Benefits Of Avoiding Cardiopulmonary Bypass In High-Risk Elderly Patients Undergoing Multi-Vessel Myocardial Revascularization

(#2001-7024 … June 27, 2001)

Leonid Sternik, MD, Kenton J. Zehr, MD

Division of Cardiovascular Surgery, Mayo Clinic, Rochester, Minnesota, USA.

Presented at the Fourth Annual Scientific Meeting of the International Society for Minimally Invasive Cardiac Surgery, June 27-30, 2001, Munich, Germany

Address correspondence to: Kenton J. Zehr, M.D., Division of Cardiovascular Surgery Mayo Clinic, Rochester, MN, Telephone: (507) 255-8191, Fax: (507) 255-7378, Email: zehr.kenton@mayo.edu

ABSTRACT

Background: Elderly patients have a high prevalence of co-morbidities associated with complications after coronary artery bypass. Cardiopulmonary bypass is a contributing factor. We sought to assess risk factors and evaluate perioperative results of off-pump coronary artery bypass grafting (OPCAB) in this high-risk group of patients compared to a similar cohort of age-matched patients undergoing conventional on-pump coronary artery bypass grafting (CCABG).

Methods: From April 1999 to July 2000, 66 patients $\geq$ 75 years of age underwent OPCAB and from March 1998 to July 2000, 66 patients $\geq$ 75 years of age underwent CCABG by the same surgeon. Pre-operative risk factors, intra-operative techniques, and post-operative complications were retrospectively evaluated.

Results: Mean age of the OPCAB group was 81 ± 3.9 years and for the CCABG 79 ± 3.2 years. The OPCAB group had significantly higher prevalence of acute MI, carotid stenosis, and calcified aorta. The prevalence of stroke history, renal insufficiency, COPD, and previous CCABG was similar. 3.0 ± 0.8 grafts were placed in OPCAB patients and 3.3 ± 0.7 grafts in CCABG patients. In-hospital mortality was 3.1% (2) in each group. Peri-operative stroke was 1.5% in the OPCAB group and 4.5% in the CCABG group (p=NS). OPCAB patients required significantly less time to extubation (13.9 ± 11.8 hours versus 23.0 ± 25.4 hours) and intensive care unit care time (33.5 ± 25.2 hours versus 60.6 ± 62.5 hours) compared to CCABG patients ($p < 0.05$). There was 1.5% (1) late mortality in the OPCAB group at a follow-up of 4.9 ± 5.4 months and 3.1% (2) in the CCABG group at 8.7 ± 8.3 months (p=NS).

Conclusions: There were similarly low peri-operative mortality in elderly patients undergoing OPCAB compared to those done on-pump, despite OPCAB patients having significantly higher prevalence of carotid disease, calcified aorta, and acute MI. They required significantly less time intubated and in the ICU post-operatively compared to similarly aged lower risk patients undergoing CCABG.

INTRODUCTION

Increased life expectancy and the genetic and social predisposition for atherosclerotic coronary artery disease in western countries has resulted in a considerable increase in the number of elderly presenting for coronary revascularization[Ivanov 1998]. This same elderly population presents with a significantly higher prevalence of previous cerebrovascular events, peripheral vascular disease, chronic obstructive pulmonary disease, and chronic renal failure, and history of previous myocardial infarction with associated decreased left ventricular function compared to younger cohorts. Many of these co-morbidities can contribute to adverse effects related to subjecting this population to cardiopulmonary bypass (CPB). In addition, age remains an isolated risk factor for increased mortality and morbidity[Kolessov 1967, Tu 1995]. Therefore, this group has been particularly targeted for off-pump coronary artery bypass grafting (OPCAB). Avoiding CPB may result in improved perioperative results in groups of high risk patients co-morbidities known to be exacerbated by the inflammatory response induced by CPB, those with renal failure, pulmonary disease, cerebrovascular disease and left ventricular dysfunction[Moshkovitz 1997, Sternik 1997, BhaskerRao 1998, Bowles 2000, Yokayama 2000]. Other reports have not found any significant difference in outcomes comparing on-pump revascularization with the OPCAB[Gamoso 2000, Kshettry 2000]. The perioperative benefit may be offset by a lower patency rate of coronary grafts after off-pump revascularization [Gundry 1998, Gaudino 2000]. The popularity of the off-pump technique has been out of proportion to the equivocal nature of the data regarding the procedure. Proof of an overall advantage has been difficult to ascertain. We sought to assess risk factors and evaluate perioperative results of OPCAB in the high risk elderly patients presenting for surgical revascularization compared to a cohort of age-matched patients undergoing conventional on-pump coronary artery bypass grafting.

