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Multiple Off-Pump Coronary Revascularization with "Aorta No-Touch" Technique Using Composite and Sequential Methods

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ABSTRACT

Background: Although off-pump coronary artery bypass grafting (OPCAB) has been widely applied in patients who are considered high risk for cardiopulmonary bypass (CPB), there is still a risk of stroke during the operation because of the ascending aortic partial clamp for proximal anastomosis. In the present study, we report the initial results of an "aorta no-touch" technique using an in-situ graft and composite and sequential grafting methods.

Methods: Between March 2000 and April 2001, 120 patients underwent OPCAB with this technique. The age of patients ranged from 47 to 86 years, with a mean age of 65.7 ± 8.7 years. On average, 3.12 ± 0.77 grafts per patient were completed. More than 4 distal anastomoses were performed in 32 patients (27%). As in-situ grafts, 140 internal thoracic arteries (ITAs) and 9 gastroepiploic arteries were used. The radial artery (RA) was used as a Y composite graft in 91 patients, as an I composite graft in 25, and as a K composite graft in 2. Sequential bypass grafting was performed using the RA in 60 patients, the saphenous vein (SV) in 6, the ITA in 4, and the gastroepiploic artery (GEA) in 3. Arterial grafts were used in 92% (345/374) of total bypass grafts. Distal anastomosed sites were 119 left anterior descending arteries (LADs) (32%), 90 posterolateral branches (24%), 64 posterior descending arteries (17%), 49 diagonal branches (13%), 39 obtuse marginal branches (10%), and 13 right coronary arteries (3.5%).

Results: There was no operative death or stroke. Early postoperative angiography revealed 95.5% (321/336) graft patency with 100% patency (119/119) of ITA to LAD grafts. Graft patency of the ITAs and RAs (98.5% and 95.9%) were significantly better than that of the GEA (79.0%, p = 0.0064 and p = 0.030) and saphenous vein (82.3%, p = 0.011 and p = 0.048).

Conclusion: OPCAB performed with the aorta no-touch technique using an in-situ graft and composite and sequential grafting methods provides excellent early clinical results and graft patency.

INTRODUCTION

Although off-pump coronary artery bypass grafting (OPCAB) has been widely applied in patients who are considered high risk for cardiopulmonary bypass [Tasdemir 1998, Arom 2000, Bedi 2000, Bhan 2000, Cartier 2000, Ömeroglu 2000], there is still a risk of stroke during the operation because the ascending aortic partial clamp for proximal anastomosis poses a risk for atheromatous emboli [Hartman 1996]. Recently, there has been a reported incidence of acute aortic dissection after OPCAB with an ascending aortic partial clamp [Chavanon 2001]. OPCAB without proximal ascending aortic anastomosis of the graft theoretically does not cause perioperative stroke unless significant low blood pressure or atrial fibrillation occurs. However, complete revascularization with multiple arterial grafts for patients with multivessel disease is difficult with only the in-situ graft [Suma 1993, Weinschelbaum 2000]. In the present study, we report the initial results of the "aorta no-touch" technique using in an-situ graft and composite and sequential grafting methods.

PATIENTS AND METHODS

Between March 2000 and April 2001, OPCAB was attempted in 147 patients. Twenty-one patients (14%) had urgent OPCAB for unstable angina pectoris, and nine had emergent OPCAB for acute myocardial infarction. At this time, OPCAB was indicated as the standard coronary artery bypass grafting approach (80% of all patients) under the following conditions: (1) when distal anastomosed sites were fewer than six, (2) target coronary arteries were larger than 1 mm in diameter, and (3) left ventricular ejection fraction (LVEF) was relatively good (>0.30). Of the 147 patients, 120 (82%) underwent OPCAB with the "aorta no-touch" technique using an in-situ graft and composite and sequential

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grafting methods. We applied the aorta no-touch technique in all patients but those who were hemodynamically unstable with acute myocardial infarction or with failed percutaneous transluminal coronary angioplasty (PTCA). The remaining 27 patients had proximal graft anastomosis to the ascending aorta. There were 99 men and 21 women, with a mean age of 65.7 ± 8.7 years (range 47 to 86 years); 41 (34%) were older than 70 years. One patient had undergone previous coronary artery bypass grafting (CABG). The demographic and clinical profiles of patients are shown in Table 1 ( ).

Graft Selection

We mainly used the radial artery (RA) as a composite graft with the internal thoracic artery (ITA). The gastroepiploic artery (GEA) was used in younger patients when we preferred to avoid bilateral use of the ITA because of sternal wound healing problems [He 1994, Borger 1998]. The saphenous vein (SV) was used when the RA was not feasible for harvesting because of a positive Allen's test in older patients or because of chronic renal failure (serum creatinine >1.5 mg/dl).

