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Comparison of the effect of 1:1 and 1:2 frequencies of intra-aortic balloon pump on hemodynamics of the patients undergoing coronary artery bypass graft surgery

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Original Article

Abstract

BACKGROUND: Some patients require intra-aortic balloon pump (IABP) after coronary artery bypass graft (CABG) surgery. IABP can be adjusted to different frequencies such as 1:1, 1:2, or 1:3. In this study, we tried to compare the effect of 1:1 and 1:2 frequencies of IABP on hemodynamic status of the patients after CABG surgery.

METHODS: In this experimental study, all patients using IABP after CABG surgery were entered the study as pretest and posttest groups. The study could not be blinded because of the clearness of posttest group for the same echocardiographist. The pretest group included patients using a 1:1 frequency of IABP device. The posttest group included patients in the pretest group who were exposed to a 1:2 frequency for 20 minutes. In both groups, on the moderate dose of inotropic support, hemodynamic parameters of patients including systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), cardiac output (CO), cardiac index (CI), stroke volume (SV), and velocity time integral (VTI) in the aorta during systole were measured. Both groups were compared using Wilcoxon signed rank test. SPSS software was used for analysis and $P < 0.05$ was considered to be statistically significant.

RESULTS: Twelve patients were entered into the study. Three patients were excluded because of open chest and instability of vital signs. Nine patients completed the study. 3 patients were men and 6 were women. The mean age was 58.32 ± 13.18 years. MAP in 1:1 frequency was significantly higher than 1:2 ($P = 0.043$); however, there was no significant difference between 1:1 and 1:2 in other hemodynamic parameters, namely CO, CI, SV, HR, and VTI.

CONCLUSION: In patients on moderate dose of inotropes, IABP frequencies of 1:1 and 1:2 have the same effect on hemodynamic parameters such as CI, SBP, DBP, HR, and left ventricular outflow tract (LVOT) VTI; meanwhile, MAP remains higher in 1:1 frequency.

Keywords: Coronary Artery Bypass; Hemodynamics; Intra-Aortic Balloon Pumping; Cardiotonic Agents; Counterpulsation

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Introduction

Intra-aortic balloon pump (IABP) is an auxiliary and highly effective invasive method for supporting of extreme heart failure (HF).[1-4] IABP has different frequencies for inflating and deflating the balloon and they include the full assistance of 1:1 to partial assistance of 1:2 to 1:8 frequencies. These frequencies correspond with patient heart rate (HR); the balloon inflates in early diastole to increase aortic blood pressure and coronary blood flow and deflates in late diastole to decrease cardiac afterload and improve cardiac output (CO).[5,6] The 1:1 frequency is the usual mode and other modes are usually used while trying for discontinuation of IABP. Coronary artery bypass graft (CABG) surgery is the most common cardiac surgery done to bypass severe stenosis of coronary arteries and improve blood delivery to myocardium.[7] At the end of operation, some patients experience low CO state who, despite inotropic support, need further assistance of myocardium to survive the operation. In this tough situation, IABP is one of the most useful mechanical supports.

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IABP rate of support differs between different patients, because it is dependent on patient HR. The frequency of IABP which supports heart beats can be selected by the operator. In this research, we tried to compare the effect of 1:1 and 1:2 frequencies on hemodynamic and cardiac parameters in patients undergoing CABG.

Materials and Methods

This study was approved by Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran (IR.MUI.MED.REC.1398.229) and the clinical trial code was IRCT20190922044844N1.

