Comparison between pulmonary arterial and aortic root venting and their effects on pulmonary functions following CABG surgery

Pulmoner arteryel venting ile aort kökü venting yöntemlerinin karşılaştırılması ve iki yöntemin koroner arter bypass cerrahisi sonrası solunum fonksiyonları üzerine etkileri

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Background: We compared the effects of pulmonary artery and ascending aorta root venting on postoperative pulmonary functions following coronary artery bypass graft (CABG) surgery.

Methods: A total of 301 patients undergoing CABG were divided into two groups according to the method of venting. Aortic root venting (group I) was performed in 151 patients (109 males, 42 females; mean age 61±9 years), and pulmonary arterial venting (group II) was performed in 150 patients (79 males, 71 females; mean age 61±10 years). Preopererative, intraoperative, and postoperative findings were compared.

Results: The mean number of anastomoses was 2.8±0.8 in group I, and 2.4±0.8 in group II (p=0.001). The mean duration of cross clamping was 42.7±17.4 min in group I, and 54.1±23.8 min in group II (p=0.001). The two groups did not differ with respect to the mean duration of cardiopulmonary bypass (86.4±56.1 min vs 77.4±28.6 min). The mean postoperative PO_2 was 92.8±4.8 mmHg in group I, and 106.9±22 mmHg in group II (p=0.001). The corresponding figures for SO_2 were 97.3±23.4% and 96±8%, respectively (p=0.001). The amount of chest tube drainage and blood transfusion, intubation time, intensive care unit stay, and hospital stay were similar in the two groups. Nasotracheal aspiration was required in 20 patients (80%) in group I, and in five patients (20%) in group II (p=0.002). The need for bronchodilator treatment and the development of atrial fibrillation were significantly less in group II (p=0.01 and p=0.02, respectively). All the patients that needed reintubation (n=7) were in group I (p=0.001).

Conclusion: Pulmonary arterial venting enables effective decompression of the lungs and left ventricle and is associated with better postoperative pulmonary functions compared to aortic venting.

Key words: Coronary artery bypass/methods; heart arrest, induced/methods; respiratory system.

Amaç: Koroner arter bypass ameliyatında kullanılan pulmoner arteryel venting ya da çıkan aort kökü venting yöntemlerinin ameliyat sonrası solunum fonksiyonları üzerindeki etkileri karşılaştırıldı.

Çalışma planı: Koroner arter bypass ameliyatı yapılan 301 hasta kullanılan venting yöntemine göre iki grupta incelendi. Aort kökü ventingi (grup I) 151 hastada (109 erkek, 42 kadın; ort. yaş 61±9), pulmoner arteryel ventingi (grup II) 150 hastada (79 erkek, 71 kadın; ort. yaş 61±10) kullanıldı. İki grubun amaliyat öncesi, amaliyattaki ve ameliyat sonrası verileri karşılaştırıldı.

Bulgular: Ortalama anastomoz sayısı grup I'de 2.8±0.8, grup II'de 2.4±0.8 (p=0.001), kros klemp süresi grup I'de 42.7±17.4 dk, grup II'de 54.1±23.8 dk (p=0.001) bulundu. Kardiyopulmoner bypass zamanı iki grupta benzer idi (sırasıyla 86.4±56.1 dk ve 77.4±28.6 dk). Ameliyat sonrası ortalama PO_2 grup I'de 92.8±4.8 mmHg, grup II'de 106.9±22 mmHg (p=0.001) bulunurken, SO_2 değerleri sırasıyla 97.3±23.4% ve 96±8% idi (p=0.001). İki grup, göğüs tüpü drenaji ve kan transfüzyonu miktarları, entübasyon süresi, yoğun bakım ünitesinde ve hastanede kalış süreleri açısından anlamlı farklılık göstermedi. Nazotrakeal aspirasyon grup I'de 20 hastada (%80) gerekirken, grup II'de beş hastada (%20) gerekti (p=0.002). Bronkodilatör ihtiyacı (p=0.01) ve atriyal fibrilasyon gelişimi (p=0.02) grup II'de anlamlı derecede daha azdı. Yeniden entübasyon yedi hastada gerekti; bu hastaların hepsi grup I'de idi (p=0.001).