MATERIALS AND METHODS

From April 1999 to July 2000 a group of 66 patients 75 years of age and older underwent OPCAB. They were compared to the same number of age-matched patients undergoing isolated conventional coronary artery bypass grafting (CCABG) with extracorporeal circulation from March 1998 to July 2000. All cases were performed by the same surgeon (KJZ). We performed a retrospective analysis of the data. Decision making for selection of a specific patient into the OPCAB group relied on the expectation of reasonable coronary targets, the absence of relative contraindications for OPCAB (small, calcified vessels, intramyocardial vessels, significant cardiomegaly, and unstable hemodynamics), and the presence of significant risk factors associated with a poor outcome from cardiopulmonary bypass. Patients with the higher risk were preselected into OPCAB group in the absence of having contraindications to OPCAB. This included those with renal failure, chronic obstructive pulmonary disease, known carotid disease, a history of stroke, acute myocardial infarction, and poor left ventricular function. Some patients in the age-matched CCABG group are in the higher risk categories as they were done in the pre OPCAB era.

Surgical Technique

OPCABs were performed through the full median sternotomy incision. The left internal thoracic artery was harvested routinely. In cases when saphenous vein was not available for conduit, the right internal thoracic artery was also prepared for grafting. Once the internal thoracic artery was dissected, two-thirds of the standard heparin dose for cardiopulmonary bypass was administered (2 mg/kg). The target ACT was 350 seconds. The right pleural space was opened in cases where grafting of the lateral wall was performed. That allowed more significant rotation of the heart into the right chest for better exposure of the lateral wall vessels. Deep left posterior pericardial stitches were used to aid in elevation and rotation of the heart. Distal anastomoses were performed with the use of Octopus Tissue Stabilizer System (Medtronic, Inc., Minneapolis, MN). Flow was occluded proximally in the coronary artery while performing anastomosis with a silastic tape (Quest Medical Inc., Allen, TX) or a metal soft spring "bulldog" clamp. Proximal graft anastomoses were performed in the usual fashion to the ascending aorta using a partial occlusion clamp. Immediate angiography was performed for angiographic control in the early portion of the series. Adequate graft flow was determined by intraoperative Doppler ultrasound in the latter portion of the series. At completion of the anastomoses, a small dose of Protamine Sulfate was given (50 mg). This was rarely repeated and only if persistent non-surgical bleeding was observed. No patients required intracoronary shunting.

CCABGs were performed in our standard technique with mild hypothermia (34°C). Blood cardioplegia was administered antegrade in the aortic root and through the by-pass grafts after performance of each distal anastomoses. After completion of distal anastomoses, the aortic cross-clamp was removed. The proximal anastomoses were sewn within a partial occlusion aortic clamp unless there were spotty calcifications or the aorta was thickened. In these patients, the proximal anastomoses were sewn while cross-clamped.

Postoperative care

After transfer to the Cardiac Surgery Intensive Care Unit (ICU), all patients were moved along on an individual basis. Most patients were extubated the evening of surgery. There was no attempt to move the patients out of the ICU till the following a.m. Postoperative management protocols were identical for each groups, including plans for weaning from the ventilator, blood and blood products transfusion and low cardiac output management.

