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Use of Carbon dioxide versus air blower in on-pump beating-heart coronary artery bypass surgery

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ABSTRACT

Introduction: The use of carbon dioxide blower has been recognized as the standard of care in patients undergoing beating coronary artery bypass grafting (CABG) due to higher solubility and lower risk of embolization. On the other hand, the compressed air blower has gone out of use since air can be easily trapped and is less soluble which can cause coronary embolism. The present study aimed to compare the outcomes of patients undergoing on-pump beating CABG using CO2, as opposed to an air blower.

Materials and Methods: A total number of 125 patients requiring coronary revascularization underwent on-pump beating CABG within February 2017-February 2018. In the current cross sectional study, 45 patients underwent CABG with CO2 blower and other patients were operated using air blower. The reported postoperative outcomes included mortality, low cardiac output state, malignant arrhythmia, postoperative myocardial infarction, blood transfusion, transient ischemic attack or stroke, intra-aortic balloon pump (IABP), as well as intensive care unit and hospital length of stay.

Results: Demographic characteristics of patients in two groups in terms of age, sex, risk factors, echocardiographic and angiography data were similar and demonstrated no significant difference. Patients' outcomes, such as cardiac arrhythmias, myocardial infarction, ICU and hospital stays, were also similar in both groups. In addition, the overall morbidity and hospital mortality showed no significant difference between the two groups.

Conclusion: Although the use of CO2 during beating CABG has been advocated with its theoretical advantages, no significant difference was observed between the two groups in terms of mortality and morbidity using CO2, as opposed to air blower.

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Introduction

Coronary artery bypass grafting (CABG) is commonly employed to treat coronary artery disease. Nevertheless, this procedure carries the risk of various complications mostly due to the use of aortic cross-clamping, cardioplegic arrest, and cardiopulmonary bypass (CPB). In this regard, numerous attempts have been made to lower the incidence of major intraoperative and postoperative complications which arise from this procedure (1). In fact, the reported satisfactory clinical outcomes and long-term results have led to a dramatic increase in the number of bypass operations; therefore, this method retains its status as the "gold standard". Earlier efforts using different techniques were completely overwhelmed

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and almost forgotten for nearly 30 years. Excellent long-term clinical results have been reported in a wide variety of patients, especially when using the internal mammary artery(2). The superiority of CABG with the use of CPB over medical treatment and percutaneous transluminal coronary angioplasty (PTCA) in the resuscitation of medical cardiac arrest is still a debated issue. Consequently, conventional bypass surgery has been recognized as safe, effective ,durable, reproducible, complete, versatile and teachable(3).In general, only 64.3% of patients developed no complications(4). In addition, based on health insurance and clinical data, 10.2% of patients do not leave the hospital within 14 days after the operation, and 3.6% of them are discharged to a non-acute care facility (5).

Although the optimal method of arteriotomy visualization has not been yet identified, it has been suggested that a catheter-directed stream of compressed air, oxygen, or carbon dioxide is beneficial. These methods provide a dry operative field during distal coronary anastomosis allowing clear visualization of the anastomotic suture line without halation. However, blowing of compressed air or oxygen into the coronary artery may cause embolic complications(6). Back-bleeding from septal perforator branches (SPBs) in the vicinity of the arteriotomy may impede the maintenance of a dry bloodless surgical field. This can be tackled by frequent blotting, intermittent saline infusion, or the use of high-flow carbon dioxide moisturized insufflation (3). As opposed to conventional CABG, surgeons need an innovative and more flexible attitude to create optimal conditions consistently during off-pump bypass surgery surgery(7). Blowers using carbon dioxide gas instead of compressed air were safely employed due to higher solubility of CO_2 in blood (8).

To the best of our knowledge, this is the first study which compares the CO_2 blower with air blower. The present study aimed to compare the outcomes of patients who underwent on-pump beating CABG using CO_2 versus air blower.

Materials and Methods

This cross sectional study aimed to evaluate the outcomes of patients undergoing on-pump beating CABG using CO_2 versus air blower. A total number of 125 patients requiring coronary revascularization underwent on-pump beating CABG within February 2017-February 2018.

Study population

The inclusion criteria entailed: 1) an ejection fraction (EF) value evaluated by pre-operation transthoracic echocardiography (TTE) between 30% and 60%, 2) ischemic heart disease that met surgical revascularization criteria, 3) no other cardiac disease, such as ventricular septal defect, 4) moderate to severe mitral regurgitation, and 5) left ventricle aneurysm that needed to be intervened at the same time. Finally, 45 patients underwent CABG with CO_2 blower, and other patients were operated on using air blower.

