Hemodynamic changes during distal anastomosis of coronary arteries in off-pump CABG surgery

Atan kalpte koroner arter anastomozları sırasındaki hemodinamik değişiklikler

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Background: The aim of this study was to assess the hemodynamic changes during off-pump coronary artery bypass graft (OPCAB) surgery following mobilization and stabilizaiton of the heart in different positions for distal coronary artery anastomoses.

Methods: The study was designed as a prospective clinical trail in between March-June 2002. Thirty patients (22 males, 8 females; mean age 69.5±6.3; range 49 to 81 years) operated on by OPCAB surgery were included in the study. The measurements of mean baseline systemic arterial pressure, right atrial pressure, pulmonary capillary wedge pressure, and cardiac index were compared with those that recorded during the mobilization and stabilization of the heart together with ST segment changes and cardiac specific enzyme analysis.

Results: The cardiac index drop was statistically significant in all territories while the mean systemic arterial pressure dropped in the left anterior descending and the posterior descending artery territories. The right atrial pressure increased 70% while performing the circumflex and the posterior descending artery anastomosis. Pulmonary capillary wedge pressure increased 13% in LAD and 39% in cirtumflex territories. No significant ST segment changes and cardiac specific enzyme rise was observed.

Conclusion: Significant hemodynamic changes can be seen during OPCAB surgery that can effect the whole course of the operation. A surgeon experienced in off pump surgery can overcome the problems caused by hemodynamic changes. Patient selection and certain manoveurs during OPCAB are important aspects that surgeons should be familiar with.

Key words: Off pump coronary artery bypass surgery; hemodynamics; ischemia.

Amaç: Bu çalışmada, off pump koroner arter cerrahisinde (OPCAB) distal koroner arter anastomozlarının yapılabilmesi için, kalbin mobilizasyonu ve stabilizasyonu sırasında oluşabilecek hemodinamik değişimlerin değerlendirilmesi amaçlandı.

Çalışma planı: Çalışma Mart-Haziran 2002 tarihleri arasında prospektif olarak düzenlendi. Off-pump koroner arter cerrahisi uygulanan 30 hasta (22 erkek, 8 kadın; ort. yaş 69.5±6.3; dağılım 49-81) çalışmaya alındı. Bu hastalarda bazal ortalama sistemik arter basıncı, sağ atriyal basınç, pulmoner kapiller kama basıncı ve kardiyak indeks ölçümleri, EKG'de ST segment değişiklikleri ve spesifik kardiyak enzim analiziyle beraber, aynı parametrelerin anastomozlar sırasında kalbe posizyon verildikten sonra yapılan ölçümleriyle karşılaştırıldı.

Bulgular: Kardiyak indeks düşüklüğü tüm bölgelerde istatistiksel olarak anlamlı iken, ortalama sistemik arteriyel basınç sol ön inen ve arka inen koroner arter bölgelerinde anlamlı şekilde düştü. Sirkumfleks ve arka inen koroner arterlerin anastomozunda sağ atriyal basınç ortalama %70 yükseldi, ama pulmoner kapiller kama basıncı sol ön inen koroner arter anastomozunda ortalama %13, sirkumfleks koroner arter anastomozunda %39 arttı. Belirgin ST segment değişikliği ve anlamlı kardiyak enzim artışı olmadı.

Sonuç: Off pump koroner arter cerrahisi sırasında, ameliyatın tüm gidişini etkileyebilecek hemodinamik değişiklikler olabilir. Bazı cerrahi teknik ve manevralarla bu tür hemodinamik değişimlerin üstesinden gelinebilir. Bu nedenle kalp cerrahları, OPCAB için hasta seçimi ve ameliyat sırasındaki sorunları gidermeye yönelik cerrahi teknikler konsunda bilgi sahibi olmalıdırlar.

Anahtar sözcükler: Off pump koroner arter bypass cerrahisi; hemodinamik; iskemi.

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Hemodynamic changes and the preservation techniques of hemodynamics during OPCAB surgery are great concern to cardiac surgeons all over the world since more patients are being operated on by OPCAB surgery.[1-8] Although beating heart surgery is not a new technique for coronary artery revascularization,[1] there are some technical aspects that are new and also there are some new devices that enable surgeons to perform beating heart surgery more easily. These devices are either suction or compression devices (Fig. 1). They are useful in positioning the heart for distal coronary artery exposures (suction devices) and in stabilizing the target coronary artery by compressing for anastomosis. All manouvers for better exposure and stabilization can cause some hemodynamic changes. The objective of our study is to assess the hemodynamic changes during off-pump coronary artery bypass graft surgery.

