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Off-Pump Coronary Artery Bypass Grafting: The Zurich Experience

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ABSTRACT

Coronary artery bypass grafting (CABG) is the surgical procedure of choice for treatment of multi-vessel coronary artery disease. The rising risk profile of the patients requiring isolated CABG and the economic pressure have prompted us to devise new operative strategies to treat these patients. Elimination of the cardiopulmonary bypass is one possible answer to the dilemma of maintaining the quality of care and reducing the exploding costs of our health system. Therefore, we developed the off-pump coronary artery bypass grafting (OPCAB) for patients requiring isolated CABG. In our experience the key to successful OPCAB relies on the order of revascularization of the myocardial walls (anterior, inferior, lateral), use of intracoronary shunt, no-touch technique for the proximal aortic anastomosis with heart string® (Guidant, IN, USA), close collaboration with the anesthesiologists, early and aggressive administration of anti-platelet therapy, endoscopic vein harvest by perfusionists, and improved body temperature control. Following these concepts, we have been able to offer the OPCAB procedure to over 90% of our patients and to reduce perioperative morbidity and global costs.

THE RATIONALE FOR OFF-PUMP CORONARY ARTERY BYPASS GRAFTING

In 1953, Walton Lillehei began the era of the open-heart surgery by using a cross-circulation between a child and his father at the University of Minneapolis [Cohen 1953]. A year later in Philadelphia, John Gibbon operated on the first patient using a self-made heart lung machine [Jones 1955]. These procedures acted as cornerstones of the modern heart surgery and triggered the worldwide use of heart lung machine for performing all types of open-heart operations. Use of the heart lung machine enabled Favaloro in 1968 at the Cleveland Clinic to introduce the coronary artery bypass grafting (CABG) of a proximal right coronary artery stenosis with a segment of saphenous vein [Favaloro 1968]. This became quickly the surgical therapy of choice for coronary artery disease across the world.

Over the past decades huge technical advances increased the safety and handiness of the cardiopulmonary bypass (CPB) to the point that it became a permanent part of the CABG procedures. During the same time not only the risk profile of the patients undergoing CABG but also the socio-economic situation changed dramatically in the western countries.

An overview of the risk profile of the patients undergoing CABG during the past 20 years in Zurich shows that the average age of the patients, percentage of patients with unstable angina and therefore the Euroscore of our patient population continuously increase (Table 1). This would be accompanied by a rise in perioperative mortality and morbidity [Nashef 1999]. On the other hand, the explosion of the costs in our health systems warrants new saving strategies in our daily practice. Thus, we are facing a socio-economic dilemma: improving the quality of care in a patient population with increased perioperative risk and realizing savings for our health systems.

We, like other authors, have considered the elimination of the CPB for isolated CABG as potential answer to the abovementioned dilemma. Disadvantages of the CPB are mediated through the contact of the blood with the foreign material of the circuit and known as the whole body or systemic inflammatory response syndrome. Clamping and unclamping of the aorta is followed by the ischemia reperfusion injury which in turn aggravates the systemic inflammatory response syndrome and by potential release of solid particles of the aortic wall to cause neurological events [Antunes 2003]. It is obvious that these undesired effects of the heart lung machine and manipulation of the aorta are more devastating in our aging patient population with increasing risk factors [Antunes 2003].

DEVELOPMENT OF AN OPCAB PROGRAM

Thus, to reduce costs and to improve the quality of care at the same time in our patients undergoing isolated CABG, we stepwise introduced the OPCAB concept into our daily practice. The endoscopic vein harvest (EVH) is the first part of this concept. The EVH compared to the open technique reduces postoperative pain and discomfort of the patients as well as infection and bleeding events [Schurr 2002]. It improves the healing process of the leg wound and has obvious esthetic advantages. We have trained our perfusionists,

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Table 1. Risk Profile of CABG Patients in Zurich over the Past 20 Years

	1980	1985	1990	1995	2000
Patients, n	208	386	517	578	595
Age, y	54	57	59	62	65
Unstable Angina, %	18	19	22	38	35
Euroscore	2.4	2.2	3.4	4.7	5.5

unemployed during the OPCAB procedure, to perform the EVH. This has allowed an optimal use of human resources during OPCAB, helping to reduce costs by saving an assistant job, as well.

In our opinion, close collaboration between the cardiac surgeon and anesthesiologist is mandatory for all OPCAB procedures. During the manipulation of the heart, the hemodynamics is stabilized by using vasoactive drugs, positioning of the operating table and sequential stimulation of the heart at a rate of 90 cycles/minute. In our experience the key to a successful OPCAB procedure is the order in which different myocardial segments are revascularized.

TECHNICAL CONSIDERATIONS

We always begin with the revascularization of the anterior wall, which necessitates the least mobilization of the heart. After securing the operative field using a stabilizer, we open the coronary artery and install an intracoronary shunt with the help of a blower. Advantages of the shunt are an improved visibility of the anastomotic site and conservation of the distal perfusion. It also serves as a guide wire for the anastomosis. The disadvantage of the shunt is the potential endothelial injury with prothrombotic effect. For this reason we start an aggressive anti-platelet regimen combining clopidogrel and aspirin as early as 3 hours after the wound closure in the absence of major bleeding.

