Off-Pump Innominate-Coronary Artery Bypass in Patients with Severely Atherosclerotic Ascending Aorta

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ABSTRACT

Background: Traditional aorto-coronary artery bypass surgery in patients with severely atherosclerotic ascending aorta is associated with unacceptable risk of neurologic injury. Recent advancement in off-pump coronary bypass technique eliminates the use of cardiopulmonary bypass as a cause of thromboembolism in patients with severely diseased aorta. The use of off-pump technique in conjunction with the use of the great vessels rather than the diseased ascending aorta as the inflow for the saphenous vein bypass grafts would theoretically eliminates any risk of thromboembolic neurologic injury.

Methods: This study consists of ten consecutive patients with severely diseased ascending aorta, who underwent off-pump saphenous vein bypasses from the innominate artery to various coronary targets with or without the use of the internal mammary artery.

Results: The average age of the patients was 81. All patients had left main coronary disease, and all were in unstable angina. Two patients were dialysis dependent. The average bypass grafts was 2.3. The operating time was less than 3 hours in all cases. All patients were extubated within 12 hours of surgery. There were no incidence of neurologic injury or evidence of other thromboembolic end organ damage. There was no perioperative myocardial infarction. The median postoperative hospital length of stay was 6 days. All patients were found to be doing well and free of angina at a median follow up of 5 months.

Conclusions: The approach of off-pump innominate-coronary bypass is an important adjunct in the management of patients with unworkable ascending aorta.

INTRODUCTION

Since its inception, the outcome of coronary artery bypass surgery has improved steadily due to advancement in cardioplegic protection, intraoperative anesthetic management, the use of intraoperative transesophageal echocardiogram, more effective inotropic agents, and specialized postoperative care. However, the incidence of neurologic complication has remained largely unchanged and is now a major public awareness and concern. This complication increases exponentially with advancing age, presence of aortic atherosclerosis, and history of neurologic disease [Roach 1996]. Studies from transesophageal echocardiogram have demonstrated a correlation between neurologic complication with the degree of atherosclerotic disease in the aorta [Hartman 1996]. When the degree of atheromatous disease was graded on a scale of 1 to 5 in the descending aorta, the incidence of postoperative strokes after coronary artery bypass was 0%, 5%, 10%, 45% for grades 1, 2, 3, 4 and 5 respectively [Hartman 1996]. The presence of mobile plaque in the aortic arch was associated with a stoke risk of 33% as compared to 2.7% in other patients [Barbut 1997]. In a Cleveland Clinic autopsy study of cardiac surgery patients over an eight-year period, 95.8% of patients found to have end organ atheroembolism was identified to have severe atherosclerotic disease of the ascending aorta [Blauth 1992].

The off-pump approach to coronary bypass theoretically eliminates the risk of atheroembolism from the aortic arch and descending aorta. However, the presence of disease in the ascending aorta still carries this risk during the implantation of the proximal vein graft anastomosis utilizing the traditional method. This study describes a novel approach, which incorporates the latest technology of off-pump coronary bypass, and the routine use of the innominate artery rather than the aorta for bypass graft inflow in patients with severely diseased ascending aorta.

MATERIALS AND METHODS

Patient Selection and Conduct of Operation

When patients are selected for off-pump preoperatively, a pulmonary artery catheter with mixed venous oximetry is placed for additional monitoring. Transesophageal echocardiogram is performed on all cases. In addition to cardiac imaging, the aortic arch and descending aorta are thoroughly examined for atheromatous disease. If significant disease is identified in these areas or ascending aortic disease is suspected as a result of the surgeon's inspection, a hand held epi-aortic echo probe is used to examine for intraluminal disease in the ascending aorta.