PATIENTS AND METHODS

The study was designed as a prospective clinical trail in between March 2002 and June 2002. 30 patients who were operated by OPCAB surgery were included into the study. The off pump coronary bypass surgery decisions for the patients were taken by the same surgeon and the patient himself. The study was approved by the institutional review board. Patient selection for OPCAB procedure was based on the decision of the experienced surgeon without any absolute contraindication for off-pump surgery. The patients that were excluded from OPCAB schedule, were those with diffuse multivessel coronary artery disease, those with hemodynamic deterioration at anesthetic induction and those that need urgent operation and redo operation.

Intraoperative measurements. Continous hemodynamics monitoring included mean systemic arterial pressure (MSAP) monitoring via radial line, the right atrial pressure, the pulmonary capillary wedge pressure (PCWP), and cardiac index (CI) were monitored through a flow directed thermodilution catheter (Abbott Critical Care Systems). Data were recorded before any manouver was done for exposure and stabilization of the coronaries and with the exact time when each of the coronaries was exposed and stabilized.

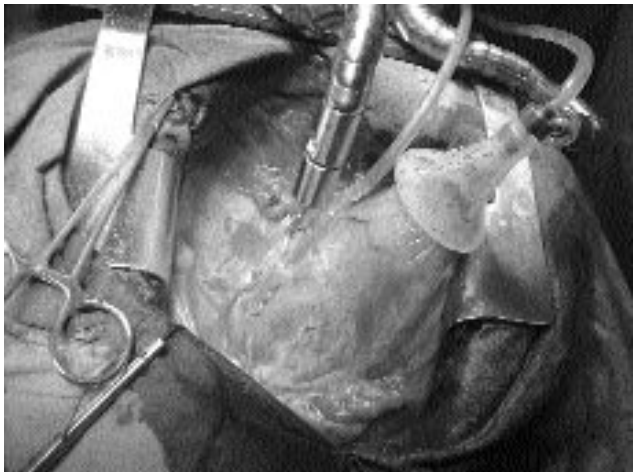

Fig. 1. Both a suction device (apical holder) and a compression device applied to the ninety degree replaced heart during the circumflex coronary artery anastomosis are seen in the picture.

Operative details. Prior to the operation, the radial artery was cannulated, and a flow directed thermodilution catheter was inserted into the pulmonary artery percutaneously via internal jugular vein. All patients received a similar balanced anesthetic regimen, including fentanyl, propofol and sevorein. Curarization was achieved with pancuronium bromide. Postoperatively, the patients were admitted to intensive care unit. The patients were extubated as soon as clinically indicated.

All off pump patients were operated through a median sternotomy approach. After median sternotomy, all patients were heparinized (100 U/kg) to achive an activated clotting time (ACT) of >250 seconds. The distal anastomoses were completed with the use of mechanical stabilizers {[Octopus Tissue Stabilizers (Medtronic, Inc., Minneapolis, MN, USA)] or [OPVAC Synergy II (Estech–Least Invasive Cardiac Surgery, Danville, California, USA)]} for immobilization of the myocardial surface at the site of the target coronary artery. The heart was positioned with heart positioners {[Starfish (Medtronic, Inc., Minneapolis, MN, USA)] or [Estech Pyramid Positioner (Estech-Least Invasive Cardiac Surgery, Danville, California, USA)]} for accessing hard-to-reach lateral and posterior vessels. To obtain a bloodless field, two 4-0 polypropylene sutures were used to temporarily occlude the coronary artery on either side of the anastomosis site. Revascularization of the left anterior descending (LAD) coronary was performed first which was followed by the revascularization of the circumflex and right coronary artery distributions. The proximal anastomoses were performed before the distal anastomoses with the assistance of a partial occlusion aortic clamp.

Statistical analysis. All statistical procedures were performed using the program SPSS (Statistical Package for Social Sciences)-Windows 12.0. Data are expressed as the mean ± the standard deviation (SD). The means of the hemodynamic changes for each parameter were compared to baseline measures using paired samples t test. Probability values less than 0.05 were considered to indicate statistically significance

RESULTS

The mean age of the study population was 69.5±6.3 years (range 49-81 years), consisting of 22 men and 8 women.