Procedure

The operation continued with the assisted beating heart. The temperature of patients was maintained at about 36°C without cooling (normothermic). The distal anastomoses were constructed before the proximal anastomoses. The left anterior descending artery (LAD) was initially revascularized with the internal thoracic artery (ITA), followed by the circumflex (Cx) and right coronary arteries (RCA). Regional myocardial immobilization was achieved by a suction stabilizer. We did not use an apical suction cardiac positioning device for revascularization. During anastomoses, target vessel homeostasis was obtained with temporary occlusion of the proximal coronary artery ,and/or a humidified carbon dioxide or air blower was used for better visualization. The proximal anastomoses were created by 5-0 or 6-0 polypropylene sutures under a partial occlusion clamp. After weaning from CPB and decannulation, the heparin was reversed by protamine infusion.

Assessment and follow-up

Postoperative complications included mortality, low cardiac output state, malignant arrhythmia, postoperative myocardial infarction (MI), blood transfusion, transient ischemic attack or stroke, intra-aortic balloon pump (IABP), as well as intensive care unit and hospital length of stay.

The patients were followed-up until discharge from the hospital. In-hospital mortality was defined as death occurring for any reason within 30 days of the operation. Perioperative acute MI was defined as the appearance of new Q-waves or a marked loss of R-wave forces and peak creatine phosphokinase (CK-MB) fractions greater than 10% of total creatine kinase.

Ethics

The present study was approved by the Ethical Committee of Mashhad University of Medical Sciences. It is worthy to note that written informed consent was obtained from all participants.

Statistics

The obtained data were analyzed in SPSS software (version 21). The descriptive variables were reported as frequency, percent, and continuous quantitative variables were indicated as mean and standard deviation. Independent T-Test was used to compare mean in two groups.

Chi square or exact fisher test was used for comparing categorical variables in two groups. A p-value less than 0.05 was considered statistically significant.

Results

The mean age of participants in CABG with CO_2 blower group (group I) patients was 67.43± 13.11 and in CABG with air blowers group (group II) was 69.33± 16.28 years (P=0.08). Twenty three patients were male (51.11%) and 22 were female (48.89%) in GroupI and 48 patients were male (60%) and 32 patients were female (40%) in Group II (P=0.073).

45 patients underwent CABG with CO_2 blower and 80 cases were operated on using air blowers. There was no significant difference between the two groups in terms of basic characteristics. Table1 depicts the basic characteristics of patients in both groups.

As illustrated in Table 1, no significant difference was detected between the two groups regarding preoperative variables. In general, three patients died in 30 days. The 30-day mortality did not differ between the two groups (P>0.05). Moreover, hospital stay in CO_2 group was not significantly different from air blower group (P>0.05). Other side effects are listed in both group and compared in Table 2.

Table 1- Demographic and past medical history of patients in two groups

Characteristics	Air group Number N=80	CO2 group Number N=45	P Value
LVEF	42.11 ± 7.51	43.61 ± 9.61	0.12
Hypertension (n, %)	51 (63.75)	27 (60)	0.34
Smoking (n, %)	16 (20)	10 (22.2)	0.88
Addiction (n, %)	25 (31.25)	14 (31.11)	1
Hypercholesterolemia (n, %)	42 (52.5)	22 (48.88)	0.78
Diabetes mellitus (I&II) (n, %)	33 (41.25)	18 (40)	0.83
Peripheral vascular disease (n, %)	6 (7.5)	3 (6.66)	0.67
Prior myocardial infarction (n, %)	42 (52.5)	23 (51.11)	0.99
Myocardial infarction < 7 days (n, %)	23 (28.75)	13 (28.88)	1
Preoperative IABP (n, %)	8 (10)	4 (8.88)	0.95
Left main stump disease (n, %)	17 (21.25)	8 (17.77)	0.89
Three Vessel disease (n, %)	60 (75)	35 (77.77)	0.99
Two Vessel disease (n, %)	18 (22.5)	8 (17.77)	0.23
Single Vessel disease (n, %)	2 (2.5)	2 (4.44)	p<0.05

LVEF: Left Ventricular Ejection Fraction; IABP: Intra-Aortic Balloon Pump.

