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Improving Hemodynamics by Atrial Pacing during Off-Pump Bypass Surgery

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ABSTRACT

Background: To avoid hemodynamic deterioration during tilting of the heart in off-pump surgery, we perform atrial pacing. We describe hemodynamic evaluation of this simple maneuver.

Methods: Eleven consecutive patients (8 men, 3 women; age, 68.14 ± 10.3 years; left ventricular ejection fraction, 51.17% ± 18.6%) admitted for coronary artery bypass grafting were equipped with a PiCCO catheter (Pulsion Medical Systems, Munich, Germany) for monitoring of cardiac output (CO), cardiac index (CI), stroke volume (SV), heart rate (HR), and systemic vascular resistance. In addition, mean and systolic arterial pressure (RRm, RRs) as well as left atrial pressure (LAP) were monitored. During the procedure, temporary pacemaker wires were installed, and hemodynamic monitoring was performed before and after atrial pacing. All procedures were performed with the same standardized off-pump technique.

Results: All patients survived the procedure without inotropic support. In all cases a branch of the circumflex artery was grafted. The number of grafts per patient was 2.7. There was a statistically significant increase in RRs (11.12 mm Hg), RRm (9.72 mm Hg), HR (31.6 beats/min), CO (1.09 L/min), and CI (0.61 L/min per m^2) ($P < .005$). SV decreased statistically significantly (11.8 mL, $P < .005$) as did LAP (6 mm Hg, $P < .05$).

Conclusions: Atrial pacing increases intraoperative RRs, RRm, CO, and CI and decreases SV and LAP significantly, thus offering stable hemodynamics during off-pump surgery. In the last 400 consecutive off-pump coronary artery bypass grafting procedures, there was only 1 (0.25%) conversion to cardiopulmonary bypass.

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INTRODUCTION

Off-pump coronary artery bypass grafting (OPCAB) has been proposed for avoiding cardiopulmonary bypass (CPB)-related complications. However, the procedure is not performed on a routine basis by many surgeons because several problems can occur.

The first problem a surgeon faces with OPCAB is hemodynamic instability while tilting the heart for exposure of side branches of the circumflex artery. Even though several maneuvers have been proposed for better tolerance of heart displacement, such as Trendelenburg maneuver or right-side rotation of the patient [Grundeman 2001], hemodynamic instability often occurs.

In this study we present the hemodynamic effect of intraoperative atrial pacing for improving hemodynamics in OPCAB.

MATERIAL AND METHODS

Eleven consecutive patients admitted for CABG at our institution were enrolled for intraoperative assessment of hemodynamics with a PiCCO catheter (Pulsion Medical Systems, Munich, Germany). The age of the 8 male and 3 female patients was 68.14 ± 10.3 years (median ± SEM), and body mass index was 25.97 ± 4.88. All patients underwent operations on an elective basis. Left ventricular ejection fraction was 51.17% ± 18.6% (median ± SEM), ranging from 22% to 73%. Three (27.3%) of the patients had undergone previous percutaneous transluminal coronary angioplasty and/or stenting, and 5 (45.5%) of the patients had previous myocardial infarction. Clinical classification found 8 (72.7%) of the patients in class II and 3 (27.3%) of the patients in class III. Eight (72.7%) of the patients were in Canadian Cardiovascular Society (CCS) stage II, and 3 (27.3%) of the patients were in stage III.

One hour before the operation all patients received morphine hydrochloride (0.1-0.2 mg/kg body weight subcutaneously [sc]) in addition to 2.5 mg dehydrobenzperidol SC. Anesthesia was induced with methohexital (1 mg/kg body weight intravenously [iv]), fentanyl (0.03 mg/kg body weight iv), succinylcholine (1 mg/kg body weight iv), and vecuronium (0.1 mg/kg body weight iv). Anesthesia was maintained by sevoflurane and fentanyl.