Patients' characteristics are listed in Table 1. An average of 1.8±0.8 grafting per patient were performed, which included 30 grafts to the left anterior descending (LAD) coronary artery, 7 to the circumflex marginal territories, 16 to the posterior descending territories of the right coronary artery. Complete revascularization was achieved in all patients; no intraoperative conversion to cardiopulmonary bypass was needed. Grafts distribution and regional coronary ischemic time are presented in Table 2. There was no postoperative mortality in this series. Atrial fibrillation developed in four patients (13%) postoperatively. All of the patients recovered in the hospital before discharge. The mean hospital stay was 6.1±1.6 days (range 4-12 days). Hemodynamic changes following stabilization for different territories are summarized in Table 3-5. The cardiac index dropped in all territories during manipulations. Variations between baseline measures and measures after mobilization and stabilization reached statistical significance for all coronary artery territories ($p<0.001$). Changes in mean SAP were significant in LAD and PDA territories and an averaged drop of 12% was observed. The right atrial pressure increased in CX and PDA territories approximately 70%. The compression of the right side of the heart at PDA position and the almost 90 degree displacement of the heart for CX anastomosis were responsible for the dramatic changes in the right atrial pressures. The significant changes in pulmonary capillary wedge pressure were observed in LAD and CX territories with an average of 13% and 39% increase, respectively.

During all these manouvers in our study group, we did not record any significant ischemic episode. There were no significant ST segment changes and creatinin kinase MB elevation. This may be due to the characteristics of the coronary artery lesion of the patients. The patients with chronic severe coronary artery obstructions display better hemodynamics during OPCAB surgery that may be due to the well developep collateral coronary circulation.

Table 1. Population demographics

		n	%
Age	69.53±6.3		
Male gender		22	73
Severe left ventricule dysfunction (EF <30%)		2	7
Diabetes		10	33
Systemic hypertension		16	53
COPD		2	7
Renal failure		2	7
Smoking		16	53
Peripheric vascular disease		6	20
Stroke		1	3
Preoperative myocardial infarction		18	60
Grafts			
Single		13	43
Double		11	37
Triple		6	20

LV: Left ventricular; EF: Ejection fraction; COPD: Chronic obstructive pulmonary disease. Values in parentheses are percentages.

Table 2. Graft distribution and occluding time

Vessel	No. of graft		Occluding time (min)
	n	%	
LAD	30	100	18.03±2.7
CXOM	7	13	16.14±2.7
RC/PDA	16	30	19.43±2.5

LAD: Left anterior descending artery; CXOM: Circumflex obtuse marginal artery; RC: Right coronary artery; PDA: Posterior descending artery.

DISCUSSION

Hemodynamic variations in OPCAB may be due to mobilization and stabilization of the heart or myocardial ischemia occuring during coronary occlusion.[8] Coronary exposure and adequate coronary stabilization are essential parameters for a qualified anastomosis in OPCAB. Different techniques have been described to achieve adequate coronary artery exposure and all of them can be effective when used by surgeons with "off pump" experience.[2-8] The target coronary artery should be properly exposed before stabilization. The stabilizer should not be used to expose the target coronary artery. Otherwise, the stabilizer foot can compress on the ventricules outflow or inflow trucks causing less blood flow through the heart and a drop in cardiac output resulting in hypotension. Intravenous infusion of fluids at that times, through a central line or directly into the pulmonary artery through a Swan-Ganz catheter may restore adequate circulating volumes in the vessels and in the cardiac cavities. The Trendelenburg position is also helpful to improve preload. Hemodynamic impairment due to the ischemia during OPCAB can be devastating with urgent need of establishing the extracorporeal circulation. Appropriate use of the intracoronary shunts limits the ischemic period and avoids impairment of the myocardial contractility. In our experience ischemic hemodynamic depression during coronary artery occlusion was not observed. There were no significant ST chances during coronary artery occlusions. Depending on our self experience because ischemic hemodynamic compromise was rarely observed, we do not use intracoronary shunts routinely. Better tolerance to ischemia and a good collateral network in significant chronic coronary stenosis permit an acceptable time for a distal coronary artery anastomosis during coronary

Table 3. Hemodynamic changes during left anterior descending, left internal mammarian artery anastomosis

	LAD 1	LAD 2	*p* value
Mean arterial pressure (mmHg)	67.9±5.5	61.4±5.0	<0.001
Right atrial pressure (mmHg)	4.8±1.5	5.5±1.1	Nonsignificant
Pulmonary capillary wedge pressure (mmHg)	9.3±2.0	10.4±1.8	<0.001
Cardiac index (ml/m^2/min)	2.81±0.35	2.55±0.31	<0.001
Heart rate (per min)	90.2±11.9	89.9±11.6	Nonsignificant

LAD 1: Baseline measures before mobilization and stabilization of the heart for distal coronary artery anastomosis.
LAD 2: Measures taken during distal coronary artery anastomosis following mobilization and stabilization of the heart.