Preparation of the Conduits

The dissection technique for the ITAs was a conventional, semi-skeletonized method. The RA was harvested with an ultrasonic dissection technique [Ronan 2000]. The ITA and RA were wrapped in a sponge soaked with a solution of papaverine hydrochloride. To release the spasm of the RA, a mixture of blood and solution of papaverine hydrochloride was gently injected into the lumen. The length of the RA ranged from 16 to 22 cm (mean 19 cm). After administration of heparin (1.0-1.5 mg/kg), the ITAs and RA were divided. The left ITA (LITA) was used as an in-situ graft, generally to the left anterior descending artery (LAD). The right ITA (RITA) was anastomosed to the LAD only when the LITA was not suitable for the graft or when the bilateral in-situ ITAs were necessary because the LITA was anastomosed to the large circumflex branch. The RA was used only for a composite graft. The RA was connected to the LITA as a Y composite, and to the RITA as an I composite for extension. The RA was anastomosed with the ITA in side-to-side fashion as a K composite when the diagonal branch was parallel to the LAD [Aguero 1999]. One end of the RA was anastomosed to a diagonal branch and the other end was anastomosed to a circumflex branch. All arterial anastomoses were performed using a continuous suture of 7-0 polypropylene (Prolene, Ethicon, Somerville, NJ) by parachute technique.

Surgical Technique and Postoperative Management

A standard median sternotomy was used in all patients. The pericardium was opened and deep pericardial retraction sutures were placed. The coronary artery was anastomosed in order of LAD, diagonal, obtuse marginal, and posterolateral to posterior descending arterial branches. End-to-end anastomosis of the I composite graft was performed after distal coronary arterial anastomoses. Proper positioning and stabilization of the heart was obtained by pericardial sutures, surgical sponges, and the Octopus III stabilizer (Medtronic, Inc., Minneapolis, MN) with steep Trendelenburg position and rotation of the operation table toward the surgeon. Transesophageal echocardiography and left atrial pressure monitoring was performed to check mitral regurgitation due to extensive left ventricular geometric change and right ventricular outflow obstruction due to right ventricular geometric change. Only transient proximal compression of the target vessel was accomplished with Retract-O-Tape (Quest Medical, Inc., Allen, TX) traction without encircling. Neither preconditioning nor distal occlusion was performed. Heart rate and blood pressure control were obtained with diltiazem and norepinephrine. After coronary arteriotomy, the operative field was kept free from blood with a CO_2 blower (Visuflo, Edwards Lifesciences LLC, Irvine, CA) and an internal shunt (Anastaflo, Edwards Lifesciences LLC, Irvine, CA and ClearView, Medtronic, Inc., Minneapolis, MN). After completion of bypass grafting, transit time flow measurement (Cardiomed Flowmeter, Medi-stim, Oslo, Norway) was performed each time. Heparin was reversed but restarted in the intensive care unit after hemostasis was secured until the next evening. Diltiazem and nitroglycerin were administered intravenously from the beginning of the operation until the next morning. Diltiazem was then prescribed orally (100-200mg/day) in conjunction with aspirin of 162mg/day from the next morning. Serial electrocardiogram and CK-MB follow-up were done for a day.

Angiographic Study

Coronary and graft angiography was performed in 106 patients (88%) at 10 to 21 days (mean 14 days) after OPCAB. Patients with depressed renal function (serum creatinine >2.0 mg/dl) were evaluated only with stress thallium myocardial scintigraphy. Graft patency and stenosis were independently assessed by cardiologists.

Data Collection

The status of patients was determined by referring to the medical records and correspondence with the responsible physicians. All cardiac and non-cardiac events were recorded in detail.

Statistical Analysis

All values were expressed as mean ± standard deviation. Continuous variables were compared by the Wilcoxon rank-sum test, while the discrete variables were analyzed with Fisher's exact test. Differences were considered statistically significant when the p value was less than 0.05.

RESULTS

OPCAB was completed in all cases but one. The only patient who required cardiopulmonary bypass had a completely intramuscular LAD, and dissection of the LAD caused right ventricular perforation. On average, 3.12 ± 0.77 grafts per patient were completed. More than four distal anastomoses were performed in 32 patients (27%). Unilateral ITA was used in 72 patients (60%), and bilateral ITA in 48 patients (40%). Arterial grafts were used in 92% (345/374) of total bypass grafts, and complete arterial revascularization

was achieved in 112 patients (93%). For in-situ grafts, 140 ITAs and 9 gastroepiploic arteries were used. Table 2 ( ) shows the method of single and bilateral use of the ITA. The RA was used as a Y composite graft in 91 patients, as an I composite graft in 25, and as a K composite graft in 2 (Table 3,). Sequential bypass grafting was performed using the RA in 60 patients, the saphenous vein in 6, the ITA in 4, and the gastroepiploic artery in 3. Distal anastomosed sites were 119 LADs (32%), 90 posterolateral branches (24%), 64 posterior descending arteries (17%), 49 diagonal branches (13%), 39 obtuse marginal branches (10%), and 13 right coronary arteries (3.5%) (Table 4,).