Statistical Analysis

Data is expressed either as percentage of the total or mean ± standard deviation of the mean. A Student's t test was used to study continuous variables. A Fisher's exact test was used to evaluate discrete variables. P-values less than 0.05 were considered as statistically significant.

RESULTS

Preoperative patient data

Demographic data were similar in both groups of patients. Mean age was 81 ± 3.9 years in the OPCAB group and 79 ± 3.2 years in the CCABG group. There were 45 males and 21 females undergoing OPCAB, and 38 males and 28 females undergoing CCABG. Groups were similar in prevalence of pre-operative history of stroke, renal insufficiency, diabetes, hypertension, chronic obstructive pulmonary disease, and history of the previous cardiac surgery (Table 1). Pre-operative cardiac parameters of left ventricular dysfunction, congestive heart failure, cardiomegaly, and need for preoperative intra-aortic balloon pump support were similar in both groups (Table 1). Pre-operative prevalence of acute myocardial infarction ($p < 0.01$), unstable angina ($p < 0.01$), severe carotid stenosis ($p < 0.03$), and calcified ascending aorta ($p < 0.03$) was significantly higher in the OPCAB group (Table 1). After initiation of OPCAB in our institution in April 1999, the higher risk patients were preferentially approached as candidates for OPCAB under the hypothesis that morbidity and mortality could be reduced by the avoidance of cardiopulmonary bypass. This explains the differences in pre-operative risk factors between the two groups.

Operative Characteristics

Revascularization data was similar (Table 2). The goal of complete revascularization was performed in all cases. Mean number of grafts per patient was 3.3 ± 0.7 in the CCABG group and 3.0 ± 0.8 in OPCAB patients. The number of the lateral wall grafts was significantly different in in CCABG and OPCAB groups, 55 and 44, respectively ($p<0.05$). Patients that did not require lateral wall revascularization were preferentially considered for OPCAB. There was no difference in the use of arterial grafts. Three OPCAB cases were converted to CCABG due to hemodynamic instability of the patients during the rotation of the heart to perform the lateral wall graft.

Early and Late Outcomes

Patients who underwent OPCAB were extubated sooner than CCABG patients (13.9 ± 11.8 hours versus 23.0 ± 25.4 hours and spent less time in the ICU (33.5 ± 25.2 hours versus 60.1 ± 62.5 hours) ($p<0.05$). Postoperative bleeding rate, transfusion of blood and blood products, and inotropic support were similar between groups. Incidence of post-operative neurological events, respiratory failure, new atrial fibrillation, and length of hospital stay were similar. There were two in-hospital deaths each group. Causes of death were stroke and arrhythmia in the CCABG patients and a Type A aortic dissection and acute on chronic renal failure with family refusal of dialysis in the OPCAB patients. Two patients died suddenly 3 and 8 months after CCABG with no definitive cause of death and one patient died 3 months after OPCAB due to congestive heart failure.

There was recurrent angina in two patients in each group. New congestive heart failure was manifest in one patient in each group. All patients were in New York Heart Association class 1-2 during follow-up, except 2 patients who were in

functional class 3 in the CCABG group and one in OPCAB group. Immediate angiography was used early in our practice for angiographic control of the procedure. In two there was an occluded left internal thoracic artery to left anterior descending artery anastomosis and in one patient a kinked proximal saphenous vein graft. All anastomoses were redone. In the CCABG group, a PTCA of a distal anastomosis was performed during the follow-up period in a patient with recurrent angina. Mean follow-up was 9.2 months (range 1-28 months) in the CCABG group and 5.1 months (range 1-26 months) in the OPCAB group.