All the patients who needed IABP after CABG were entered the study. They were operated by different surgeons. The inclusion criteria were isolated CABG patients who needed IABP postoperatively and available echocardiographist while the patient was on moderate dose of inotropes. Exclusion criteria were death prior to evaluation, not tolerating moderate dose of inotropes, low dose inotropes, extracorporeal membrane oxygenation (ECMO), and open chest (sternotomy not closed). All the patients were divided to pretest and posttest groups. IABP machine was Maquet Datascope CS 100 with catheter size chosen based on factory recommendations according to the length of the body. When the patient was partially stable on moderate dose of inotropes, the echocardiography was done to evaluate primary outcomes, namely cardiac index (CI), CO, HR, stroke volume (SV), and velocity time integral (VTI) in aorta during systole. Mean arterial pressure (MAP), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were other primary outcomes recorded simultaneously. All the evaluations were done two times, one time while the IABP rate was 1:1 (pretest) and one while the patient was on IABP rate of 1:2 for 20 minutes (post-test) (Figure 1). Blood pressure was recorded by invasive radial artery pressure monitoring and HR was recorded by electrocardiogram (ECG) rate shown on the monitor. Echocardiography was used for evaluation of CIs. VTI was measured by left ventricular outflow tract (LVOT). The LVOT diameter was measured in the parasternal long axis view in mid-systole. The LVOT velocity time integral (VTI) provides information regarding blood velocity across the time period of systole, and is in the units of cm. It is considered a stroke distance. One needs to use pulsed wave doppler in either the apical long axis or 5 chamber view to obtain it. The VTI can be traced out on the ultrasound machine or using digital software offline. Formulas used for calculations are as below:

LVOT cross-sectional area (CSA) = 3.14 × (LVOT diameter/2)^2

SV = VTI × CSA

CO = SV × HR

CO = VTI × LVOT area × HR[8]

CI = CO/body surface area (BSA)[9]

BSA was computed by Mosteller formula:[10] BSA (m^2) = [Height (cm) × Weight (kg)]/3600]$^{0.5}$

Moderate dose of inotrope was defined as dopamine (5-10 mcg/kg/minute), dobutamine (5-7.5 mcg/kg/minute),[11-13] epinephrine (5-8 mcg/kg/minute),[14,15] and norepinephrine (5-8 mcg/kg/minute).[16]

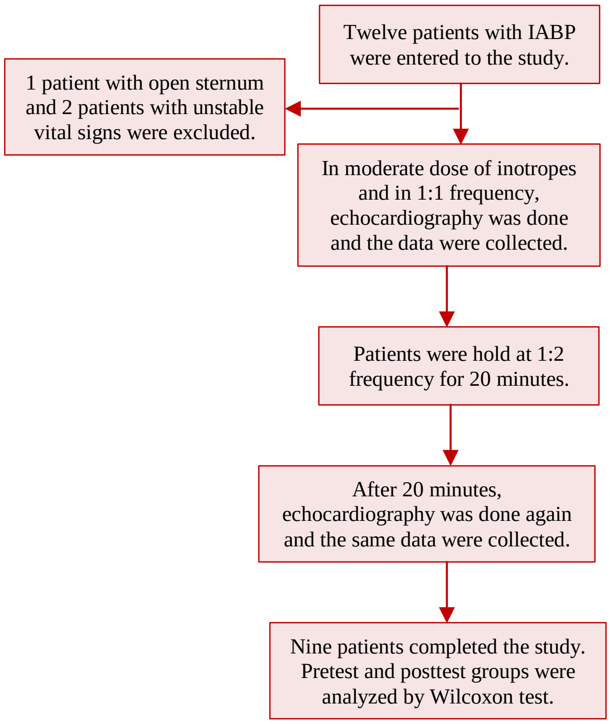

Figure 1. Study design

Statistical analysis: Continuous data were reported as mean ± standard deviation (SD). Sample size was computed as follows: $N = (Z_{1-\alpha/2} + Z_{1-\beta})^2 (S_{\sigma1}^2 + S_{\sigma2}^2)/(\mu_1-\mu_2)^2$. Considering test power of 80%, $\alpha = 0.05$, and expected mean and SD of the paired differences (102 ± 18% in 1:1 and 79 ± 15% in 1:2 group), eight patients were calculated for sample size.[17] Considering 15% breakdown, 9 patients were considered for the final sample size. Because of low sample size, Wilcoxon signed-rank test was applied for comparing the pre and post values. SPSS software (version 23.0, IBM Corporation, Armonk, NY, USA) was used for analysis and $P < 0.05$ was considered to be statistically significant.

Results

Twelve patients were entered the study. Three patients were excluded, 2 patients for unstable hemodynamic status and one patient for open chest. 3 patients were men and 6 were women. Their mean age, weight, height, and BSA were as described in table 1.

