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Innovative Minimally Invasive Surgical Approaches to Coronary Revascularization in the High Risk Patient

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Resurgent interest in off pump coronary artery bypass (OP-CAB) has resulted in the recent development of a number of tools and techniques. These developments have facilitated the safe and reproducible application of the OP-CAB procedure in a broader group of patients [Jansen 1998, Puskas 1998, Spooner 1998, Tasdemir 1998]. It is estimated that 18% of the 360,000 patients that underwent surgical revascularization in the United States in 1999 were done off pump [Corporate field survey]. Although prospective randomized trials are lacking, and long term data scarce, several authors have reported a decrease in mortality in certain high-risk groups [Bergsland 1997, Koutlas 2000]. Moreover, many surgeons have performed OP-CAB on patients in whom the risk of conventional CABG was felt to be prohibitive. We have identified a number of maneuvers that seem to be of value in off-pump revascularization of these older and sicker patients.

OP-CAB is an attractive approach for revascularization of patients with poor systolic function as it avoids the technical challenges inherent in myocardial protection of the severely impaired ventricle. Exposure and stabilization of obtuse marginal (OM) and posterior lateral (PL) branches of the circumflex system presents an occasional challenge in these patients, however, especially in the presence of significant cardiomegally. Deep pericardial sutures, as first described by Lima [Benetti 1991], allow subluxation of the heart into the "apex up" position. Although this position is generally well tolerated from a hemodynamic standpoint, access to the OM is often limited by the left hemisternum. Furthermore, use of a stabilizer to retract the heart to the right in an effort to improve access often results in poor stabilization and hemodynamic deterioration.

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In these challenging patients, we have found right hemi-sternal elevation, extensive right pleurotomy, and deep vertical right pericardiotomy to be enabling techniques. Although clearly multi-factorial, hemodynamic compromise in large low EF hearts is frequently a result of right ventricular compression and reduction in right ventricular end diastolic volume and stroke volume [Grundeman 1997]. Widely opening the pleura and incising the pericardium down to the inferior vena caval-atrial junction allows the heart to herniate into the right chest with little change in ventricular geometry. Elevating the right hemisternum allows the apex to clear the posterior aspect of the sternum, rotating the lateral wall rightward into the center of the operative field with less hemodynamic compromise.

Another challenging group of patients is those with hemodynamic instability due to acute ischemia. Although many will argue that these patients are best treated with a conventional CABG utilizing cardiopulmonary bypass, occasionally comorbidities make this an unattractive alternative. In addition, peripheral vascular disease or aortic atheroma often makes the risk of intra-aortic balloon pump insertion prohibitive.

We have found aorta-coronary shunting to be helpful in these extremely high-risk patients. Aorta-coronary shunting is accomplished by connecting a 5 French or larger cannula inserted in the ascending aorta to a short length of large bore I.V. tubing, at the end of which is a 1-2.5mm olive-tipped PVC catheter. A stabilization device can then be used to immobilize the coronary artery supplying the acutely ischemic territory, generally the LAD or RCA, and the arteriotomy created. The olive-tipped catheter, size specific for the particular vessel, is then inserted through the arteriotomy into the distal coronary and flow initiated. Although the catheter imposes a small fixed resistance, the flow is generally adequate to dramatically improve regional wall motion abnormalities and improve hemodynamics. In contrast to the use of a traditional intraluminal continuity-type shunt, which minimizes the affects of transient coronary occlusion [Dapunt 1999, Lucchetti 1999], aorta-coronary shunts actually increase regional flow compared to the preoperative state. As such, insertion of an aorta-coro-

nary shunt may be the most expeditious means of treating acute ischemia, arguably more so than cannulation and institution of cardiopulmonary bypass. After completion of the distal anastomosis of a free graft, the shunt is removed and the graft attached to the ascending aortic cannula to establish graft flow. Coaxial insertion and removal of the shunt is facilitated by the unidirectional geometry. Retrograde insertion into the LAD proximal to the arteriotomy may be of benefit in ischemic patients with left main stenosis. Alternatively a "T"-type shunt such as the Rivetti-Levinson, could be used to increase flow both proximal and distal to the arteriotomy.