DISCUSSION

In recent years, the number of elderly patients undergoing surgical coronary revascularization is increasing [Ivanov 1998]. Age continues to be an independent predictor of increased mortality and morbidity [Parsonnet 1989, Tu 1995]. Nonfatal complications reported for elderly patients after coronary revascularization have been as high as 70% [Glower 1992, Ascione 1999]. Operative mortality in elderly patients following isolated coronary artery bypass procedure varies between 5% and 24% [Edmunds 1988, Glower 1992, Cane 1995, Ascione 1999]. Complications of balloon angioplasty are higher in the elderly and range from 2% to 7% [Jollis 1995, De Gregoria 1998]. Reocclusive disease after angioplasty is higher in the elderly. De Gregorio et al. [De Gregoria 1998] found that restenosis rate post coronary angioplasty in elderly patients is as high as 47% versus 28% in younger patient population. In comparison, after surgical revascularization, over 80% of elderly patients remain free of angina [De Gregoria 1998]. According to the most recent long-term follow up from the Coronary Artery Surgery Study, 59% of patients aged 75 years at the time of surgery are alive 10 years after surgery and 33% are alive at 15 years [Knapp 1981]. Thus the surgical approach remains effective.

Off-pump coronary artery bypass was the technique used for the first direct coronary artery revascularization procedures [Kolessov 1967]. While advancements in the conventional approach were the introduction of internal thoracic artery grafts and other arterial conduits, several centers continued to advance the technique of performing direct coronary artery revascularization on a beating heart [Bennetti 1985, Buffolo 1996, Tasdemir 1998]. There has been a global interest in off-pump revascularization in the last 5 years. In some situations, the driving force is economic benefit. In others, interest seems to be driven by the fact that it can be done. The theoretical prospect of avoiding the small but present risk of complications of cardiopulmonary bypass is the most attractive potential benefits of off-pump coronary surgery. This was the impetus for embarking on an OPCAB approach for selected patients at our institution.

In this retrospective study, we compared two groups of patients 75 years of age
and older, who were undergoing surgical coronary artery revascularization. The group of
patients undergoing off-pump coronary artery revascularization were selected as high risk patients. Assessment of these patients as a group confirmed their high-risk status. The OPCAB patients had a statistically higher prevalence of acute MI and unstable angina before surgery, severe carotid stenosis, and calcified ascending aorta. The number of grafts and the number of lateral wall vessels that were grafted were similar in both groups.

Early and late mortality were similar in both groups as well as the rate of postoperative complications, and bleeding and transfusion requirements. One post-operative death deserves mention. One of two patients who died early after OPCAB had developed a Type A acute aortic dissection. This complication has already been described in the literature [Charanon 2001]. It underscores the importance of being careful with the partial occlusion clamp during creation of the proximal anastomoses. We lower the systolic blood pressures to 80 mm Hg pressure during this portion of the procedure. With the availability of proximal connectors for the aorta to saphenous vein graft anastomosis, injury to the aorta caused by a partial occlusion clamp can now be eliminated.

Several series report improved peri-operative outcomes in patients with various risk factors for complications often related to cardiopulmonary bypass. Patients with left dysfunction have been shown to have a decreased morbidity and mortality when done off-pump. A trend was shown for lower peri-operative mortality in an OPCAB group in comparison to a CCABG group [Moshkovitz 1997, Sternik 1997]. Perioperative mortality was as low as 2.7% in patients with left ventricular ejection fraction below 35% in these series. In our series, patients with cardiomegaly were preferentially done on pump because of the concern of hemodynamic instability while revascularizing the lateral wall. Thus the reason the percentages of patients with EF <35% is less in the OPCAB groups compared to the CCABG group. Therefore, no conclusions regarding OPCAB in the elderly with decreased left ventricular function can be drawn from this study.

Locker et al. [Locker 2000] showed that acute myocardial infarction patients have lower perioperative mortality when operated without cardiopulmonary bypass, but have higher rate of reintervention for recurrent angina and late mortality rate. We did presume that patients with acute MI would benefit from avoiding cardiopulmonary bypass. Twenty percent of the OPCAB patients suffered a pre-operative acute MI and only 1.5% of the CCABG patients. We have not observed any significant recurrent angina or late mortality as early follow-up.