The revascularization of the anterior wall is followed by that of the inferior, whose exposure is accompanied by little hemodynamic compromise. Now as the anterior and inferior walls as well as the septum are revascularized, the manipulation of the heart to expose the circumflex territory is hemodynamically much better tolerated. In fact no conversion to extracorporeal circulation was necessary during the anastomosis to the circumflex territory during our last 400 OPCAB patients. In our experience this is the key to a complete revascularization in the vast majority of the patients with 3-vessel disease [Genoni 2004]. The average time for OPCAB distal anastomosis is between 15 minutes for LAD and RCA and 20 minutes for RCX.

Table 2. Neurological Outcome in Patients Undergoing OPCAB by Using Heart String® (Guidant, IN, USA) for Construction of the Proximal Aortic Anastomoses

	03-12/2003 *N* = 189	01-12/2004 *N* = 256
Proximal anastomoses, n	333	451
Neurological events	1%	0%

Table 3. OPCAB Strategy in Zurich

Order of revascularization of the myocardial walls
Use of intracoronary shunt
No-touch technique for the proximal aortic anastomosis with heart string
Close collaboration with the anesthesiologists
Early administration of anti-platelet therapy
Endoscopic vein harvest by perfusionists
Improved body temperature control

An important part of our concept to maintain the quality of care in this patient population is the no-touch technique to perform the proximal anastomoses on the aorta. Since the beginning of 2003, we exclusively use the heart string® (Guidant, IN, USA) to construct all proximal anastomoses on the aorta (Table 2).

The quality of the anastomoses is controlled at the end of the operation using transient time flow measurement (Medistim, Norway). This has prompted us the revision of 1.3% (27/2052) of the distal anastomoses [Tavakoli 2004].

Another important issue during the OPCAB procedure is body temperature loss with following bleeding and hemodynamic disorder. We addressed this in a randomized prospective study comparing 3 different warming systems during the OPCAB procedure [Hofer, in press]. The Allon Thermo Regulatory System allowed a significantly more constant body temperature control, resulting in less postoperative bleeding and transfusion requirements as well as shorter intubation time.

CURRENT RESULTS

Thank to this strategy (Table 3), we have been able to offer the OPCAB procedure to an increasing number of our patients requiring isolated CABG with reduced operative mortality and perioperative myocardial infarction and neurological events. From 2002 to 2004, more than 90% of isolated CABG have been OPCAB procedures in our department.

To assess the potential benefits of the OPCAB procedure, we compared a group of 269 patients undergoing OPCAB to a group of 312 patients undergoing on-pump CABG during

Table 4. Comparative Outcome OPCAB versus On-Pump Patients

	OPCAB *N* = 269	On-pump *N* = 312	*P*
Perioperative infarction, %	3.3 ± .7	5.8 ± 1.1	.01
Intubation time, h	11.4 ± 2.3	14.2 ± 4.1	.001
Red blood cells/patient	1.5 ± .8	2.1 ± 1.1	.0001
Costs, SFr.	29,961 ± 1887	33'628 ± 1347	.01
Early mortality, %	1.6 ± .4	1.9 ± .5	ns
Euroscore	5.6 ± 1.8	5.1 ± 1.7	

the same period at our center. The two groups were comparable with regard to the age, instability, and Euroscore, although other selection bias could not be excluded. The number of distal anastomoses/patient was also similar between the groups. As a result (Table 4), the incidence of perioperative myocardial infarction and neurological events was smaller in the OPCAB group. The intubation time was shorter in the OPCAB group and these patients required less blood transfusions as compared to the on-pump patients. Taking into account the higher Euroscore of the OPCAB patients, it seems that the elimination of the CPB in this patient population lowers the operative mortality. The length of ICU stay was 1.2 ± 0.2 for OPCAB versus 2.2 ± 0.2 days for on-pump patients ($P < .05$). The length of hospital stay was 9.9 ± 1.6 for OPCAB versus 10.5 ± 1.9 days for on-pump patients ($P < .05$). Thus, optimal use of human resources by saving an assistant's position and significant reduction in length of ICU and hospital stay allowed in significantly reducing the costs of an OPCAB procedure compared to an on-pump procedure.

Despite our efforts, 5%-10% of our patients requiring an isolated CABG could not benefit from the OPCAB procedure. Currently, our indication for primary use of CPB in this patient population are patients with acute ongoing myocardial infarction not amenable to catheter-based intervention with severe impairment of the left ventricular function and/or left ventricular dilatation.

CONCLUSION

In conclusion, we believe that over 90% of the patients requiring an isolated CABG could and should be operated on using the OPCAB procedure. Thus, high-risk patients would also be managed with good results. This procedure results in reduced perioperative morbidity and potentially mortality as well. It makes savings in our health systems possible and allows us to increase the cost-effectiveness compared to on-pump procedures.

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