The patients were equipped with a central venous catheter, a radial artery catheter for continuous monitoring of arterial blood pressure, and a PiCCO catheter via the femoral artery

Table 1. Hemodynamic Parameters*

	Before Atrial Pacing	After Atrial Pacing	*t* Test
Heart rate, beats/min	61.7 ± 8.6	93.3 ± 4.5	$P < .001$
Mean arterial pressure, mm Hg	64.09 ± 7.9	73.81 ± 5.5	$P < .005$
Systolic arterial pressure, mm Hg	88.6 ± 10.7	99.72 ± 10.1	$P < .01$
Cardiac output, L/min	4.02 ± 1.3	5.11 ± 0.7	$P < .005$
Cardiac index, L/min per m^2	2.05 ± 0.5	2.66 ± 0.41	$P < .005$
Stroke volume, mL	60.8 ± 10.8	49 ± 11.4	$P < .005$
Left arterial pressure, mm Hg	18.50 ± 5.2	12.50 ± 3.0	$P < .05$
Peripheral vascular resistance, dynes × s/cm^{-5}	1210.9 ± 406.6	1092.7 ± 306.6	NS

*NS indicates not significant.

for continuous monitoring of cardiac output (CO) expressed in liters per minute, cardiac index (CI) expressed in liters per minute per square meter, stroke volume (SV) expressed in milliliters, heart rate, and peripheral vascular resistance expressed in dynes × s/cm^{-5}.

At surgery the patients were placed in the supine position. After median sternotomy and left internal mammary artery (LIMA) harvesting, a catheter was placed via the right superior pulmonary vein into the left atrium for continuous left atrial pressure (LAP) monitoring. Temporary epicardial pacemaker wires were sutured on the right atrium. In addition, systolic, mean, and diastolic pressure and central venous pressure were monitored. All hemodynamic parameters were monitored before and after atrial pacing.

Coronary anastomoses were performed after proximal anastomoses using the Trendelenburg maneuver, right-side positioning of the operating table, atrial pacing, and the Xpose (Guidant, Santa Clara, CA, USA) heart displacing device for exposure of the obtuse marginal arteries. Coronary shunts were used in all cases.

Grafts per patient, marginal branch grafting, conversion to CPB, myocardial infarction, adverse events, and need for inotropic support were monitored.

For statistical analysis, a *t* test was used, and a difference of a *P* value less than .05 was defined as statistically significant.

RESULTS

All patients survived the procedure and left the operating room in sinus rhythm without signs of ischemia and without inotropic support. All procedures were completed as planned without the use of CPB. The number of grafts per patient was 2.7, and all patients had at least 1 graft to an obtuse marginal artery. Postoperatively 12-lead electrocardiographic and cardiac enzyme results excluded myocardial infarction.

Table 1 shows the hemodynamic parameters monitored. Time of procedure, postoperative ventilation, intensive care unit stay, and hospitalization are listed in Table 2.

Median creatine kinase (CK) level was 3.22 ± 2.39 μmol × L^{-1}. Median CK level in our conventional cases was 4.28 ± 1.15 μmol × L^{-1} (normal range, 0-2.65 μmol × L^{-1}). Postoperatively all patients were in CCS stage I. Echocardiographic left ventricular ejection fraction was always preoperative value or higher. With the described technique of this maneuver in 400 consecutive cases, the conversion rate was 0.25% (1 patient).

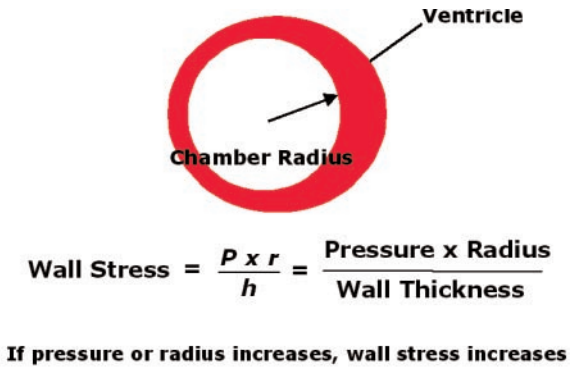
DISCUSSION

Although the first LIMA to left anterior descending coronary artery (LAD) anastomosis on a beating heart was performed in the mid-1960s [Kolessov 1967], development of CPB made CABG procedures more comfortable and became a standard in surgical treatment of coronary artery disease over the next 4 decades. A further reason for use of CPB was the ability to tilt the heart for exposure of coronary vessels of the posterior wall without hemodynamic deterioration. Later methods of CABG avoiding CPB entailed medical stabilization of the heart with β-blockers for decelerating heart rate. Use of these agents, however, did not find broad acceptance, because true comfort was not achieved during operations and because the results were not as expected [Gundry 1998]. β-Blockade may immobilize the heart for a short period but certainly does not stabilize hemodynamics during tilting of the heart. This problem is the first limiting factor in off-pump surgery in which attempts are made to access posterior wall vessels. In many developing countries, mechanical stabilization of the anastomotic area of the target coronary vessel often was used by surgeons with broad experience in coronary surgery. The decision to use this method was based mostly on the technical skills of the surgeon. In some cases, however, the motives were commercial rather than medical or scientific.