Early and Late Mortality and Morbidity

There were no hospital deaths. No neurological complications or stroke occurred in the early postoperative period, and there was no re-exploration for bleeding or mediastinitis. Perioperative myocardial infarction (CK-MB >50) occurred in four patients (3.3%), and two patients suffered strokes at one and two months after the operation, respectively. There were two late deaths in the follow-up period that resulted from gastric cancer and cerebral infarction.

Angiographic Study

Typical Y composite RA sequential bypass grafting is shown in Figure 1 ( ), and an RA I composite graft with a RITA is shown in Figure 2 ( ). A postoperative angiography of a K composite graft is shown in Figure 3 ( ). There was no stenosis at the site of the ITA and composite graft. In four patients with mild coronary arterial stenosis, coronary to coronary flow phenomenon was recognized. Of these four cases, the distal coronary artery, which was grafted by the RA in side-to-side fashion, was perfused from the other native coronary artery, which in two cases was grafted by the RA in end-to-side fashion retrogradely via the RA (Figure 4,). In the other two cases, the blood flow of the RA Y composite graft was supplied from the in-situ ITA graft retrogradely, which was anastomosed to the very mildly stenotic LAD and the right coronary artery, respectively.

The postoperative angiography showed a graft patency rate of 95.5% (321 of 336), with ITA to LAD patency of 100% (119 of 119). Graft patency for each source of graft material is shown in Table 5 ( ). Graft patencies of the ITA and RA (98.5% and 95.9%) were significantly better than that of the gastroepiploic artery (79.0%, $p = 0.0064$ (vs. ITA) and $p = 0.030$ (vs. RA) and saphenous vein (82.3%, $p = 0.011$ (vs. ITA) and $p = 0.048$ (vs. RA)).

DISCUSSION

OPCAB has become an established method of coronary artery bypass grafting, and the advantages of OPCAB over standard CABG with cardiopulmonary bypass have been reported [Nader 1999, Arom 2000, Diegeler 2000, Matata 2000]. However, there is still a risk of neurological complication and stroke because the partial aortic cross-clamp may cause atheromatous emboli [Hartman 1996]. In addition, the incidence of acute ascending aortic dissection may also increase with side-clamping of the aorta under high blood pressure [Chavanon 2001]. One of the greatest risk factors for neurological complications after CABG is the presence of aortic atheromatous disease [Diegeler 2000]. Although the use of the innominate artery or the subclavian artery as an inflow site for the bypass graft has been recommended, these vessels are likely to be affected by severe atherosclerosis when the ascending aorta is atherosclerotic or calcified. In the present series, there were no strokes or cerebral complications during the operation or in the early post-operative period. Watershed infarction due to low blood pressure during the manipulation of the heart for OPCAB was thought to be rare. OPCAB with the aorta no-touch technique is feasible and may reduce the incidence of stroke.

The LITA is widely recognized as the ideal graft to the LAD, and, according to several studies [Pick 1997, Lytle 1999], the bilateral use of the ITA further improves the long-term results after CABG. However, bilateral use of the ITA did not provide a conduit of sufficient length to achieve complete revascularization even if the skeletonized technique was used for harvesting [Kramer 2000]. Bilateral ITA harvesting may also increase the risk of sternal infection for patients of older age, insulin users, the severely obese, and patients suffering from emphysema [He 1994, Borger 1998]. The gastroepiploic artery is the second arterial conduit available as an in-situ graft. However, size variations of this conduit may make it unsuitable for grafting to important large branches. Ten-year graft patency for the GEA was reported by Suma et al. [Suma 2000] to be 62.5%. As for the saphenous vein, the RA has been used with increasing frequency instead of the SV because of easier harvesting and handling [Acar 1992]. The LITA and the left RA can be harvested simultaneously.

