring. In each group, 25 patients were examined. Patients with moderate-to-severe left ventricular dysfunction (ejection fraction < 35%) were enrolled in the study. In our center, patients undergo anesthesia induction with midazolam (0.1 mg/kg), sufentanil (0.5 µ/kg), and cisatracurium (0.2 mg/kg), in conjunction with the maintenance doses of midazolam (1 µ/kg/min), sufentanil (0.5 µ/kg/min), and cisatracurium (1 µ/kg/min). In this study, all the patients had arterial lines and central venous lines, and the patients in the case group were placed on the FloTrac cardiac output monitor. Advanced monitoring is used as a therapeutic guide in the operating room and the intensive care unit (ICU). The therapeutic measures were investigated in the advanced monitoring group and registered. The exclusion criteria consisted of age less than 18 years, pregnancy, renal failure requiring dialysis, prior atrial fibrillation, and re-transfer to the operating room due to bleeding.

RESULTS

In this study, 25 patients in each group of control and advanced monitoring were examined. There were no significant differences in terms of demographic variables between the 2 groups.



Hemodynamic algorithm for the patients in the advanced monitoring group is presented herein.
CI, Cardiac index; ELWI, Extravascular volume index; HR, Heart rate; MAP, Mean arterial pressure; optGEDI, Optimal global end-diastolic volume index; RBC, erythrocyte concentrate; SVV, Stroke volume variation [10]



Hemodynamic algorithm for the patients in the control group is illustrated herein.
CVP, Central venous pressure; HR, Heart rate; MAP, Mean arterial pressure; RBC, Erythrocyte concentrate [10]

Table 1: Demographic and clinical characteristics of the patients

Variable		Case Group (n = 25)	Control Group (n = 25)	*P*-value
Age (y) Median (range)		62 (57-67)	61 (56-71)	0.721
Sex (male)		88%	80%	0.4
Sex (female)		12%	20%	
BMI Median (range)		24.82 (23.44-29.92)	28.08 (25.96-31.58)	0.067
CPB_time (min) median (range)		90 (82-108)	80 (67-91)	0.055
Aortic cross-clamp time (min) median (range)		51 (41-61)	35 (23-47)	0.01
HTN		20%	28%	0.5
DM		4%	28%	0.02
CABG	Count	18	20	0.6
	% within group	72.0%	80.0%	
BENTAL	Count	1	0	
	% within group	4.0%	0.0%	
AVR+CABG	Count	1	0	
	% within group	4.0%	0.0%	
AVR+CABG+MVR	Count	1	0	
	% within group	4.0%	0.0%	
HOCM	Count	1	0	
	% within group	4.0%	0.0%	
MVR	Count	1	1	
	% within group	4.0%	4.0%	
MVR+CABG	Count	1	1	
	% within group	4.0%	4.0%	
PVR+TVR	count	1	0	
	% within group	4.0%	0.0%	
ASD+CABG	Count	0	1	
	% within group	0.0%	4.0%	
AVR	Count	0	1	
	% within group	0.0%	4.0%	
AVR+MVR	Count	0	1	
	% within group	0.0%	4.0%	

BMI, Body mass index; CPB, Cardiopulmonary bypass; DM, Diabetes mellitus; HTN, Hypertension; CABG, Coronary artery bypass graft surgery; MVR, Mitral valve replacement; AVR, Aortic valve replacement; TVR, Tricuspid valve replacement; PVR, Pulmonary valve replacement; ASD, Atrial septal defect; HOCM, Hypertrophic obstructive cardiomyopathy

Hemodynamics

The median mean arterial pressure (MAP) after anesthesia induction was 80 mm Hg in both groups, while after CPB, it was 86 mm Hg in the advanced monitoring group and 68 mm Hg in the control group; the difference between the 2 groups was statistically significant (P = 0.003). The median MAP at the time of admission to the ICU was 83 mm Hg in the advanced monitoring group and 73 mm Hg in the control group (P = 0.027). The average MAP in the first 4 hours after ICU admission was 80 mm Hg in the advanced monitoring group and 78 mm Hg in the control group, indicating no statistically significant difference between the 2 groups. The median MAP in the first 6 hours after ICU admission was 83 mm Hg in the advanced monitoring group and 79 mm Hg in the control group. The median MAP in the first 12 hours after ICU admission was 81 mm Hg in the advanced monitoring

group and 82 mm Hg in the control group. Moreover, the median MAP in the first 24 hours following ICU admission was 86 mm Hg in the advanced monitoring group and 82 mm Hg in the control group, which was not statistically significant.