Sonuç: Pulmoner arteryel venting ile akciğerlerin ve sol kalp boşluklarının dekompresyonu etkin bir şekilde sağlanabilir. Aortik venting yöntemiyle karşılaştırıldığında, hastaların ameliyat sonrası solunum fonksiyonları daha iyi olmaktadır.

Anahtar sözcükler: Koroner arter bypass/yöntem; kalp arresti, indükleme/yöntem; solunum sistemi.

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Ventricle distension in patients undergoing on-pump coronary artery bypass graft (CABG) surgery increases oxygen requirement of the myocardium by increasing ventricle wall tension, impairs the subendocardial coronary arterial blood flow and contractility, and causes pulmonary edema by increasing pulmonary venous pressure. Therefore, cardiac venting is necessary during the operation.[1,2]

Decompression of the left chambers of the heart is possible using different methods. Replacement of a root cannula through the ascending aorta is one of these methods. The same cannula may be used as an antegrade cardioplegia route and the place of the cannula may be used for proximal anastomosis. The other regions for cardiac venting are right superior pulmonary vein, left atrial appendix, superior wall of the left atrium and directly the left atrium and left ventricular apex in patients undergoing left atriotomy. Another method of venting is the use of the pulmonary artery.[3]

The aim of this study was to compare the effects of pulmonary artery and ascending aorta root venting on postoperative pulmonary functions in patients undergoing on-pump CABG surgery.

PATIENTS AND METHODS

This retrospective study included 301 patients who underwent on-pump CABG between August 2004 and 2006 in our clinic. The patients were operated on by two different surgeons; hence, group I included 151 patients (109 males, 42 females; mean age 61±9 years; range 38 to 69 years) in whom aortic root venting was performed, and group II included 150 patients (79 males, 71 females; mean age 61±10 years; range 31 to 79 years) in whom pulmonary arterial venting was performed.

The patients were evaluated with respect to age, gender, the presence of smoking habits, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, and previous myocardial infarction. Data on preoperative medications (beta-blockers, calcium channel blockers, digitalis, and other antianginal and antiaggregants), results of total blood count and routine laboratory tests, ejection fraction (EF), the number of target coronary arteries, and functional capacity were analyzed. Preoperative clinical characteristics of the two groups are presented in Table 1. The two groups differed significantly with respect to the presence of diabetes mellitus, hypertension, and previous myocardial infarction. There were no significant differences with regard to the preoperative blood urea nitrogen, creatinine, hematocrit values, and EF levels.

Operative technique. A two-stage ascending aortic cannulation from the right atrial appendix was performed in both groups. Antegrade cold potassium blood cardioplegia was administered at a dose of 10 ml/kg and systemic hypothermia at 28 ºC was applied. In group I, antegrade cardioplegia was applied via an aortic root cannula, whereas in group II antegrade cardioplegia was applied via a 16-gauge needle from the ascending aorta. Proximal anastomoses were performed after the removal of the cross clamp and during cross clamping in groups I and II, respectively. The patients were followed-up by the same anesthesiology team peri- and postoperatively.

For pulmonary venting, a small incision was made in the main pulmonary artery to insert a venting catheter. After the cross clamp was removed and the heart started to pump again, a 4-0 Prolene purse-string suture was placed around the pulmonary venting catheter and the incision was closed. No surgical complications occurred relevant to the procedure applied to the pulmonary artery.

The number of anastomoses, the duration of cross clamping and total cardiopulmonary bypass (CPB) were compared between the two groups. Postoperatively, the patients were compared for total drainage volume, amount of blood transfusion, oxygen saturation, partial arterial oxygen pressure, duration of intubation, the need for medical (bronchodilator), mechanical and manual respiratory physiotherapy after extubation (nasotracheal aspiration, CPAP), atrial fibrillation, the need for reintubation, intensive care unit stay and hospital stay.

Patients who needed inotropics and had neurological deficits after the operation were excluded from the study as these factors might affect the pulmonary functions.