Mechanical stabilization of the anastomotic area of the target coronary vessel was first developed systematically in the mid-1990s on the basis of the concept of either pressure [Benetti 1995, Calafiore 1996] or suction [Borst 1996, Jansen 1997] for stabilization. Because of the easy exposure, stabilizing coronary vessels on the anterior wall (LAD, diagonals) does not seem to be a problem for most surgeons. If tilting of the heart is required to gain access to the posterior wall, the first hurdle is hemodynamic deterioration, which often leads to conversion to CPB. This problem explains why most surgeons would prefer to see as off-pump candidates only patients who need grafting of the anterior wall vessels and of the right coronary artery. These vessels are more easily accessible. This phenomenon is probably the reason the number of grafts per patient is rather low, mostly with statistical significance, in off-pump surgery compared with CPB procedures [Arom 2000, Kshettry 2001, Lund 2001, Patel 2002].

Table 2. Perioperative Data

Time of procedure, min	158.57 ± 24.61
Postoperative ventilation, h	7.07 ± 4.61
Intensive care unit stay, d	1.36 ± 0.67
Hospitalization, d	8.57 ± 1.90
Grafts/patient	2.7



Law of Laplace.

Medical therapy for most patients suffering from coronary heart disease routinely includes β-blockers. During anesthesia, the negative chronotropic effects of several drugs (at our institution, opiates) become more evident, and further bradycardia occurs [Bovill 1993].

The reason hemodynamic deterioration often occurs during tilting of the heart for exposure of the posterior wall vessels is well documented and understood [Grundeman 1999]. Ventricular geometry is changed through lifting and pressing of the heart toward the right pericardium, a maneuver that compromises left ventricular performance [Grundeman 1999]. This stress reaction is recognized immediately and is documented by a decrease in mean (RRm) and systolic arterial pressure (RRs) and an increase in LAP. The law of Laplace teaches that wall stress is directly proportional to luminal radius, meaning that with increasing left ventricular radius, wall stress also increases and leads to left ventricular decompensation (Figure). The loaded ventricle—already stressed by higher stroke volume due to bradycardia and by increased volume due to the Trendelenburg position, which is necessary for continuous volume supply—is additionally stressed by pressure against the right pericardium. This pressure further increases the radius of the left ventricular cavity. At this point the beneficial effects of atrial pacing become evident as a significant decrease in stroke volume (Table 1). In general, the decrease in left ventricular radius is followed by a decrease in left ventricular wall stress (law of Laplace). Left ventricular geometry is better preserved, and pressure of the ventricle against the right aspect of the pericardium during tilting of the heart is better tolerated.

A question arises about the reason for a heart rate of 90 beats/min. At rest, as during anesthesia, cardiac performance expressed in cardiac output is best at approximately 90 beats/min, as described by Sowton [1964]. RRs and RRm are immediately significantly increased with atrial pacing (Table 1). The result is additional hemodynamic reserve for better tolerance of the exposure maneuver.

The significant decrease in LAP (Table 1) is a product of the decrease in left atrial radius due to accelerated heart rate. Preload also is controlled, and because of the decrease in ventricular radius, mild to moderate mitral valve ring dilatation resolves. The result is resolution of mild to moderate mitral valve regurgitation if observed. Potential V wave on an LAP curve then decreases or even disappears with the described maneuver.

In case of chronic atrial fibrillation and if the patient is not to receive microwave ablation [Knaut 1999], an attempt is made at electrical cardioversion after opening of the pericardium and installation of pacemaker wires for atrial stimulation. If cardioversion still is not successful, temporary pacemaker wires are installed for both the atrium and the ventricle, and sequential pacing is performed with similar effect. The proposed maneuver of atrial stimulation is used only intraoperatively and early postoperatively. As patients recover from the operation and the negative chronotropic effects of sedation retreat, cardiac rhythm returns to normal, and atrial pacing is abandoned.

In this series, cardiac enzyme evaluation revealed a mild increase compared with preoperative values. Myocardial infarction levels never were reached, and myocardial infarction always was avoided.