The mean central venous pressure (CVP) after CPB was 9 mm Hg in the case group and 4 mm Hg in the control group; the difference constituted statistical significance (P = 0.0). The median CVP after ICU admission in the advanced monitoring group and the control group was 10 mm Hg. The mean CVP in the first 4 hours following ICU admission was 12 mm Hg in the advanced monitoring group and 14 mm Hg in the control group, which did not show a statistically meaningful difference between the study groups. The mean CVP in the first 6 hours after ICU admission was 14 mm Hg in the advanced monitoring group and 16 mm Hg in the control group. Furthermore, the mean CVP in the first 12 hours following ICU admission in the advanced monitoring group and the control group was 15 mm Hg. In addition, in the first 24 hours after ICU admission, the mean CVP in the advanced monitoring group and the control group was 14 mm Hg, which was not statistically significantly different between the 2 groups. The mean stroke volume variation (SVV) in the advanced monitoring group was 10 after anesthesia induction, 10 after CPB, 12 after ICU admission, and 10 in the first 4 and 6 hours following ICU admission.

The mean cardiac index in the advanced monitoring group was 2.5 L/min/m^2 after anesthesia induction, 3.2 L/min/m^2 after CPB, 2.3 L/min/m^2 following ICU admission, 2.8 L/min/m^2 in the first 4 hours after ICU admission, 2.7 L/min/m^2 in the first 6 hours following ICU admission, 2.8 L/min/m^2 in the first 12 hours after ICU admission, and 3.2 L/min/m^2 in the first 24 hours following ICU admission.

The stroke volume (SV) and the stroke volume index (SVI) were 55 mL/beat and 32 mL/m^2, respectively, after anesthesia induction, 60 mL/beat and 35 mL/m^2 after CPB, 51 mL/beat and 28 mL/m^2 following ICU admission, 57 mL/beat and 33 mL/m^2 in the first 4 hours after ICU admission, 57 mL/beat and 33 mL/m^2in the first 6 hours following ICU admission, 53 mL/beat and 33 mL/m^2 in the first 12 hours after ICU admission, and 56 mL/beat and 33 mL/m^2 in the first 24 hours after ICU admission.

Hypertension was reported in 20% of the patients in the advanced monitoring group and 28% of the patients in the control group.

The mean serum level administered to the advanced monitoring group was 1000 cc in the first 6 hours following ICU admission and 500 cc in the second 6 hours after ICU admission. The average SVV in the advanced monitoring group was 10 in the first 6 hours after ICU admission and 11 in the second 6 hours following ICU admission. The median cardiac index was 2.7 L/min/m^2 in the first 6 hours after ICU admission and 2.82.7 L/min/m^2 in the second 6 hours following ICU admission. In the advanced monitoring group, serum administration was based on advanced monitoring. In this group, the mean CVP was 14 mm Hg in the first 6 hours and 15 mm Hg in the second 6 hours after ICU admission. The median MAP was 85 mm Hg in the first 6 hours and 81 mm Hg in the second 6 hours after ICU admission. In the control group, the mean serum level administered was 2000 cc in the first 6 hours and 500 cc in the second 6 hours; the difference between the 2 study groups in the first 6 hours was statistically significant (P = 0.01).

After CPB, 36% of the patients in the advanced monitoring group and 40% of those in the control needed inotropes. After admission to the ICU, 24% of patients in the advanced monitoring group and 48% of those in the control group needed inotropes. In the first 4 hours following ICU admission, 16% of the patients in the advanced monitoring group and 24% of

those in the control group needed inotropes. In the first 6 hours after admission to the ICU, 8% of the patients in the advanced monitoring group and 4% of those in the control group needed inotropic treatment. However, the differences between the 2 groups failed to constitute statistical significance.

According to the results, a significant relationship was found concerning the median MAP between the 2 groups with respect to the time between CPB termination and ICU admission. However, no significant relationship was observed at 4, 6, and 12 hours after entering the ICU. It should be noted that in this study, in the advanced monitoring group, serum therapy and inotropic therapy were based on advanced monitoring to achieve an SVV of less than 13 and a cardiac index of 2.4 to 3.6 L/min/m^2. Thus, a better MAP with this monitoring could be expected before ICU arrival. In both groups, the necessary steps were taken to establish acceptable hemodynamics with fluid therapy and the use of inotropes after ICU entrance. Hence, 6 hours after admission to the ICU, similar improvement was expected in the clinical condition of both groups. There was no significant relationship between the 2 groups vis-à-vis hemodynamics at 4, 6, 12, and 24 hours after ICU arrival. Still, the patients in the advanced monitoring group had hemodynamics upon arrival at the ICU and in the first 6 hours following ICU admission. SVV after CPB (before arrival to the ICU) and following ICU admission in the advanced monitoring group was 10 and 12 with corresponding cardiac indices of 3.2 and 2.3 L/min/m^2. SV and SVI were, respectively, 6055 mL/beat and 35 mL/m^2 after CPB and 51 mL/beat and 28 mL/m^2 after ICU admission, indicating the appropriateness of fluid therapy and inotropic treatment in the time interval between CPB termination and ICU arrival.

