

Coronary Artery Bypass Grafting (CABG) without Cardiopulmonary Bypass (CPB): A Strategy for Improving Results in Surgical Revascularization



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ABSTRACT

Background: Coronary artery bypass grafting (CABG) was performed on patients with cardiopulmonary bypass (CPB group) or without CPB (non-CPB group). A series of patients, operated between January 1, 1995 and September 30, 1997 is reported.

Methods: Data were collected and analyzed as determined by the New York State Department of Health. Preoperative comorbidity, postoperative morbidity and mortality were compared. There were 2869 patients in the CPB group and 505 patients in the non-CPB group.

Results: Demographics of the two groups were similar but preoperative risk factors were more common in patients undergoing CABG without CPB. Of the non-CPB patients, 31.9% had reoperations as compared to 8.5% in CPB patients ($p = 0.00005$). The presence of an extensively calcified aorta was more common in the non-CPB patients (5.9% vs. 2.8%, $p = 0.0002$). Immune deficiency was also more common in the non-CPB group ($p = 0.001$). Risk-adjusted mortality was similar in the two groups while major complications were much less common when CPB was not utilized. In CPB patients only 84.3% avoided major complications, while among non-CPB patients 90.1% were complication-free ($p = 0.0008$).

Conclusions: CABG without CPB is an attractive method of surgical revascularization. Increasing age and preoperative comorbidity in patients referred for CABG dictate changes in surgical strategy, of which avoidance of CPB appears most beneficial.

INTRODUCTION

Coronary artery bypass grafting (CABG) is one of the most efficacious invasive therapies for symptomatic coronary artery disease. Short, intermediate, and long-term results have been extensively documented. Interventional therapies such as balloon angioplasty and stenting have gained popularity because they are less invasive and have lower rates of early complications.

Recent technological developments have made it possible to perform CABG using a less invasive surgical approach (LISA). The major element of LISA is the elimination of cardiopulmonary bypass (CPB). At present we are able to perform CABG without CPB in over 90% of unselected patients referred for surgical treatment of coronary artery disease, including multivessel disease, reoperations, emergencies and hemodynamically unstable patients. Increasingly, small incisions are utilized, although median sternotomy is by far the most common surgical approach. The purpose of this paper is to describe LISA as practiced in our institution, documenting early results of the procedure compared to traditional CABG.

MATERIALS AND METHODS

Since 1995, CABG without CPB has gained popularity at our institution. Initially LISA was used mainly when CPB was contraindicated, or was considered dangerous due to calcification of the ascending aorta, bleeding tendency, or other co-morbidities [Bergsland 1997]. As we gained experience and new technology became available, LISA was used as the primary approach in the majority of the authors' cases.

Preoperative risk factors, postoperative complications and mortality data were entered in the New York State (NYS) database as previously described [Hannan 1990, Bergsland 1998]. This database is considered highly reliable due to the strict verification process mandated by the

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state. Risk-adjusted mortality, complications, and preoperative risk factors were compared between patients undergoing CABG with and without CPB. Statistical analysis was performed and differences were considered significant when $p < 0.05$.

Surgical Techniques

CPB group: Patients were operated on using median sternotomy with aortic and right atrial cannulation. Occasionally femoral artery cannulation was utilized. Cold blood cardioplegia was used almost exclusively, administered ante- and/or retrogradely. Venting of the ascending aorta was used frequently to facilitate exposure and visualization. Graft patency verification techniques were rarely utilized.

LISA group (non-CPB group): Most patients were operated on using median sternotomy. Left thoracotomy was used occasionally for bypassing the LAD with LIMA (LAST or MIDCAB operation) [Calafiore 1996], and for bypassing the circumflex artery in reoperations [Grosner 1990]. Partial sternotomy was used in some cases keeping the manubrium intact. In the early phase of the series, incomplete revascularization was occasionally accepted or an integrated approach [Angelini 1996] combining surgical and interventional treatment was utilized because of difficulties in approaching the circumflex coronary artery and its obtuse marginal branches. With the current technique, complete revascularization can almost always be accomplished. The technical aspects are described below and shown in the video (Movie 1 ●).

Stabilization

Mechanical stabilization has been used routinely since becoming commercially available. A disposable stabilizing retractor system (Cardiothoracic Systems Inc., Cupertino, CA) generally gives excellent stability of the vessel.

Control of Bleeding

A proximal snare on the target coronary artery (4-0 polypropylene) is routinely used. A surgical blower (VisuFlow, Research Medical, Salt Lake City, Utah) is essential in optimizing exposure [Teoh 1991]. An intraluminal obstructer or shunt is used to further facilitate suturing and/or avoid distal ischemia. We consider shunting essential for right coronary artery (RCA) and desirable for other vessels.

Suturing

Continuous 7-0 or 8-0 polypropylene suture is utilized for distal, and 6-0 for proximal anastomosis.