If significant atheromatous disease is identified in the aortic arch or descending aorta but not the ascending aorta (a common scenario), off-pump coronary bypass is done if at all possible with proximal anastomosis placed on the ascending aorta

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utilizing a side-biting aortic clamp. If significant atheromatous disease is identified in the ascending aorta as in the ten patients in this study, then off-pump coronary bypass surgery is performed with plans made to place a venous bypass graft proximal anastomosis on the innominate artery. The coronary targets are inspected first to determine if they are epicardial and if there is any anatomical obstacle to be done off-pump. Once the decision is made to go off-pump and to use the innominate artery rather than the ascending aorta, the sternal incision is extended superiorly along the right sternocleidomastoid border for about two centimeters. The innominate vein is dissected free and retracted with a vessel loop. The innominate vein did not need to be divided in any of the ten cases; it may be retracted cephalad or caudad depending on the individual anatomy. The innominate artery is then dissected free from its origin from the aorta to its bifurcation into the common carotid artery and subclavian artery. Vessel loops are placed at the two ends. There is almost always calcified plaque at the removal of the innominate artery extending from the base of its origin to about half a centimeter cephalad. Manipulation of this plaque needs to be strictly avoided. A decision is made whether there is enough length on the innominate artery for a proximal and a distal clamp. If the arterial line is on the right radial artery, a femoral arterial line should be placed at this time, since clamping of the innominate artery for the proximal anastomosis will eliminate this monitoring route. The left internal mammary artery (LIMA) and the saphenous veins are prepared. Despite the advance ages of this group of patients, the LIMA was always the graft of choice if it was judged long enough to reach the epicardial portion of the left anterior descending (LAD) coronary artery. One of the saphenous vein grafts needs to be two to three centimeters longer than usual to reach the innominate artery. Only one proximal anastomosis is recommended on the innominate artery for ease of implantation; the average length of the innominate artery is not enough for more than one. Either the graft from the LAD or the circumflex coronary artery lies most naturally from the left side to the innominate artery. The other vein grafts are anastomosed to the proximal portion of the one attached to the innominate artery.

Once the grafts are prepared, heparin is given to maintain an activated clotting time (ACT) of greater than 300 seconds. Routine off-pump techniques are employed.

The LAD is always bypassed first either with vein or LIMA. An intracoronary shunt was used in these cases because of the presence of left main disease. If a vein is used on the LAD, the heart is allowed to fall back into the pericardium at the completion of the anastomosis, and the proximal anastomosis is performed next. The innominate artery is clamped distally first, followed by proximal clamping placed with care not to disrupt the common proximal plaque. A standard arteriotomy is made with a punch, and the proximal anastomosis is done with running 6-0 Prolene suture. The distal innominate clamp is released first with a surgeon's finger compressing the right common carotid artery, followed by the release of the proximal clamp. The vein graft is deaired with a 25-gauge needle before its bulldog clamp is released to perfuse the LAD. The circumflex is bypassed before the right coronary, since the latter is more likely to induce heart block or hemodynamic upset. These subsequent grafts are anastomosed end to side of the LAD graft. If the LIMA is used for the LAD, this is done first followed by the circumflex graft distal anastomosis and then proximal anastomosis on the innominate artery as described above for LAD vein graft.

Heparin is completely reversed with Protamine after the completion of the anastomoses, and confirmed by ACT. The patient is either extubated in the operating room or shortly after arriving to the intensive care unit. The postoperative care is no different from other off-pump patients with minimal fluid shifts. Clopidogrel (Plavix) as advocated by some programs for off-pump cases is only reserved for patients with diffuse coronary artery diffuse in our program and it was not used for these ten patients.

RESULTS

The ten patients in this study were identified from one surgeon's practice from August of 1999 to July of 2000. During this time, a total of 347 cardiac cases were performed, of which 228 were primary coronary artery bypass cases. Thirty-five percent of the coronary artery bypass cases were done off-pump. Table 1 () tabulates the patients' characteristics. As noted on the surgery dates, these cases were well spread out over the study period. The average age of the patients were 81, and six of the ten patients were octogenarians. Two patients were on chronic hemodialysis. The average left ventricular ejection fraction was 55%. All patients had significant left main coronary disease in addition to other coronary disease. All were in unstable angina requiring intravenous heparin with or without intravenous nitroglycerin. However, none of the patients had preoperative myocardial infarction, and all were hemodynamically stable. Extensive calcification was detected in the ascending aorta only in two patients (both were octogenarians) on preoperative chest X-rays.

