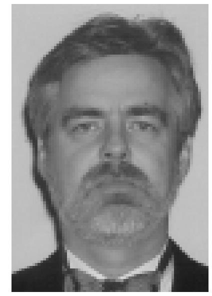
The Heart Surgery Forum #2001-3372
4 (4):335–338, 2001 Online address: www.hsforum.com/vol4/issue4/2001-3372.html

Hemodynamic Stability and Lessons Learned: A Four-Year OPCAB Experience

(#2001-3372)

James C. Hart, MD

Capital Area Cardiovascular Surgical Institute, Camp Hill, PA
Pinnacle Health Systems, Harrisburg, PA



Dr. Hart

INTRODUCTION

Off-pump coronary artery bypass (OPCAB) is being used with increasing frequency in many cardiac centers worldwide [Hart 2000]. The avoidance of cardiopulmonary bypass is believed to result in lower morbidity and mortality rates, particularly in higher risk patients. Early proponents of beating heart coronary artery bypass grafting (CABG) limited their target arteries primarily to anterior wall vessels, with some operations on the right coronary artery (RCA) as well [Benetti 1991]. Lateral wall vessels were much more difficult to approach because of limited exposure and prohibitive hemodynamic deterioration seen with cardiac displacement. It is estimated that 80% of CABG patients require circumflex branch revascularization. These facts precluded OPCAB from being practical in most patients. Because many surgeons felt that OPCAB potentially would provide substantial improvement in patient outcomes, several centers began to focus on the development of surgical techniques to allow safe access to the lateral wall, and progress was made.

BACKGROUND

Grundeman et al. studied the hemodynamic consequences of verticalization of the heart using suction stabilization in a porcine model [Grundeman 1999]. They demonstrated a 30% drop in cardiac output and mean arterial blood pressure, primarily related to reduced stroke volume. In an elegant echocardiographic analysis of their hemodynamic findings, they demonstrated impaired right ventricular filling as the primary culprit [Grundeman 1999]. Augmenting preload using 25-30 degrees of Trendelenberg position returned blood pressure and cardiac output to near baseline levels at the expense of increased central filling pressures. Early adventurers into lateral wall OPCAB relied primarily on this technique to help preserve hemodynamics during cardiac displacement, but access was still difficult and hemodynamic stability was unpredictable. Pharmacological support with inotropes and pressor agents was frequently necessary.

Burfeind et al. assessed left ventricular function during compression stabilization of the left anterior descending coronary artery (LAD) in pigs and demonstrated significant reduction in cardiac output (4.2 to 3.6 L/min.) [Burfeind 1998]. The authors felt that this fall in cardiac output was likely secondary to the left ventricular deformation caused by compression stabilization.

Mathison et al. offered the first clinical report of hemodynamic changes during OPCAB [Mathison 2000]. Sternotomy incisions were used for multivessel OPCAB in 44 consecutive patients. Following baseline hemodynamic measurements, hearts were positioned for anterior, lateral oblique marginal branch (OM), or posterior descending anastomoses. Hemodynamics were optimized and measurements were repeated. The report demonstrated hemodynamic alterations in all three regions, with lateral wall access producing the most significant changes. There was evidence of biventricular failure, which was more pronounced on the right side. Unlike the porcine model, augmentation of preload with Trendelenberg positioning did not reliably normalize cardiac output.

Nierich et al. reported on a similar group of 150 patients undergoing beating heart CABG (54 by anterolateral thoracotomy and 96 by sternotomy) [Nierich 2000]. Stabilization was accomplished with a suction stabilizer. When compared to LAD and right coronary artery (RCA) vessels, OM anastomoses produced more hemodynamic alterations and required more frequent use of the Trendelenberg position and/or inotropic support. Overall, there was no clinically significant deterioration of global circulation when managed as described.

Watters et al. reported on their technique of OPCAB using a sling technique for cardiac displacement and a reusable mechanical compression stabilizer [Watters 2001]. Twenty-nine patients having multivessel OPCAB were studied. No patient had a history of myocardial infarction within one month of the procedure and all patients had left ventricular ejection fractions (LVEFs) of at least 40%. During occlusion and coronary grafting, intraluminal shunts were routinely employed. The hemodynamic results of this study echoed those described above. There were target vessel-dependent changes in filling pressures, stroke volume, and cardiac index that were most pronounced in the circumflex distribution.

Presented at the Minimally Invasive Cardiac Surgery (MICS) Symposium, Key West, Florida, May 27, 2001.