Bowles et al. [Bowles 2001] found significant decrease (P=0.003) in cerebral microemboli after OPCAB using transcranial Doppler in comparison to CCABG and BhaskerRao et al. [BhaskerRao 1998] had similar results. ... Gaudino et al. [Gaudino 2000] found less neurological complications after surgery in patients with unclampable ascending aortas who were operated without cardiopulmonary bypass than with use of CPB and a “no-touch” technique. We did not perform cognitive studies on these patients and did not observe a reduction in permanent stroke although there was only one stroke in the OPCAB group and 3 in the CCABG group. As there was significantly more carotid disease and calcified aortas in the OPCAB group, one would have expected the data to be reversed. We believe this series strongly suggests that patients with a calcified aorta and carotid disease should be considered for OPCAB

Overall, our results suggests that there is a perioperative benefit of OPCAB in elderly patients who have pre-operative organ system dysfunction. Yokoyama et al. [Yokoyama 2000] demonstrated a consistent decreased trend in morbidity in patients with left ventricular dysfunction, renal failure, chronic obstructive pulmonary disease, and prior neurologic event. Gamoso et al. [Gamoso 2000] reported no significant difference in the renal function comparing OPCAB and CCABG groups. Koutlas et al. [Koutlas 2000] evaluated occurrence of postoperative renal failure, neurological complications, and atrial fibrillation between patients undergoing

OPCAB and CCABG and found no differences. But in his series elderly patients after OPCAB had significantly better early survival, shorter length of in-hospital stay and lower transfusion requirements. We did not notice a post-operative benefit in the reduction of the incidence of atrial fibrillation. This is in contrast to others, Ascione et al. [Ascione 2000b] reported a significantly lower incidence of atrial fibrillation after beating heart coronary surgery. The high prevalence of atrial fibrillation in our series did result in increasing our hospital stay in both the OPCAB and CCABG patients. Several studies found that the reduction of morbidity has resulted in decreases in the postoperative length of stay [Doty 1997, King 1997, Puska 1998, Spooner 1998], hospital cost [Doty 1997, King 1997, Del Rizzo 1998], and blood product requirements [Koutlas 2000]. The reduction of length of stay and blood product requirements were not significantly reduced in our study. Most importantly, patients after OPCAB spent significantly less time on the ventilator and in the ICU compared to those undergoing CABG. This directly translates to cost savings. The times are clear indicators that the patients recovered more quickly within the peri-operative period. In this study the differences were evident despite the OPCAB patients being at considerably higher risk of having more ICU and hospitalization time.

The question whether the quality of the anastomoses performed off-pump is adequate must be asked. Kshettry et al. [Kshettry 2000] found similar postoperative mortality and complications in OPCAB patients compared to CCABG in the face of less distal anastomoses. Gundry et al. [Gundry 1998] reported a twofold increase in coronary recatheterization in the follow-up period after off-pump revascularization in comparison to CCABG. Gaudino et al. [Gaudino 2000] reported a higher recurrence of ischemia after beating heart revascularization. In regards to documentation of patency, Calafiore et al. [Calafiore 1997] have reported that postoperative angiography found overall patency of anastomoses after OPCAB to be 89.8%, "perfect" patency was found in 85.2% of patients after OPCAB. "Perfect" patency was defined by the presence of any stenosis to be less than 50%. It is logical that the use of stabilization devices has resulted in an improved patency rate. These devices have allowed surgeons to perform multivessel revascularization [Jansen 1998, Puskas 1998]. The difficult locations of the coronary targets have become less of an obstacle in OPCAB surgery [Koutlas 2000]. In some patients, the lateral and inferior aspects of the heart remain challenging. Therefore, it is unlikely that OPCAB will be applicable to all cases. We have chosen a conservative approach to offering OPCAB because of the question of long-term patency. We presume there are patients whose revascularization is likely to be inadequate or nearly impossible when done off-pump. These are those with small, intramyocardial, diffusely diseased, and/or calcified coronary vessels. In these patients, the potential benefits of avoiding cardiopulmonary bypass must be weighed against the consequences of incomplete revascularization. The decreased number of lateral wall anastomoses in our OPCAB group does not reflect incomplete revascularization. It reflects the preference of doing patients as an OPCAB that do not require a lateral wall graft.