The average number of bypass grafts was 2.3. The LIMA was used for the LAD for six of the ten patients. Two patients had the LAD in the epicardial position only in the distal third, and therefore, the LIMA was deemed too short to reach and not taken down. One patient had a left radical mastectomy followed by external beam radiation for breast carcinoma in the distant past; and therefore, the LIMA was not taken for obvious reasons. The last patient did not have the LIMA taken down because of his cachectic state.

There was no hemodynamic instability during the anastomosis, or worsened regional wall contractility on transesophageal echocardiogram after the bypass surgery. The peaked CPK-MB, and CPK-MB index were 7.06+10ug/L, and 1.34+2.4, respectively. There was no new Q-wave or persistent ST segment changes in the postoperative electrocardiogram. None of the patients required inotropic, or intraaortic balloon support. There was no clinical evidence of transient or permanent neurologic injury in any of the patients. There was no new onset of renal insufficiency or failure, or any other end-organ damage in any of the patients. The two chronic dialysis patients received hemodialysis the

Table 1. Patient characteristics

Surgery date	Age	Sex	DM	HTN	COPD	Dialysis	LVEF	% Coronary stenosis				No. bypasses	LIMA	Extubation	LOS
								LM	LAD	CIRC	RCA				
082699	86	M	-	+	-	-	60%	60	100	90	90	3	-	12	4
091499	80	M	+	+	-	-	50%	50	90	90	100	2	+	12	8
032300	86	M	-	+	-	+	40%	85	0	0	100	2	+	3	7
040500	77	M	-	-	+	-	60%	60	70	0	80	3	+	6	12
042100	85	M	-	-	+	+	70%	85	90	80	99	2	+	6	10
060900	68	F	-	+	-	-	60%	70	0	90	90	3	+	11	5
062200	82	F	-	-	-	-	60%	95	0	0	100	2	-	12	6
070100	77	M	-	+	-	-	45%	60	50	70	100	2	-	12	12
072100	78	M	-	-	-	-	60%	70	90	70	0	2	+	6	5
080800	86	F	-	+	-	-	55%	75	85	85	100	2	-	1	6

DM, HTN, COPD, LVEF, LM, LAD, CIRC, RCA, LIMA, LOS denote diabetes, hypertension, chronic obstructive pulmonary disease, left ventricular ejection fraction, left main, left anterior descending, circumflex, right coronary artery, left internal mammary artery, postoperative hospital length of stay respectively. Nomenclature for surgery date is month/day/year. Extubation times are presented in hours, and LOS are presented in days.

day before surgery, and regular schedule for dialysis resumed on the second postoperative day.

The incidence of atrial fibrillation was 20%, and all were discharged in normal sinus rhythm. The cachetic patient who did not have his LIMA taken down, developed a purulent sternal wound infection requiring a sternal wound debridement on the eighth postoperative day followed by full recovery. This patient had the longest length of stay. All of the other patients had uneventful postoperative courses without complication, and were discharged expeditiously with a median postoperative length of stay of 6 days, range 4 to 12 days (Table 1,).

At the median follow-up of 5 months, all patients were doing well with no angina. None of the patients had required hospitalization for cardiac symptoms after discharge, nor required further cardiac intervention.

COMMENT

The etiology of neurologic injury in traditional coronary artery bypass surgery with the use of cardiopulmonary bypass is multi-factorial. In a prospective randomized study done at Cornell, maintaining a mean blood pressure of 80-100mmHg on pump had a three times lower stroke rate than maintaining the pressure at 60-80mmHg [Gold 1996]. Recently, an overwhelming amount of data has pointed toward the atherosclerotic aorta as a major source of atheroemboli [Blauth 1992, Barbut 1994, Gold 1996, Hartman 1996, Roach 1996, Barbut 1998]. In a previous study, we demonstrated that only a small percentage (5%) and small particles are released during the initiation of cardiopulmonary bypass [Barbut 1994]. More than half of the debris are released during the release of the straight aortic clamp (34%) placed for cardioplegic arrest, and the release of the partial side-biting aortic clamp (24%) placed for proximal anastomosis [Barbut 1994]. These data identified the manipulation of the ascending aorta as a major problem in patients with disease located there.