Statistical analysis. Statistical analyses were performed using SPSS 10.0 statistical software program. Data were expressed as mean ± standard deviation. A p value less than 0.05 was considered to indicate statistical significance. Chi-square test was used for categoric variables

Table 1. Preoperative clinical characteristics of the two groups

	Aortic root venting (n=151)		Pulmonary arterial venting (n=150)		
	n	%	n	%	*p*
Diabetes mellitus	52	34.4	107	71.3	0.001
Hypertension	112	74.2	32	21.3	0.001
Previous myocardial infarction	23	15.2	40	26.7	0.01

Table 2. The number of anastomoses, cross clamp time, partial arterial oxygen pressure and oxygen saturation values

	Aortic root venting (n=151)	Pulmonary arterial venting (n=150)	*p*
Number of anastomoses	2.8±0.8	2.4±0.8	0.001
Cross clamp time (min)	42.7±17.4	54.1±23.8	0.001
Partial arterial oxygen pressure (mmHg)	92.8±4.8	106.9±22.0	0.001
Oxygen saturation (%)	97.3±23.4	96.0±8.0	0.001

and Student's t-test was used for variables with normal distribution.

RESULTS

The mean number of anastomoses was 2.8±0.8 in group I, and 2.4±0.8 in group II (p=0.001). The mean duration of cross clamping was 42.7±17.4 minutes in group I, and 54.1±23.8 minutes in group II (p=0.001) (Table 2). The two groups did not differ with respect to the mean duration of CPB (86.4±56.1 min *vs* 77.4±28.6 min; p=0.08).

The mean postoperative PO_2 was 92.8±4.8 mmHg in group I, and 106.9±22 mmHg in group II (p=0.001). The mean postoperative SO_2 was 97.3±23.4% with aortic root venting and 96±8% with pulmonary arterial venting (p=0.001; Table 2).

The following postoperative variables were similar in the two groups (p>0.05): the amount of chest tube drainage (531.7±324.2 ml *vs* 514.3±346 ml), the need for blood transfusion (1.2±0.9 units *vs* 1.2±1.0 units), intubation time (8.5±4.6 hours *vs* 8.0±3.2 hours), intensive care unit stay (1±0.2 days *vs* 1±0.1 days), and hospital stay (6.6±4.4 days *vs* 6.8±1.6 days).

Nasotracheal aspiration was required in 20 patients (80%) in group I, and in five patients (20%) in group II (p=0.002; Table 3). The need for bronchodilator treatment and the development of atrial fibrillation were significantly less in group II (p=0.01 and p=0.02, respectively; Table 3). All the patients with an indication for reintubation (n=7) were in group I (p=0.001).

There were no significant differences between the two groups with respect to other postoperative findings, including the need for emergent operation, use of the left internal mammary artery, revision for chest tube drainage, incidence of arrhythmias, diaphragm paralysis, stroke, low cardiac output, development of acidosis, usage of inotropics, and development of neurological deficits.

DISCUSSION

Left ventricular distension that may occur while cross clamping during open heart surgery impairs the subendocardial blood flow by increasing ventricle wall tension. If the distension is prolonged, this may result in severe ventricular dysfunction. Negative effects of distension on myocardium may be prevented by venting the left ventricle. This method also enables a bloodless surgical area for the surgeon and emptying of the air in the ventricle. During on-pump coronary bypass surgery, the sites that can be used for venting are the ascending aorta, right superior pulmonary vein, apex of the left ventricle, and pulmonary artery.[4]

The sources for the return of the blood to the left ventricle are the thebesian veins which drain a little portion of the coronary arterial blood flow to the left atrium and ventricle, and bronchial veins which drain to pulmonary veins and then the left atrium and ventricle.[5] Left ventricular distension may also occur due to pathological conditions such as patent ductus arteriosus, extracardiac left to right shunts (Blalock-Taussig, etc.), systemic venous return abnormalities, and aortic valvular insufficiency. In the preoperative period, aortic valvular insufficiency may be hemodynamically unimportant, but this insufficiency may increase during the operation due to the distortion of the root by surgical manipulations or while the cardioplegia is given to the aortic root, resulting in left ventricular distension.

Salomon and Copeland[6] performed left ventricular decompression and the application of cardioplegia via a single double-lumen cannula placed in the ascending

Table 3. The incidence of postoperative atrial fibrillation and the need for nasotracheal aspiration and bronchodilator treatment

	Aortic root venting		Pulmonary arterial venting		*Total*		
	n	%	n	%	n	%	*p*
Atrial fibrillation	22	68.8	10	31.2	32	100	0.02
Nasotracheal aspiration	20	80.0	5	20.0	25	100	0.002
Inhaler usage	106	70.2	15	29.4	51	100	0.01

aorta, and they reported that aortic root venting was a simple, safe, and effective method. Catinella et al.[7] reported similar results in a series of 200 patients who underwent aortic root venting.