One of the limitations of the study is the inclusion of some patients in the CCABG group from the time period immediately preceding the initiation of OPCAB in our institution for the higher risk elderly patients. This resulted in some high-risk patients being done conventionally. After April 1999, most of these higher risk patients would have been done off-pump. Although, the OPCAB group is clearly higher risk, the objective of the study was to subject the higher risk patients to

OPCAB and the lower risk to a conventional procedure and determine if the avoidance of cardiopulmonary bypass could reduce the risk enough to provide similar peri-operative outcomes. The conclusion could have more pronounced had the higher risk conventional CCABG patients been excluded. In addition, in our practice, small, diffusely diseased and calcified vessels, and intramyocardial vessels are relative contraindications for off-pump revascularization. In 3 cases we had to convert an OPCAB into a CABG due to hemodynamic instability during rotation of the heart to graft the lateral wall vessel. This resulted in 3 higher risk cases being included in the on-pump group. The lack of comparison angiographic data is a limitation. This has been true of nearly all of the comparison studies of OPCAB and CCABG. A randomized trial is needed to definitely answer most of the questions that have been analyzed via retrospective means.

In conclusion, high-risk elderly patients undergoing OPCAB had a low postoperative morbidity and mortality and had a considerably smoother peri-operative course compared to lower risk patients of the same age undergoing conventional CABG. A larger number of neurological complication should have occurred in the OPCAB group compared to the conventional CABG group because of their significantly higher rates of previous stroke, carotid disease, and calcified aortas. In fact, there were less neurological complications. We particularly encourage OPCAB in these elderly patients at risk for neurological complications.

REFERENCES

1. Ascione R, Lloyd CT, Underwood MJ, et al. On-pump versus off-pump coronary revascularization. Ann Thorac Surg 68:493-98, 1999.
2. Ascione R. Caputo M, Calori G, et al. Predictors of atrial fibrillation after conventional and beating heart coronary surgery: A prospective, randomized study. Circulation 102:1530-5, 2000.
3. Bennetti FJ. Direct coronary surgery with saphenous vein bypass without either cardiopulmonary bypass or cardiac arrest. J Cardiovasc Surg 26:217-22, 1985.
4. BhaskerRao B, VanHimbergen D, Edmunds LH, Jr, et al. Evidence of improved cerebral function after minimally invasive bypass surgery. J Cardiac Surg 13:27-31, 1998.
5. Bowles BJ, Lee JD, Dang CR, Taoka SN, et al. Coronary artery bypass performed without the use of cardiopulmonary bypass is associated with reduced cerebral microemboli and improved clinical results. Chest 119:25-30, 2001.
6. Buffolo E, Silva de Andrade JC, Branco JNR, et al. Coronary artery bypass grafting without cardiopulmonary bypass. Ann Thorac Surg 61:63-6, 1996.
7. Calafiore AM, Teodori G, Di Giammarco G, et al. Minimally invasive coronary artery bypass grafting on a beating heart. Ann Thorac Surg 63:S72-S75, 1997.
8. Cane ME, Chen C, Bailey BM, et al. CABG in octogenarians. Ann Thorac Surg 60:1033-37, 1995.
9. Chavanon O, Carrier M, Cartier R, et al. Increased incidence of acute ascending aortic dissection with off-pump aortocoronary bypass surgery? Ann Thorac Surg 71:117-21, 2001.
10. De Gregoria J, Kobayashi Y, Albiero R, et al. Coronary artery stenting in the elderly. J Am Coll Cardiol 32:577-83, 1998.
11. Del Rizzo DF, Boyd WD, Novick RJ. Safety and cost-effectiveness of MIDCABG in high-risk CABG patients. Ann Thorac Surg 66:1002-7, 1998.