Table 1. Demographic parameters of patients completing the study (n = 9)

Variable	Mean ± SD
Age (year)	58.32 ± 13.18
Weight (kg)	75.67 ± 7.55
Height (cm)	164.78 ± 8.38
BSA (m^2)	1.86 ± 0.12

BSA: Body surface area; SD: Standard deviation

Hemodynamic parameters: Patients were grouped as pretest and posttest groups, and for each patient, the difference in hemodynamic parameters between 1:1 and 1:2 frequencies was compared. Wilcoxon test was used to analyze the data. MAP in 1:1 (84.1 ± 18.4 mmHg) was significantly higher than 1:2 (77.6 ± 17.1 mmHg) (P = 0.043). Mean SBP and DBP had no significant difference (Table 2).

There was no significant difference in CI between both groups (P = 0.109). Mean CI was 1.9 ± 0.8 l/minute/m^2 in 1:1 and 2.3 ± 1.1 l/minute/m^2 in 1:2 frequency.

Moreover, there was no significant difference in CO, HR, SV, and VTI in both groups (Table 2).

All patients had HR less than 120 beats/minute; therefore, the effect of IABP on different HRs could not be compared.

Discussion

IABP is a common assist device which is used for improving CO in cardiogenic shock cases and patients who could not be disconnected from cardiopulmonary bypass (CPB).[1] The 1:1 frequency is used commonly but the effects of this frequency and other IABP frequencies on hemodynamic status of patients have not been completely determined. In our study, we measured and compared the effect of 1:1 and 1:2 frequencies on hemodynamics of patients when their hearts were partially dependent on IABP and moderate dose of inotrope medicines was injected. Moderate dose was chosen because of ethical considerations and we were concerned about aggravating patient course by decreasing patient support in a fully dependent patient. Swan-Ganz catheter was a better option to evaluate CI, but it was not available at the time of study and it is not a routine monitoring in our center. When the patient has tachycardia, especially more than 140, some surgeons of our center choose 1:2 frequency instead of 1:1, although there is no supporting evidence for this decision.[6,18] We tried to assess whether 1:1 and 1:2 frequencies differ in terms of supporting the heart. Unfortunately, when the patients are on moderate dose of inotropes, the HR usually decreases to less than 120, as in our patients which all 9 patients had HR less than 120.

We found that on moderate dose of inotropes and in HRs of less than 120 beats/minute, the 1:2 and 1:1 frequencies made no significant difference in CI and other indexes except the MAP which was higher in 1:1 frequency. We recommend other investigators to compare 1:1 and 1:2 frequencies in HRs more than 140 and when the patient is on high dose of inotropes; the recommended tool is Swan-Ganz catheter which gives the real time evaluation of hemodynamic parameters and possible drawback of frequency if the patient hemodynamic parameters worsen. Our possible assumption is that in higher HRs, the dependency of the heart on the higher IABP frequencies will be even less which needs to be proven by a well-designed study. Further, we recommend a larger study with higher included number of patients to more definitely clarify the impact of different frequencies of IABP.

Table 2. Hemodynamic parameters in pretest and posttest groups (n = 9)

Variable	1:1 frequency (mean ± SD)	1:2 frequency (mean ± SD)	P*
MAP (mmHg)	84.1 ± 18.4	77.6 ± 17.1	0.043
SBP (mmHg)	114.2 ± 21.7	112.3 ± 22.9	0.734
DBP (mmHg)	63.9 ± 21.2	56.6 ± 21.1	0.152
HR (bpm)	101.3 ± 12.1	101.3 ± 10.4	0.891
CI (l/minute/m^2)	1.9 ± 0.8	2.3 ± 1.1	0.109
CO (l/minute)	3.4 ± 1.7	4.4 ± 2.4	0.109
SV (ml)	34.3 ± 16.0	43.8 ± 23.6	0.109
VTI (cm)	9.5 ± 2.9	12.0 ± 3.7	0.109

*Wilcoxon signed rank test

MAP: Mean arterial pressure; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate; CI: Cardiac index; CO: Cardiac output; SV: Stroke volume; VTI: Velocity time integral; SD: Standard deviation

Conclusion

In patients on moderate dose of inotropes, IABP frequencies of 1:1 and 1:2 have the same effect on hemodynamic parameters such as CI, SBP, DBP, HR, and LVOT VTI; meanwhile, MAP remains higher in 1:1 frequency.

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Conflict of Interests

Authors have no conflict of interests.

Authors' Contribution

AM and MAA contributed to design, data collection, analysis, and writing the paper. RZ participated in design, data collection, and writing.

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