Address correspondence and reprint requests to: Dr. James C. Hart, Capital Area Cardiovascular Surgical Institute, 423 North 21st Street, Camp Hill, PA 17011, Phone: (717) 975-0900, Fax: (717) 975-2724, Email: Jchart51@earthlink.net

Figure 1. The retro-sternal musculofascial insertions are divided from the inferior part of the sternum, shown here on the patients right side. This is done bilaterally.

Figure 3. A vertical posterior pericardiotomy is made along the diaphragm approaching the IVF but avoiding the phrenic nerve.

These changes rapidly reversed with return of the heart to anatomical position and were clinically well tolerated.

DISCUSSION

Current Surgical Technique

The author has performed more than 500 beating heart operations since July 1996. Since June 1997, all OPCAB cases have used a commercially available, suction-based stabilizer (Medtronic Octopus' 1, 2, 2+, 3). Over the last 30 months, more than 95% of CABG patients have been operated on without CPB. During this time, various surgical maneuvers have proven to be valuable in maintaining hemodynamic stability, allowing for unhurried, precise anastomoses in virtually all target arteries. Anterior vessels and RCA targets are easily approached using previously described techniques [Hart 1999]. Lateral wall anastomoses require strict attention to surgical details to allow for hemodynamic stability. The techniques that accomplish this are the subject of the following discussion.

Since most of the disturbances seen are related to right heart compression and diminished stroke volume, heart rate is an important consideration. Many patients have been pretreated with beta-adrenergic blocking agents preoperatively and are bradycardic. In early attempts at beating heart CABG, slow heart rates were felt to be advantageous. However, with the excellent mechanical stabilization achieved with current-generation suction stabilizers, bradycardia is not required. Bradycardic patients with marginal hemodynamics during cardiac displacement can sometimes be stabilized easily by temporary atrial pacing.

The remaining techniques all are used with the intent to minimize right heart compression during cardiac displacement for OM grafting. Unlike early attempts at cardiac tilting with the apex elevated outside the chest, every effort is made to allow the heart to drop posteriorly in the chest and then to have the heart rotate into the right chest cavity without compression against the pericardium or the right hemi-sternum.

To allow this posterior rolling of the heart, the retro-sternal musculofascial insertions on the posterior part of the inferior sternum are divided, allowing the mediastinum to drop posteriorly (Figure 1, ◎). A sternal spreading retractor (Chaux Retractor™, Pilling) that allows a lifting action on the right hemi-sternum is used, making more space for the heart to drop under the edge of the sternum.

The right pleural space is opened widely in virtually all patients needing lateral wall grafting. The pleuropericardial fat pad is then removed using cautery, again to make more space for the apex to enter the right chest cavity (Figure 2, ◎).

Early attempts at cardiac displacement to the right chest cavity were impeded by the right pericardium. Currently the right pericardium is incised in a posterior direction from its attachment to the diaphragm. This incision is carried posteriorly to near the inferior vena cava while avoiding the identified phrenic nerve (Figure 3, ◎). With the right pericardial

Figure 2. Removal of the right pleuropericardial fatpad allows more space for the heart to enter the right chest without compression.

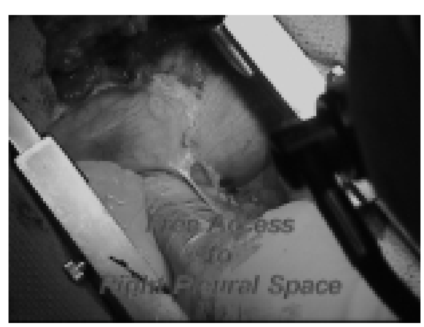


Figure 4. With the pericardiotomy completed ample space is available for rotation of the cardiac apex into the right chest, avoiding compression.

Figure 5. Excellent exposure and access to OM vessel with cardiac rotation is shown. The apex rests on the right hemidiaphragm and minimal compression of the right heart allows hemodynamic toilerance.

Figure 6. Placement of the superior deep pericardial stay suture just inferior to the inferior pulmonary vein and posterior to the left phrenic nerve.

flap free to fold into the right chest, the heart has an unrestricted route to rotate behind the sternum into the pleural space without significant compression (Figure 4, ◎). Figure 5 (◎) shows a heart fully rotated into the right chest with the apex resting on the dome of the right hemidiaphragm.