A number of adjunctive techniques have been devised to minimize the risk of thromboembolism from the diseased aorta. These include the use of epi-aortic echo probe to delineate the character and location of atheroma, to enhance the safety of cannulation and aortic clamping [Hartman 1996]. Before the development of off-pump multi-vessel coronary artery bypass, an approach using cardiopulmonary bypass with cannulation in the aortic arch, distal revascularization without aortic clamping, using internal mammary arterial grafts as outflow for other grafts, and using gastroepiploic arterial grafts was reported [Dietl 1995]. By all standards, this approach requires an extensive amount of surgery and long pump run. The most radical approach reported was one involving the replacement of the atherosclerotic ascending aorta with artificial graft without aortic clamping under circulatory arrest [Wareing 1992]. This is done with the enormous risks of circulatory arrest and aortic replacement. The single clamp technique for both distal and proximal anastomosis is a commonly adopted approach in most programs when the ascending aorta is suspected to be at risk of embolism, and it avoids the use of the side-biting aortic clamp to minimize the amount of debris liberated. Deep cannulation into the distal aorta arch appear to reduce turbulent flow and the blasting effect on the aortic arch and theoretically may reduce the incidence of atheroemboli to the brain [Grossi 1996].

The industries have designed a number of devices to combat this problem. The aortic cannula with a "lighthouse" shaped tip design provides a homogenous rather than a jet stream like outflow. Most recently, aortic cannulae with intraaortic balloon occlusion are designed to eliminate the need for clamping the aorta. A preliminary study on an intraaortic filter designed to be inserted through a special aortic cannula, has been shown to catch debris during cardiac surgery [Reichenspurner 2000]. An ongoing clinical study is designed to delineate its potential benefits. A "one shot" anastomotic device for the placement of saphenous vein graft on the aorta without the need of clamping has been developed. If proven efficacious, this device will enhance the placement safety of proximal anastomosis on the ascending aorta with spotty disease. All of these relatively new techniques are

important in the cardiac surgeon's armamentarium to combat the diseased aorta; however, they are not expected to eliminate its potential problem entirely as long as the aorta is manipulated for cannulation, or for proximal anastomosis. This problem is especially acute in patients with so called the "porcelain" aorta, which does not appear to tolerate any surgical manipulation.

The technique described in this study eliminates the risk of atheroembolism from the diseased aorta. The approach used in the ten patients presented in this study utilizes straightforward cardiac techniques, and can be done in all programs without added expenses. In our program, coronary artery bypass surgery was done successfully in these ten high-risk patients who would have been exposed to substantial risk of stroke, or had the operation aborted as in our past experience.

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REVIEW AND COMMENTARY

1. Editorial Board Member NC124 writes:

What about using the right mammary artery, right gastroepiploic, epigastric for total arterial revascularization, or even radial, in the form of "t" grafts from an arterial inflow graft?

Authors' Response by Wilson Ko, MD:

As suggested, the use of complete aterialization with either all pedicled grafts or "T" grafts is an excellent option for this particular problem. However, the average age of this group of patients was over 80 and many had other major comorbidities. Most surgeons would find severely diseased ascending aorta in this type of patient in their practice. One may argue that the lesser operation as delineated in this article may serve these patients well.

2. Editorial Board Member AN153 writes:

Could the authors clarify if they established the absence of any gradient between the aorto-innominate junction either preop or by intraoperative echo?

Authors' Response by Wilson Ko, MD:

A hand held echo probe was always used in the setting of diseased aorta. The origin of the innominate artery was routinely inspected to detect any significant disease. The measurement of any potential gradient across the aorto-innominate junction in the operating room is an excellent idea.