In the current clinical practice, cardioplegia is given via an aortic root cannula with a double-lumen placed in the ascending aorta after cross clamping during on-pump coronary bypass surgery, and then left ventricle decompression is effectively performed. The place of the cannula is also used for proximal anastomosis. This method has the following disadvantages: removal of the root cannula is required during proximal anastomosis, and left ventricle decompression cannot be performed until proximal anastomoses are finished. Venting during postischemic reperfusion after the removal of the cross clamp decreases the pressure in the left ventricle, and therefore, decreases the intramyocardial epicardial/endocardial pressure gradient and left ventricle wall tension. As a result, myocardial oxygen demand is decreased.[4] This is especially important in case of left ventricular hypertrophy and ventricular fibrillation.

Another disadvantage of aortic root venting is that diastolic arrest is present during cross clamping and aortic valve is closed. To obtain effective left ventricular decompression, manual compression over the left ventricle may be necessary to maintain the passage of the blood to the aorta. The need for an extra double-lumen cannula and the complexity of the surgical area are other disadvantages of aortic root venting method.

Little et al.[4] demonstrated that pulmonary arterial venting method was effective in maintaining left ventricle decompression. Pulmonary arterial venting enables aspiration of the blood coming from the right heart through the coronary sinuses, part of systemic venous blood, and blood from the thebesian veins draining to the left atrium, and blood from the bronchial veins draining to the pulmonary veins. Sometimes manual compression of the left ventricle may be necessary in this method. Furthermore, mitral valve is incompetent during cardiac arrest or fibrillation. In this case, the left atrium and left ventricle act as a single chamber. As a result, pulmonary arterial venting can aspirate the blood in both chambers. This is not surprising because there are no valves in the pulmonary circulation.[5]

The advantages of pulmonary arterial venting are the continuation of decompression of the left ventricle in early ischemic reperfusion, thereby decreasing the myocardial oxygen demand, enabling a simple vision at the surgical site, and prevention of pulmonary stasis and edema.

Pulmonary dysfunction following cardiopulmonary bypass is still an important problem. Although the changes in pulmonary functions are well-known, the pathogenesis is complex and not fully understood. Median sternotomy, hydrostatic pulmonary edema, the accumulation of tracheobronchial secretions, phrenic nerve paralysis are the factors that impair pulmonary functions. The contact of blood with nonphysiological surfaces during CPB causes an inflammatory response. This inflammatory response includes neutrophils, platelets, complements, kinins, and other systems. This result in an increase in microvascular permeability and pulmonary dysfunction.[8,9] We encounter this process in several clinical forms in daily practice. Lung injury after CPB is characterized by increased extravascular pulmonary fluid due to endothelial injury and atelectasis.[10-14]

In our study, postoperative intubation times were similar with aortic root venting and pulmonary arterial venting. The mean postoperative PO_2 was significantly higher and SO_2 value was significantly lower with pulmonary arterial venting ($p=0.001$). The need for nasotracheal aspiration ($p=0.002$) and bronchodilator treatment ($p=0.01$) was significantly less with pulmonary arterial venting. All seven patients that needed reintubation were in aortic root venting group ($p=0.001$). These findings favor pulmonary arterial venting in terms of postoperative pulmonary functions.

With pulmonary arterial venting, the pulmonary vascular bed and the left heart are emptied as occurs in total bypass and as a result, hydrostatic pulmonary edema is prevented, resulting in better postoperative pulmonary functions. Roach and Bellows[15] reported a case in which serious left ventricle distention occurred with pulmonary arterial venting. We did not encounter this complication in our patients. In another study, it was reported that inadequacy in the pulmonary blood flow might result in insufficient pulmonary circulation and lung injury.[16] However, insufficiency in pulmonary circulation may be restored by increasing aortic perfusion pressure.[17] In our study, drainage of the pulmonary vascular bed via pulmonary arterial venting did not result in any postoperative respiratory problems.

In conclusion, pulmonary arterial venting may be used as an alternative to aortic root venting during on-pump coronary bypass surgery. Postoperative pulmonary functions are better with this method. Pulmonary arterial venting is an effective and easy method in CABG surgery.

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