Table 2: Postoperative Morbidity and Mortality No (%)

Characteristics	Air group Number (percent) N=80	CO2 group Number (percent) N=45	P Value
30-Day Mortality	2 (2.5%)	1 (2.22%)	0.89
Re-exploration for bleeding	3 (3.75%)	2 (4.44%)	0.92
Intraoperative IABP	4 (5%)	2 (4.44%)	0.35
Sternal Infection	3 (3.75%)	1 (2.22%)	0.17
Atrial Fibrillation	7 (8.75%)	4 (8.88%)	0.99
Ventricular Arrhythmias	3 (3.75%)	2 (4.44%)	0.87
Myocardial infarction	3 (3.75%)	2 (4.44%)	0.75
CVA	1 (1.25%)	1 (2.22%)	0.94
Respiratory Failure	5 (6.25%)	3 (6.66%)	0.91
Acute Renal Failure	7 (8.75%)	4 (8.88%)	0.86
Estimated blood loss (milliliter)	530 ± 312	550 ± 245	0.81
Intensive care unit stay (days)	2.1 ± 1.4	2.0 ± 1.3	0.62
Hospital stay (days)	6 ± 3.7	6.1 ± 3.8	0.79

IABP: Intra-Aortic Balloon Pump, CVA: Cerebro-Vascular Accident, NS: Not significant

Discussion

Apart from the snaring of the coronary arteries during off-pump revascularization, the use of compressed gas blower facilitates bloodless surgical field and high-quality distal anastomosis.

The spray pressure of the gas blower can exceed the diastolic pressure, especially during grafting on the lateral or posterior wall when hemodynamic compromise is most severe due to mechanical displacement (9).

Good visualization is required for anastomosis quality in on-pump and off-pump surgery. Two features are of paramount importance in this regard: accurate visualization of the anastomosis site regarding blood flow and the prevention of endothelial damage (10).

Carbon dioxide has a 20-fold higher solubility coefficient in blood, as compared to oxygen. These properties can theoretically minimize air embolization of the coronary arteries which were reported by other researchers in previous case reports (11, 12); therefore, using CO2 blower can be of great help in CABG surgeries. To the best of our knowledge, there is a paucity of data concerning the use of CO2 blower instead of air blower in on-pump beating CABG, and we evaluated the outcomes of using both of them in the present study.

The results of the present study indicated that the use of air blower had no significant adverse effects on patients who undergo on-pump beating CABG. The optimal visualization of coronary artery anastomosis by gas jet provides a dry surgical field for coronary anastomosis allowing clear visualization of the anastomotic suture line without halation. Nonetheless, embolic complications may arise from the blowing of compressed air or oxygen into the coronary artery(13). In a case-series with 10 cases of CABG using compressed air blowing, low cardiac output syndrome, probably due to coronary air embolism, occurred in three patients out of whom two cases needed intra-aortic balloon pumping. The authors have found that carbon dioxide gas can be safely employed instead of oxygen or air owing to its high solubility in the blood.

Carbon dioxide is 34 times more soluble than O2 when it goes into water at 30°C and only slightly less soluble in serum at 38°C. Therefore, CO 2 gas trapped in the coronary artery is highly unlikely to cause coronary embolism due to the formation of microbubbles. Blowing CO2 gas provides a bloodless operative field by blowing off the blood and allows a wider anastomotic orifice by inflating the coronary artery. This technique has been found to be simple and safe and can even be conveniently employed in coronary anastomosis under a beating heart where the ascending aorta is not cross-clamped(8).Carbon dioxide has been used by surgeons to flood the pericardial well during valvular operations to minimize the risk of air embolization in the coronary arteries and brain. CO2 has a higher blood solubility, thereby decreasing the complications associated with embolization (8). CO2 dissolves easily in water to form a weak acid called carbonic acid (H2CO3); therefore, the use of CO2 has been advocated as an alternative to air (14). As mentioned earlier, CO2 would rapidly dissolve in blood; nonetheless, if used for a long time, it might bring about local change to pH at the irrigation pool of the targeting vessel. In many centers, the use of oxygen has been limited due to fire hazard when cautery and oxygen blower are used together(15).

In fact, the use of deep pericardial CO2 insufflation in valvular heart surgeries is associated with a marked decrease in the incidence of microemboli (16, 17). However, massive CO2 pulmonary embolism has been detected while repairing an injured coronary vein using a CO2 blower which led to haemodynamic deterioration (18). Every study has some limitations which should be addressed in the paper. Some limitations are imposed on the present study. One of the major limitations was the non-randomized design of the study. Further investigations are needed, especially to determine the benefits provided by increasing myocardial revascularization among patients who underwent on-pump beating-heart CABG. Moreover, larger-scale studies in multi-centric pattern with long-term outcome comparison are needed to obtain more reliable results.

Conclusion

Although the use of CO2 during beating CABG has been advocated with its theoretical advantages, no significant difference was observed between the two groups in terms of mortality and morbidity using CO2, as opposed to air blower.

Conflicts of interest

The authors declare that they have no conflict of interest regarding the publication of the present article.

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