Table 4. Hemodynamic changes during the distal anastomosis of the circumflex coronary artery territory with saphenous vein

	CX 1	CX 2	*p* value
Mean arterial pressure (mmHg)	70.5±5.7	59.5±4.2	Nonsignificant
Right atrial pressure (mmHg)	5.8±1.0	9.4±0.9	<0.001
Pulmonary capillary wedge pressure (mmHg)	10.1±2.4	14.1±3.2	=0.001
Cardiac index (ml/m^2/min)	2.84±0.34	2.16±0.36	<0.001
Heart rate (per min)	86±10.6	86.2±7.7	Nonsignificant

CX 1: Baseline measures before mobilization and stabilization of the heart for distal coronary artery anastomosis.
CX 2: Measures taken during distal coronary artery anastomosis following mobilization and stabilization of the heart.

Table 5. Hemodynamic changes during the distal anastomosis of the posterior descending territory of the right coronary artery with saphenous vein

	PDA 1	PDA 2	*p* value
Mean arterial pressure (mmHg)	68±5.7	58.6±4.5	<0.001
Right atrial pressure (mmHg)	4.9±1.5	8.8±1.3	<0.001
Pulmonary capillary wedge pressure (mmHg)	9.7±1.9	10±1.8	Nonsignificant
Cardiac index (ml/m^2/min)	2.78±0.29	2.25±0.19	<0.001
Heart rate (per min)	89±10.5	90.6±9.1	Nonsignificant

PDA 1: Baseline measures before mobilization and stabilization of the heart for distal coronary artery anastomosis.
PDA 2: Measures taken during distal coronary artery anastomosis following mobilization and stabilization of the heart.

artery occlusion. Other important aspects about ischemia and hemodynamic compromise during coronary artery occlusion are the sequence of coronary grafting and the dominance of the coronary artery that is being treated. The sequence of coronary grafting is important for preservation of the hemodynamics. We first revascularize LAD territories, as the most of the beating heart surgery performing surgeons do, with the aim of revascularizing the largest myocardial field first. Early revascularization of the left ventricule may improve overall cardiac performance during manipulation for other anastomoses. On the otherhand, a dominant right coronary artery needs coronary shunt insertion anyway, since occlusion of a dominant right coronary artery may cause rhythm problems in a short time period.

In our study, the main cause of the drop in CI and MAP in LAD and PDA positions was probably the compression effect of the stabilizer foot on the left ventricular outflow track in LAD position and the compression on the right ventricular inflow in PDA position.

There are some manouvers to overcome these hemodynamic changes: deep pericardial traction sutures are helpful for further elevation and rightward rotation of the heart during the exposure of the left coronary artery territories.[9,10] Rotation of the table to the right side and opening of the right pleural space allowing the heart to rotate towards the right pleural cavity improves exposure of the circumflex territory. Apical suction device is useful both for exposure of circumflex and PDA territories. Ninety degree displacement of the heart is well tolerated if the manouver is performed in a stepwise manner. The help of apical suction device during the exposure of the PDA territory lessens the compressive effect of the stabilizer foot and provides better exposure with better hemodynamic parameters.

We did not use any pharmocological stabilization. All procedures were achieved with purely mechanical stabilization. Negative chronotropic drugs are not used in our standart OPCAB procedures. These drugs may precipitate cardiac failure, especially in those patients who are scheduled for OPCAB because of poor myocardial contractility. There is no need for slowing heart rate if the target coronary artery is adequately exposed and secondly stabilized. Some times pacing the slow hearts may be needed. Inotropic support may be needed in a small group of patients who have persistent depressed myocardial function despite adequate fluid administration.

Depressed left ventricular function is not a contraindication for OPCAB surgery.[11] Gentle and progressive traction is helpful to slowly accustom the dilated heart to its new position.

In conclusion, hemodynamic changes during OPCAB surgery is great concern for the cardiac surgeons all over the world. In Turkisk literature, we could not find any study that focuses on the hemodynamics during OPCAB surgery. Our study has limited power for establishing clear directions for OPCAB performing surgeons because of the small patient group and limited hemodynamic parameters that were measured. Future studies can be designed with larger patient population and with more hemodynamic and biochemical parameters such as pH measurements of myocardium which can be useful to show any relation between ischemia and hemodynamic changes occuring during coronary artery occlusion.

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