12. Doty JR, Fonger JD, Nicholson CF, et al. Cost analysis of current therapies for limited coronary artery revascularization. Circulation 96(Suppl II):16-20, 1997.
13. Edmunds LH Jr, Stephenson LW, Edie RN, et al. Open-heart surgery in octogenarians. N Engl J Med 319:131-36, 1988.
14. Gamoso MG, Phillips-Bute B, Landolfo KP, et al. Off-pump versus on-pump coronary artery bypass surgery and postoperative renal dysfunction. Anesth Analg 91:1080-4, 2000.
15. Gaudino M Glieca F, Alessandrini F, et al. The unclampable ascending aorta in coronary artery bypass patients: A surgical challenge of increasing frequency. Circulation 102:1497-502, 2000.
16. Glower DD, Christopher TD, Milano CA, et al. Performance status and outcome after coronary artery bypass grafting in persons aged 80 to 93 years. Am J Cardiol 70:567-71, 1992.
17. Gundry SR, Romano MA, Shattuck OH, et al. Seven year follow-up of coronary artery bypasses performed with and without cardiopulmonary bypass. J Thorac Cardiovasc Surg 115:1273-8, 1998.
18. Ivanov J, Weisel RD, David TE, et al. Fifteen-year trends in risk severity and operative mortality in elderly patients undergoing coronary artery bypass graft surgery. Circulation 97:673-80, 1998.
19. Jansen EW, Borst C, Lahpor JR, et al. Coronary artery bypass grafting without cardiopulmonary bypass using the octopus method. J. Thorac Cardiovasc Surg 116:60-7, 1998.
20. Jollis JG, Peterson ED, Bebchuk JD, et al. Coronary angioplasty in 20,006 patients over age 80 in the United States. J Am Coll Cardiol 25:47, 1995.
21. King RC, Reece TB, Hurst JL, eta al. Minimally invasive coronary artery bypass grafting decreases hospital stay and cost. Ann Surg 225:805-11, 1997.
22. Knapp WS, Douglas JS, Craver JM et al. Efficacy of coronary artery bypass grafting in elderly patients with coronary artery disease. Am J Cardiol 47:923-30, 1981.
23. Kolessov VI. Mammary artery-coronary artery anastomosis as method of treatment for angina pectoris. J Thorac Cardiovasc Surg 54:534-44, 1967.
24. Koutlas TC, Elbeery JR, Williams JM, et al. Myocardial revascularization in the elderly using beating heart coronary artery disease surgery. Ann Thorac Surg 69:1042-7, 2000.
25. Kshettry VR, Flavin TF, Emery RW, et al. Does multivessel, off-pump coronary artery bypass reduce postoperative morbidity? Ann Thorac Surg 69:1725-30, 2000.
26. Locker C, Shapira I, Paz Y, et al. Emergency myocardial revascularization for acute myocardial infarction: Survival benefits of avoiding cardiopulmonary bypass. Eur J Cardiothorac Surg 17:234-8, 2000.
27. Moshkovitz Y, Sternik L, Paz Y, et al. Primary coronary artery bypass grafting without cardiopulmonary bypass in impared left ventricular function. Ann Thorac Surg 63(6 Suppl):S44-7, 1997.
28. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratification of risk for evaluating the results of surgery in acquired adult heart disease. Circulation 79:I3-12, 1989.
29. Puskas JD, Wright CE, Ronson RS, et al. Off-pump multivessel coronary bypass via sternotomy is safe and effective. Ann Thorac Surg 66:1068-72, 1998.