A fairly common high-risk group of patients is those with extensive calcification or atheromatous involvement of the ascending aorta. Although the OP-CAB technique obviates the need for insertion of an arterial cannula and application of a cross clamp, the use of a partial occluding or side biting clamp during construction of proximal anastomoses when performing OP-CAB is arguably as harmful as these maneuvers, if not more so. A number of published series of off-pump CABG have failed to show a reduction in the incidence of stroke when compared to conventional CABG, which may support this notion [Benetti 1991, Spooner 1998, Tasdemir 1998]. Careful palpation of the aorta during relative hypotension, and maintenance of systolic blood pressure less than 90mm Hg while the clamp is applied are commonly employed techniques. Although palpation is probably a fairly sensitive technique for identifying calcification or discrete dense atheroma, in our experience it is a poor technique for identifying diffuse atheromatous thickening or soft endophytic lesions [Royse 1998, Ostrowski 2000]. On three separate occasions early in our OP-CAB experience, we made the unfortunate diagnosis of diffuse soft atheromatous involvement only at the time of aortotomy, after the partial occluder was applied. In one of these occasions, the result was disastrous. We now use epi-aortic ultrasound in a large percentage of our patients, and have found this an extremely sensitive means of identifying aortic pathology [Davila-Roman 1996, Nicolosi 1996, Sylivris 1997]. Our indications for epi-aortic scanning include any abnormality identified during palpation, a history of peripheral vascular or cerebral vascular disease or prior stroke, age greater than 70 or any abnormality in consistency or dissection planes noted during excision of the epi-aortic fat pad. Using this algorithm has eliminated the incidence of stroke in our last 100 OP-CAB patients. In two of these 100 patients, the epi-aortic scan demonstrated significant disease not appreciated on palpation.

In the event that aortic pathology is identified, there are a few options available that minimize aortic manipulation. My personal preference is to run one free graft off of the inominate artery, and attach the other grafts end-to-side to the proximal portion of the inominate-coronary graft. Although the incidence of atherosclerotic involvement of the inominate artery in the presence of severe ascending aortic disease may be significant, in my limited experience this has not been the case. Perhaps of greater significance, however, is the fact that proximal and distal exposure and cross clamping of the inominate artery is readily accomplished. In contrast to the partially occluded aorta, the inominate artery can be aggressively flushed in both antigrade and retrograde directions prior to completing the anastomosis and restoring flow through the right carotid. In the event that particulate material is liberated during clamping or suturing, this flushing decreases the likelihood of distal atheroembolism. The five to ten minute period of cross clamping required to perform a single proximal anastomosis is generally well tolerated. In the six patients in whom we have used this technique, there have been no post-operative strokes.

Another technique is to attach free grafts to the proximal portion of the in-situ left internal mammary graft. Published reports by Tector and Royse [Tector 1994, Royse 1999] using a free right internal mammary artery or radial artery, respectively, have documented excellent results when this construct is used in a conventional on-pump bypass. Furukawa and others have had similar results using this strategy in conjunction with OP-CAB in a truly "aortic no-touch" procedure [Furukawa].

The Baladi Inverter is a unique tool that was developed as a potential alternative to the side-biting clamp. The device is a small inverted umbrella on a shaft that can be stretched into a fusifom shape by actuating a mechanism in the handle. This allows it to be introduced into the aorta through a small puncture. Once inside the aorta, it is allowed to return to the umbrella geometry. The umbrella is pulled firmly against the luminal aspect of the aortic wall by applying gentle traction on the handle. This excludes blood from a small area adequate for performing the aortotomy and constructing the anastomosis. After completion of the suture line, the umbrella is made fusiform once again, the device is withdrawn, and the suture tied. Although clearly not a "no touch" technique, the area of disease free aortic wall required for use of the device is much smaller than that required for side biting, and the forces applied theoretically much less. There is, however, a significant learning curve for the Baladi Inverter tool and technique. Moreover, it has yet to be demonstrated that proper use of the Inverter results in a reduction in the incidence of particulate emboli.