It may seem as if the study was underpowered, because only 11 patients were enrolled. The fact is that the original intention was to include 25 patients. However, because statistical significance was reached after the first 11 patients, it was unnecessary to spend resources to continue through patient 25, so the study was interrupted.

With the use of temporary atrial pacing in off-pump surgery, RRs, RRm, CI, and CO increased, and, in parallel, LAP and SV decreased significantly. These results overcame the first hurdle in OPCAB, which is hemodynamic deterioration during tilting of the heart. The second hurdle in beating-heart bypass grafting is myocardial ischemia during coronary occlusion. This limiting factor is eliminated at our institution by routine use of coronary shunts [Borst 1996].

At our institution, the beneficial effects of temporary atrial pacing in OPCAB are achieved because we always ensure stable hemodynamics during tilting of the heart. The result is almost complete elimination of the need for conversion to CPB. In the last 400 consecutive cases of OPCAB using the described maneuver, there was only 1 conversion (0.25%) to CPB.

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REFERENCES

Arom KV, Flavin TF, Emery RW, Kshettry VR, Janey PA, Peterson RJ. 2000. Safety and efficacy of off-pump coronary artery bypass grafting. Ann Thorac Surg 69:704-10.

Benetti FJ, Ballester C, Sani G, Boonstra P, Grandjean J. 1995. Video assisted coronary bypass surgery. J Card Surg 10:620-5.

Borst C, Jansen EW, Tulleken CA, et al. 1996. Coronary artery bypass grafting without cardiopulmonary bypass and without interruption of native coronary flow using a novel anastomosis site restraining device ("Octopus"). J Am Coll Cardiol 27:1356-64.

Bovill JG, Boer J. 1993. Opioids in cardiac anesthesia. In: Kaplan JA, editor. Cardiac anesthesia. 3rd ed. Philadelphia: WB Saunders. p 467-511.

Calafiore AM, Giammarco GD, Teodori G, et al. 1996. Left anterior descending coronary artery grafting via left anterior small thoracotomy without cardiopulmonary bypass. Ann Thorac Surg 61:1658-65.

Grundeman PF, Borst C, Verlaan CW, Damen S, Mertens S. 2001. Hemodynamic changes with right lateral decubitus body positioning in the tilted porcine heart. Ann Thorac Surg 72:1991-6.

Grundeman PF, Borst C, Verlaan CWJ, Meijburg H, Mouës CM, Jansen EWL. 1999. Exposure of circumflex branches in the tilted, beating porcine heart: echocardiographic evidence of right ventricular deformation and the effect of right or left heart bypass. J Thorac Cardiovasc Surg 118:316-23.

Gundry SR, Romano MA, Shattuck OH, Razzouk AJ, Bailey LL. 1998. Seven-year follow-up of coronary artery bypasses performed with and without cardiopulmonary bypass. J Thorac Cardiovasc Surg 115:1273-7.

Jansen E, Grundeman P, Borst C, et al. 1997. Less invasive off-pump CABG using a suction device for immobilization: the "Octopus" method. Eur J Cardiothorac Surg 12:406-12.

Knaut M, Spitzer SG, Karolyi L, Richter P, Tugtekin SM, Schüler S. 1999. Intraoperative microwave ablation for curative treatment of atrial fibrillation in open heart surgery. The MICRO-STAF and MICRO-PASS pilot trial. Thorac Cardiovasc Surg 47(suppl III):379-84.

Kolessov VI. 1967. Mammary artery–coronary artery anastomosis as a method of treatment for angina pectoris. J Thorac Cardiovasc Surg 54:535-44.

Kshettry VR, Flavin TF, Emery RW, Nicoloff DM, Arom TV, Petersen RJ. 2001. Does multivessel off-pump coronary artery bypass reduce postoperative morbidity? Ann Thorac Surg 71:1751-2.

Lund O, Christensen J, Holme S, et al. 2001. On-pump versus off-pump coronary artery bypass: independent risk factors and off-pump graft patency. Eur J Cardiothorac Surg 20:901-7.

Patel NC, Deodhar AP, Grayson AD, et al. 2002. Neurological outcomes in coronary surgery: independent effect of avoiding cardiopulmonary bypass. Ann Thorac Surg 74:400-6.

Sowton E. 1964. Hemodynamic studies in patients with artificial pacemakers. Br Heart J 26:737-46.