Positioning and presentation of vessels

Anterior vessels are easily positioned by simply placing a sponge behind the heart (Movie 1 ●). When multivessel bypass is required the positioning for each planned bypass is prepared prior to grafting. Two main methods are used alone or in combination. By using one of these methods or occasionally combining the two, any vessel can be presented reliably for grafting.

Gauze strings (1/2-inch gauze packing) are placed through the transverse sinus and around the inferior vena cava. The strings are used to elevate the appropriate part of the heart for grafting. This method is efficient but frequently causes mild to moderate hypotension. This is usually easily controlled by volume-infusion and low-dose vasoconstrictors.

The so-called Lima-sutures (as described by Dr. Ricardo Lima, Recife, Brazil) are placed posteriorly in the pericardium just anterior to the pulmonary veins (Movie 1 ●). When traction is applied to these sutures, the heart is luxated out of the chest without hemodynamic compromise. After application of the stabilizer foot ideal grafting conditions are generally obtained. In most cases a single Lima stitch is adequate. A Number 2 polyester suture is placed in the posterior pericardium perpendicular to the anatomic center of the heart. This corresponds to a point just lateral to the left inferior pulmonary vein. The suture is covered with a rubber tourniquet to prevent damage to the myocardium. Manipulation of the suture will expose all aspects of the coronary tree for grafting. When needed the positioning is further improved by the gauze strings.

Avoiding Ischemia and Hemodynamic Compromise

We feel strongly that the LAD should be the first vessel to be grafted. This is the most important vessel and it requires the least dislodgment of the heart. When the LAD has been bypassed excellent perfusion of the anterior wall and septum is assured and less likely to be compromised by maneuvers used to expose the rest of the heart. In general, all vessels except the RCA may be occluded during grafting without demonstrable hemodynamic instability or arrhythmias. However, we prefer to avoid ischemia by inserting a local shunt in the arteriotomy whenever possible. For the main RCA, shunting is mandatory since third-degree atrioventricular block and hemodynamic collapse may occur during its occlusion. Although prophylactic atropine has been found to ameliorate this complication, we prefer to use either a local or aortico-coronary shunt during grafting of the main RCA. A ventricular pacing wire is also routinely placed prior to RCA snaring.

Graft Verification

Intraoperative verification of graft patency should be done in all CABG. We have used a transit-time computer system routinely for the last 18 months. This device (Cardiomed Flowmeter, Medistim Inc., Oslo, Norway) measures mean, as well as systolic and diastolic flow [Bergsland 1998]. By evaluating these flow measurements, as well as visually inspecting the flow curve of the graft, malfunctioning grafts can be detected and revised. When revision is required it is usually performed without the need for CPB.

Pharmacologic Management

Patients are routinely given aspirin preoperatively. Heparin is given prior to grafting at 1 mg/kg. Additional heparin is given as needed to obtain an ACT of more than 300 seconds and partially reversed at the end of the procedure. Neosynephrine is used as needed during heart elevation, but adequate volume loading decreases or elimi-

Table 1. Patient characteristics

	CPB (n = 2869)	Non-CPB (n = 505)
Gender		
Males	1963 (68.4%)	339 (67.1%)
Females	906 (31.6%)	166 (32.9%)
Age, y		
Average	64.2	66.1
Minimum	31	36
Maximum	89	89
Ejection fraction, %		
Average	50.3	51.1
Minimum	9	17

nates the need for this drug. We have been surprised that compromised left ventricles tolerate positioning and grafting equally well when compared to normal ventricles.

Anesthesia Techniques

The anesthesiologist is an important member of the surgical team especially during LISA. Adequate volume loading is essential and acute ischemic episodes must be avoided. The ischemic heart tolerates positioning poorly.

The patient must be kept at normothermia. A method developed by one of the authors (Yanulevich) has been extremely valuable. A special hood is placed on the patient's head and shoulders and warm air blown into this hood. By using this simple method, normothermia is maintained throughout the case in spite of the cool operating room temperature.

Balanced anesthesia with short-acting agents is utilized. Low-risk patients are extubated in the operating room. Toradol is frequently administered towards the end of the operation to ameliorate postoperative pain. A patient controlled analgesia pump should be available for the patient after extubation.

Table 2. Preoperative Risk Factors

	CPB, % (n = 2869)	Non-CPB, % (n = 505)	Significance, p values
Previous operation	8.5	31.9	<0.00005
Previous MI	63.2	62.2	
Transmural MI	40.9	30.7	<0.00002
Stroke, preoperatively	7	9.9	<0.025
Cerebrovascular disease	22.5	23.8	
Aortoiliac disease	4.4	5.9	
Unstable, preoperatively	2.9	2.8	
COPD	22.9	24.6	
Extensively calcified aorta	2.8	5.9	=0.0023
Diabetes	25.9	24.2	
IABP, preoperatively	2.8	2.2	
Immune deficiency	1.2	3	=0.0012
Renal failure (cr>2.5)	1.5	2.8	
Renal failure dialysis	0.7	1.2	

Table 3. Mortality

	CPB, %	Non-CPB, %
Observed Mortality	2.50	4.00
Expected Mortality	2.50	4.20
Risk-Adjusted Mortality (RAM)	2.50	2.40

Alternate Incisions

Although the vast majority of procedures were performed with median sternotomy exposure other incisions are used in selected patients. Patients with single LAD disease are frequently operated on using the LAST-approach as described by Calafiore [Calafiore 1996]. For reoperations, left thoracotomy has been used for bypassing the circumflex artery and its branches [Grosner 1990] and a low mid-line incision used to bypass the RCA and distal branches with the gastroepiploic artery [Akther 1997].