The mean CVP after CPB was 9 mm Hg in the advanced monitoring group and 4 mm Hg in the control group; the difference was statistically significant (P = 0.0). This event was also expected due to fluid therapy and the use of inotropes with advanced monitoring. Further, the average fluid level administered in the first 6 hours after ICU admission was 1000 cc in the advanced monitoring group and2000 cc in the control group, indicating proper monitoring after CPB (before arrival at the ICU) and less need for fluid therapy at the time ICU admission. In this study, 84% of the patients in the advanced monitoring group were extubated in the first 6 hours, whereas in the control group, the bulk of fluid therapy was performed in the first 6 hours, and the patients achieved appropriate hemodynamics after the first 6 hours and were thereafter extubated. There was a significant correlation between both groups in this study (P = 0.0). In regard to ICU discharge, both groups were discharged from the ICU after 24 hours.

DISCUSSION

The results of the current study showed that hemodynamic therapy based on goal-directed hemodynamic therapy with advanced monitoring for high-risk patients and patients in complicated and high-risk surgical operations both before ICU admission and during ICU stay could confer better hemodynamics, curtail the duration of intubation in the ICU, and improve clinical symptoms.

Cardiocirculatory dysfunction is the main cause of morbidity and mortality after cardiac surgery, especially in high-risk patients. Inadequate myocardial protection, in tandem with the patient's status and several perioperative factors such as prolonged aortic cross-clamp times and myocardial ischemia, might contribute to the development of this complication. The treatment of cardiocirculatory dysfunction, albeit complex, is done by augmenting tissue oxygen delivery

and providing sufficient hemodynamic support to prevent organ dysfunction exacerbation and failure. Goal-directed algorithms assist in the early detection and suitable treatment of cardiocirculatory dysfunction, leading to corrected clinical outcomes. The choice of appropriate inotropic agents to treat cardiocirculatory dysfunction should be based on their mechanism of action and clinical circumstance. [6] There is increasing evidence of the early optimization of the cardiac output insofar as the organ blood flow contributes to a reduction in postoperative complications. Hamilton et al [7] recently concluded that such a preventive strategy of hemodynamic optimization might also confer improved survival.

A few previous studies have indicated that this strategy also holds true for elective cardiac surgery. Mythen et al [8] reported that the intraoperative optimization of the cardiac output increased the splanchnic blood flow among their study population. Subsequently, McKendry et al [9] concluded that a flow-directed hemodynamic algorithm after cardiac surgery in the ICU reduced complications and the length of hospital stay. Hanc et al [10] further stated that early goal-directed hemodynamic therapy based on the cardiac index, SVV, and improved global end-diastolic volume index could reduce complications and the length of ICU stay after cardiac surgery.

All those studies, however, assessed a treatment algorithm implementing the parameters of flow or oxygen consumption and compared the results with a control group where hemodynamic management was not based on an algorithm. [11-14] Jhanji et al [15] recently published data on goal-directed hemodynamic optimization in high-risk noncardiac surgery patients. Although their data proved that peripheral and, therefore, most probably organ perfusion was improved in the treatment groups, there was no significant effect on the rate of postoperative complications.

In our study, using advanced monitoring and preserving the cardiac index and MAP, we managed to maintain proper perfusion for the organs of the body. More helpful in this domain are the so-called "functional parameters of preload"—namely SVV and pulse pressure variation—which allow a special titration of patients' optimal preload. Unfortunately, their major limitations are that not only are they dependent on controlled mechanical ventilation without any spontaneous breathing efforts but also they are unreliable in patients with arrhythmias. Consequently, these parameters are not suitable for guiding fluid therapy, if the treatment model is to be followed both during surgery and in the ICU.

During the mechanical ventilation of patients with sinus rhythms, SVV is employed to improve preload. In specific conditions, the global end-diastolic index (GEDI) is used. Whenever SVV cannot be drawn upon, (eg, when the weaning process from mechanical ventilation is initiated), the GEDI is utilized alternatively, allowing the adjustments of hemodynamics during perioperative and postoperative treatment.[15]

CONCLUSIONS

The results of the present study showed that elective cardiac surgery in patients with moderate-to-severe left ventricular dysfunction with the aid of advanced monitoring and goal-directed hemodynamic therapy based on the cardiac index, SVV, and SVI could shorten the duration of intubation after surgery.

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