Composite grafts make more efficient use of the conduit by placing the inflow close to the coronary arteries. Complete arterial revascularization with the LITA and RA Y composite has been reported [Calafiore 1995, Royse 1999]. It has also been speculated that the LITA is superior to the ascending aorta as the inflow of the RA [Calafiore 1995]. The RA anastomosed to the aorta is particularly vulnerable to the development of fibrous intimal hyperplasia because of the high wall stress to which it is exposed. The RA is not long enough to reach the posterior descending artery if the right ventricle is very large. In this situation, an RA I composite graft with the RITA could reach to the branches of the right coronary artery. Although the RITA can be used as an in-situ graft to the right coronary artery, the graft patency has been found to be less than that of the LITA to LAD because the target right coronary artery was sometimes very thick and calcified [Dietl 1995]. In addition, right coronary arterial temporary occlusion may cause bradyarrhythmia and hypotension during OPCAB. We prefer to anastomose the RA to the posterior descending artery.

For younger patients with a positive Allen's test, we tried to use the gastroepiploic artery or the RITA as an in-situ graft. However, those patients usually had severe systemic atherosclerosis or insulin-dependent diabetes and were therefore not suitable subjects for harvesting those grafts [He 1994, Borger 1998]. For those patients we had to use a

saphenous vein as a composite graft [Peigh 1991]. The saphenous vein was mostly used as a short composite graft with the LITA to the diagonal branch or to unimportant branches with a relatively small run-off area. The poor graft patency of the SV in the present study may be attributed to lower graft flow velocity resulting from limited inflow of the ITA compared to inflow of the aorta. We should avoid using the SV if the target coronary vessel is small. The graft patency of the gastroepiploic artery in our study was not as good as the patency described in a previous report [Suma 1991]. This may be the result of our performing the sequential bypass graft using the gastroepiploic artery when, at the time of the Suma study, the GEA was thought to be difficult to use in OPCAB in a sequential fashion.

One of the problems that has been encountered with use of the RA is spasm early after the operation [Acar 1992, Weinschelbaum 2000]. In our series, the graft patency of the RA was as good as in the earlier study [Acar 1992]. Partial irregularity of the RA seen upon early angiography usually disappeared with time due to the marked reduction in the contractile response [Possati 1998]. The patency rate of the RA at five years was 92%, and all RA grafts that were patent immediately after the operation remained patent at mid-term follow-up [Acar 1998]. These results were better than the graft patency of the SV but worse than the LITA [Loop 1986]. Because the RA was anastomosed to smaller target vessels than the LAD, the difference in patency could be partially related to the graft reconstructed sites.

In 60% of patients in the present series, the total coronary artery system was supplied by single ITA and composite grafts. The hypoperfusion syndrome was neither seen nor expected. Demand of the flow to the reconstructed coronary vessel may increase immediately after standard CABG with cardiopulmonary bypass and anoxic arrest. The LITA graft probably has enough flow reserve for all the coronary artery system after OPCAB. Only patients with unstable angina pectoris and tight left main trunk disease are likely to need a bilateral ITA flow source early after the operation. Because possible stenosis of the proximal LITA may be a cause for concern, we routinely evaluate the LITA by preoperative angiography. Subclavian arterial stenosis should be checked by preoperative pressure measurement of both arms.

In the remaining 40% of patients, we used bilateral ITA for the composite inflow mainly because of the dilated left ventricle. A composite RA from the LITA could not reach to the posterior descending artery in those cases. Another reason was that we prefer to graft to a coronary artery with mild stenosis in side-to-side fashion, and the termination of this conduit was to the coronary artery of severe stenosis. When the posterior descending coronary artery had only mild stenosis, we anastomosed the side of the RA I composite graft to that branch and the end of the RA to the circumflex branches.

One of the major problems in the present method is the flow competition of arterial grafts. Royse et al. reported that the graft patency of the RA as a composite graft is lower than that of the RA from the aorta when the stenosis of the target coronary vessel was mild due to lower perfusion pressure [Royse 2000]. In four patients in our study with mild coronary arterial stenosis, blood flow to the coronary artery grafted by RA side-to-side anastomosis was supplied from the mildly stenotic native coronary artery grafted by the RA in end-to-side fashion via the RA in two cases. In the other two cases, the blood flow to the RA Y composite graft was supplied retrogradely from the in-situ ITA graft, which was anastomosed to the very mildly stenotic LAD and right coronary artery. It is a very difficult clinical question whether a particular coronary artery with a mild stenosis should be grafted by the arterial graft with the higher risk of reduced graft patency rate for the preparation of future progression of the native coronary artery. Although the fate of arterial grafts that showed competition or string sign is still controversial, I believe that those grafts will work with the progression of the native coronary artery disease because arterial grafts are "alive."

CONCLUSION

OPCAB by arterial graft reconstruction with the aorta no-touch technique using an in-situ graft and RA composite grafts combined with the sequential anastomosis technique provided satisfactory early clinical results and graft patency.

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