RESULTS

Patient characteristics are outlined in Table 1 (●). There were 2869 patients in the CPB group and 505 patients in the non-CPB group. As can be seen, age, gender and preoperative left ventricular functions were similar between groups.

Table 2 (●) shows comparisons of other preoperative risk factors compiled in the NYS database. The non-CPB group consisted of higher-risk patients which is also reflected in a higher calculated expected mortality in non-CPB patients (Table 3, ●).

As can be seen from Table 3, risk-adjusted mortality (RAM) was lower in the non-CPB group. None of the differences in mortality were significant.

Postoperative complications are listed in Table 4 (●). The freedom from complications overall was much higher in the non-CPB group. Stroke incidence was reduced from 2.7% to 1.0% ($p = 0.02$). The need for postoperative intra-aortic balloon (IABP) was reduced from 4.6% to 2.4% ($p = 0.02$). Most other complications showed a trend to be lower in the non-CPB group.

Table 4. Postoperative Complications

	CPB, % (n = 2869)	Non-CPB, % (n = 505)	Significance p values
No Complications	84.3	90.1	0.00079
Stroke	2.7	1	0.019
Transmural MI	2.4	2.2	
Non transmural MI	3.1	1.6	
Deep sternal infection	0.6	0.8	
Bleeding requiring reoperation	1.8	1	
GI-bleed or perforation	1.3	0.8	
Renal failure, dialysis	2	2.2	
IABP inserted	4.6	2.4	0.024
Respiratory failure	2.7	1.6	
Malignant vent. Arrhythmia	2.2	2	

Table 5. Length of Stay

	With Pump	W/o pump
Admission to discharge, d	12.3	11.9
Surgery to discharge, d	8.2	7.6

Length of stay was slightly lower in the non-CPB group (see Table 5, ●).

DISCUSSION

The invasive treatment of coronary artery disease has evolved rapidly. However, in spite of its well-documented efficacy, CABG has been increasingly challenged by endovascular therapies such as PTCA, stenting, directed atherectomy, etc. Although the long-term results of these interventions are largely unknown, the fact that they are less invasive makes them attractive for patients, especially the older and sicker patients presently being referred for therapy. The surgical approach to coronary artery disease using traditional CPB techniques represents a maximally invasive therapeutic option. Major and minor complications are common. The risk of neuropsychological disturbances after CPB represents a major threat to the patient's quality of life and ability to return to productive work [Murkin 1997, Roach 1996].

Using the relatively simple methods described above it is possible to accomplish complete revascularization in at least 90% of all cases.

The major objection to LISA or off-CPB coronary surgery has been the fear of reduced graft patency. Although occasional previous studies have demonstrated unfavorable graft patency in off-CPB CABG, it must be remembered that these studies were done without stabilization and graft verification techniques. Also, studies from abroad have repeatedly demonstrated excellent results using off-CPB CABG [Benetti 1980, Buffolo 1985].

Using the techniques described in this paper we can assure close to 100% graft patency, at least at the time the chest is closed. When flow measurements are less than ideal the graft is corrected. We have only had a single graft during the whole experience which we were unable to correct (a saphenous vein graft to a diagonal which was dissected from the arteriotomy). Although we do not have follow-up angiography in many patients, clinical follow-up and postoperative stress testing has shown a very low incidence of recurrent ischemia. Others have shown that graft patency in off-pump CABG is at least as good as those reported with CPB.

The major reason for avoiding CPB is prevention of morbidity. All major complications are drastically reduced when compared to on-pump CABG. We have previously demonstrated this by using the NYS database [Bergsland 1997]. When reoperations are analyzed separately the benefit of LISA is even more dramatic [Bergsland 1998].

We have not studied the more subtle neuropsychological changes in our own series. Certainly, our impression is that such complications are drastically reduced.

The authors have been performing coronary artery surgery for a number of years. The main reason we believe that the LISA approach represents a major turning point in cardiac surgery is the relative ease with which complete revascularization is now accomplished off pump. In most cases we are operating on a hemodynamically stable patient with a heart beating in normal sinus rhythm. The mechanical devices provide "on-pump conditions" for suturing. Our flowmeter confirms patency of the grafts. Bleeding is minimal and the patient is usually extubated shortly after the operation. There simply is no longer the need for the heart lung machine in coronary artery surgery.

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