Clinical observations by Pym demonstrated that moderate right lateral decubitus positioning at 30-45 degrees allowed for gravity-assisted rotation of the heart rightward and seemed to preserve hemodynamics [Pym 1998]. Trendelenberg positioning for augmentation of preload has been used sparingly, as the author believes that significant increases in central venous pressure may actual impair perfusion of secondary vascular beds. Deeply placed left pericardial stay sutures (Figure 6, ◎) or slings, as described by Spooner, are also used to assist in cardiac displacement.

Many surgeons believe that the order of grafting of target vessels is important. Most feel that the anterior vessels should be revascularized first, perhaps allowing better hemodynamic tolerance to displacement for OM grafting. The author has followed this rule, with some exceptions, without obvious differences in levels of tolerance. Intracoronary shunting has only been used in rare instances, most often during grafting of large RCA vessels with only moderate proximal stenosis.

Anticoagulation is achieved with 2 mg/kg of heparin, with a target-activated clotting time of >300 seconds. Test occlusion of each target artery is undertaken for five minutes, watching for signs of hemodynamic deterioration. Significant changes are very unusual but, when present, will occur within two or three minutes. Restoration of flow and return to baseline hemodynamics permits alterations in plans, such as adding a shunt, changing the order of grafting, or optimizing positioning, to be made.

Using these techniques, more than 320 OM grafts have been completed without CPB with remarkably little hemodynamic deterioration. Pharmacological support during displacement and grafting is not often required. In the last 42 months, no patient has been converted to CPB once the decision to proceed with OPCAB has been made. Less than 1% of patients have required inotropic support leaving the operating room, and no patient has required a new intra-aortic balloon pump (IABP). Although several patients had preoperative placement of an IABP to control symptoms, none were used electively to allow mechanical support for OPCAB.

CONCLUSION

As surgeons, referring physicians, and patients have become more interested in the avoidance of CPB for CABG, strict attention to the details of planning and execution of beating heart procedures has become increasingly important. By avoiding right heart compression with the techniques described above, hemodynamics can be preserved, thereby maintaining cerebral, renal, gut, and myocardial perfusion. Only when these objectives are met will OPCAB patients enjoy both maximum safety during their procedures and improved outcomes.

For OPCAB to be viable, graft patency rates must equal those achieved with arrested heart techniques. Maintenance of optimal hemodynamics, even in patients with impaired left ventricular function, can almost always be achieved and will allow a precise, unhurried anastomosis under ideal conditions, maximizing the chance for successful revascularization. Inattention to detail, however, is likely to result in hemodynamic instability, hurried and imprecise anastomoses, and altered secondary organ perfusion, with inferior outcomes.

REFERENCES

1. Benetti FJ, Naselli G, Wood M, et al. Direct myocardial revascularization without extracorporeal circulation. Experience in 700 patients. Chest 100:312-6,1991.
2. Burfeind WR, Duhaylongsod FG, Samuelson D, et al. The effects of mechanical cardiac stabilization on left ventricular performance. Eur J Cardiothorac Surg 14:285-9, 1998.
3. Grundeman PF, Borst C, van Herwaarden JA, et al. Hemodynamic changes during displacement of the beating heart by the Utrecht Octopus method. Ann Thorac Surg 63:S88-92, 1997.
4. Grundeman PF, Borst C, Verlaan CWJ, et al. Exposure of circumflex branches in a tilted, beating porcine heart: echocardiographic evidence of right ventricular deformation and the effects of right or left heart bypass. J Thorac Cardiovasc Surg 118:316-23, 1999.
5. Hart JC, Spooner T, Edgerton JR, et al. Off-pump multivessel coronary artery bypass utilizing the Octopus' tissue stabilization system: initial experience in 374 patients from three separate centers. Heart Surg Forum #1999-5150 2(1):15-28, 1999.
6. Hart JC, Spooner T, Pym J, et al. A review of 1582 consecutive

Octopus off-pump coronary bypass patients. Ann Thorac Surg 70:1017-20, 2000.
7. Mathison M, Edgerton JR, Horswell JL, et al. Analysis of hemodynamic changes during beating heart surgical procedures. Ann Thorac Surg 70:1355-61, 2000.
8. Nierich AP, Diephuis J, Jansen EW, et al. Heart displacement during off-pump CABG: How well is it tolerated? Ann Thorac Surg 70:466-72, 2000.
9. Pym J. Personal communication. 1998.
10. Watters MPR, Ascione R, Ryder IG, et al. Haemodynamic changes during beating heart coronary surgery with the "Bristol Technique." Eur J Cardiothorac Surg 19:34-40, 2001.