30. Spooner TH, Dyrud PE, Monson BK, et al. Coronary artery bypass on the beating heart with the octopus. Ann Thorac Surg 66:1032-35, 1998.
31. Sternik L, Moshkovitz Y, Hod H, et al. Comparison of myocardial revascularization without cardiopulmonary bypass to standard open heart technique in patients with left ventricular dysfunction. Eur J Cardiothorac Surg 11:123-8, 1997.
32. Tasdemir O, Vural KM, Karagoz H, et al. Coronary artery bypass grafting on the beating heart without the use of extracorporeal circulation: review of 2052 cases. J Thorac Cardiovasc Surg 116:68-73, 1998.
33. Tu JV, Jaglal SB, and Naylor CD. Multicenter validation of a risk index for mortality, intensive care unit stay, and overall hospital length of stay after cardiac surgery. Steering Committee of the Provincial Adult Cardiac Care Network of Ontario. Circulation 91:677-84, 1995.
34. Yokayama T, Baumgartner FJ, Gheissari A, et al. Off-pump versus on-pump coronary bypass in high-risk subgroups. Ann Thorac Surg 70:1546-50, 2000.

Table 1 - Preoperative data

Pre-operative Variables	OPCAB Patients (n = 66)	CCABG Patients (n = 66)	p Value
Age	81 $\pm$ 3.9 years	79 $\pm$ 3.2 years	NS
Sex	45M, 21F	38 M, 28F	NS
Severe Carotid Stenosis	21.5% (14)	6.1 (4)	< 0.03
Calcified Ascending Aorta	23.1% (15)	7.7% (5)	<0.03
Acute MI	20% (13)	1.5% (1)	<0.01
Unstable Angina	87% (57)	40% (26)	<0.01
COPD	20% (13)	15.2% (10)	NS
Renal Insufficiency (Cr > 1.5)	24.6% (16)	24.6% (16)	NS
Re-operations	7.7% (5)	9.1% (6)	NS
Cardiomegaly	19% (12)	26% (18)	NS
Preoperative IABP	1.5% (1)	7% (4)	NS
EF < 35%	17% (11)	23.1% (15)	NS
Congestive Heart Failure	23.1% (15)	19% (12)	NS
Hypertension	59% (38)	45% (29)	NS
Diabetes Mellitus	30.4% (20)	23.1% (15)	NS

CCABG: Conventional coronary artery bypass grafting
OPCAB: Off-pump coronary artery bypass grafting
COPD: Chronic obstructive pulmonary disease
EF: Ejection fraction
IABP: Intraaortic balloon pump
NS: Nonsignificant

Table 2 - Results

	OPCAB patients (n = 66)	CCABG patients (n = 66)	p Value
Obtuse marginal grafts	64% (42)	85% (55)	<0.05
Number of Grafts	3.0 ± 0.8	3.3 ± 0.7	NS
Peri-operative Stroke	1.5% (1)	4.5% (3)	NS
In-hospital Mortality	3.1% (2)	3.1% (2)	NS
Time to Extubation	13.9 ± 11.8 hours	23.0 ± 25.4 hours	<0.05
Time in ICU	33.5 ± 25.2 hours	60.6 ± 62.5 hours	<0.05
In-hospital Length of Stay	8.4 ± 3.1 days	9.5 ± 5.5 days	NS
Bleeding postoperatively	925 cc ± 242 cc	880 cc ± 347 cc	NS
Patients who received blood products	61% (40)	50% (33)	NS
Inotropes postoperatively	55% (36)	53.3% (35)	NS
Recurrent angina	3% (2)	3% (2)	NS
New congestive heart failure	1.5% (1)	1.5% (1)	NS

CCABG: Conventional coronary artery bypass grafting
OPCAB: Off-pump coronary artery bypass grafting
ICU: Intensive Care Unit
NS: Nonsignificant