A number of automatic anastomotic devices are currently being developed for attaching free grafts to the ascending aorta. In all likelihood, one or more of these will be commercially available in the next year or so. These may prove to be extremely enabling. As these devices can readily be used on the pressurized blood-filled aorta, no aortic clamping is required. Although the risk of atheroembolism still exists if the procedure is carried out on a diseased segment of the aorta, the mechanism is such that only a small area of aortic wall is manipulated. As such, using epi-aortic imaging, it is probable that a disease free site one-to-two square centimeters in area could be identified on most patients even in the presence of severe aortic atherosclerosis. These tools may also prove enabling on reoperative cases in patients with patent but diseased

grafts, in whom application of a side-biting clamp is a potentially hazardous maneuver.

A final group of challenging patients worth discussing is those who have undergone previous coronary artery bypass and in whom there are patent but diseased grafts. If the patient is done off-pump, great care must be taken to avoid manipulation of the grafts due to the risk of graft embolism.

A number of novel procedures have been described that allow some of the technical challenges of reoperative bypass to be circumnavigated. The standard MIDCAB procedure in which the left internal mammary artery (LIMA) is used to graft the left anterior descending (LAD) on a beating heart through a small anterior left thoracotomy avoids the hazards inherent in re-operative sternotomy. Several published reports [Subramanian 1997, Calafiore 1998, Del Rizzo 1998] describe excellent results using the MIDCAB procedure in re-operation. Adequate mobilization of the LIMA through a limited access incision is demanding, however, and for many surgeons, decreased their enthusiasm for the procedure. Our group, in an effort to obviate the need for LIMA harvest, developed the H-graft MIDCAB, in which a 2-5 cm segment of free graft (radial artery, inferior epigastric artery, or saphenous vein) is interposed between the side of the in-situ LIMA and the LAD through an anterior mini-thoracotomy [Cohn 1998]. Although technically easy to perform, the long-term patency in our experience has been poor when compared to a conventional LIMA-to-LAD graft [Caulfield 2000], and concern has been raised about the possibility of coronary steal if the proximal LIMA should become occluded [Karamanoukian 1999]. Simultaneous with our work, Coulson developed the TRU-CAB, which is similar to the H-graft except that the LIMA is ligated just distal to the origin of the free graft, making it a functional LIMA-to-free graft end-to-end anastomosis [Coulson 1998a]. It is possible that this difference will result in improved intermediate and long term results.

In re-operations on patients with patent LIMA-to-LAD grafts and critical stenosis in the circumflex distribution we have found the off pump descending thoracic aorta-to-obtuse marginal (OM) graft to be a safe and readily reproducible procedure [Coulson 1998b, Baumgartner 1999]. We use a posterior lateral thoracotomy, which provides excellent exposure of the aorta, and open the pericardium posterior to the left phrenic nerve. This allows good exposure and stabilization of the proximal OM. We run the graft below the hilum, after dividing the left inferior pulmonary ligament. In our small series of 9 patients, we have had excellent results with this technique. We have also used the interthoracic left subclavian artery for a proximal anastomosis in one patient, and the thoracoacromial branch of the left axillary artery as the proximal anastomotic site in three cases. Others have reported use of the gastroepiploic artery for off pump revascularization of the inferior wall by way of a limited access incision [Akhter 1997]. Each of these techniques, if used in appropriately selected patients, has the potential to decrease operative complexity and improve results in patients undergoing repeat surgical revascularization.

In recent years, we have seen progressively older and sicker patients being considered for surgical myocardial revascularization. New tools and techniques have the potential to offer lower risk options to these patients who are at increased risk for conventional coronary artery bypass. Clearly long-term data will be required before the relative risk and benefit of each option can be determined.

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