ADVANCES IN CORONARY ARTERY BYPASS SURGERY

Although the first saphenous vein aorta-coronary artery graft was performed by Sabiston in 1962 and Kolessov successfully created internal mammary artery-coronary artery anastomoses in the early 1960s, it was not until the late 1970s that the use of the coronary artery bypass graft (CABG) became widespread as a treatment for coronary artery disease. Three major developments enabled this expansion of the safe and successful performance of CABG procedures, namely cine coronary arteriography in the late 1950s and 1960s (where the advances achieved by Sones in Cleveland, with the brachial approach, and by Judkins in Loma Linda, with the femoral approach, were fundamental), the introduction of safe mechanical cardiopulmonary bypass (CPB) technique in the 1950s and 1960s, and the routine adoption of cold cardioplegic arrest by the mid-late 1970s. From these beginnings, CABG has become the most frequently performed and most successful cardiac surgical procedure, with acceptably low operative mortality and morbidity. Today, taking into account a patient's age, coronary anatomy, degree of ischemia, and left ventricular function, the available data can be used to define the expectations for bypass surgery with reasonable accuracy. If important ischemia is present and the coronary anatomy is favorable, bypass surgery should improve the patient's quality of life and may significantly enhance survival. Any proposed new technique or procedural variation, therefore, has much to prove before being universally accepted as a real advance.

Because the patients now being operated upon are generally older, in worse general health, and with poorer cardiac function than those in earlier years, especially those categorized as emergency, it is clear that any improvement in morbidity and mortality during the last three decades is due to progress in perioperative management. This includes myocardial protection, conduit selection, ensuring as good a revascularization as possible, blood conservation, advances in anesthetic management, pharmacological developments to control the load on the myocardium and arrhythmias, follow-up antiplatelet therapy, and cardiac-assist devices. From the many studies designed to compare bypass surgery with interventional cardiac catheter techniques and procedures, it emerges that CABG has not been displaced from its prime position today as the procedure that will give the most complete and durable myocardial revascularization. This holds true from single-vessel to multiple-vessel disease, in elderly patients, and those with poor left-ventricular function.

Safe cardioplegic myocardial protection was finally achieved in the mid-1970s; the solution was cold crystalloid with antegrade delivery. There are now many variations on this theme: intermittent or continuous delivery-warm, tepid, or cold blood; antegrade or retrograde delivery through the coronary sinus or ante-retrograde delivery; and combinations of crystalloid for the majority of the bypass procedure together with warm blood as a final "hot shot". Patient normothermia or various degrees of hypothermia are also being applied, in conjunction with, or in the absence of, cardioplegia. Intermittent aortic cross-clamping with or without cardioplegia has also been used for myocardial management during bypass procedures.

Against the background of the many known, conventional risk factors for the outcome of CABG surgery, comparison of the results of these numerous and confusing variations on the cardioplegic theme is difficult; the surgeon's individual preference may be the deciding factor for the use of anyone of them. The fact that there is no consensus on an outright first choice is sufficient to illustrate that none of the various methodologies has been universally accepted as superior to all others. Nevertheless, each may have a specific role in the management of a particular set of circumstances, such as patient's condition, degree and mass of...
myocardial damage, or state of the coronary vessels—all of these factors are taken into account.

The potentially deleterious effects of CPB upon the brain and kidney are well documented and argue in favor of short bypass times, preferably of less than 60 minutes duration. This, together with the added advantages of reduced cost of equipment, intensive care, and overall hospital stay, have reawakened interest in the performance of CABG surgery without CPB. The economic arguments have been stimulated by comparison of the cost of CPB with relatively low-cost coronary angioplasty procedures. Some surgeons have persisted with a no-pump technique for lesions of the left anterior descending (LAD) or right coronary vessels, using saphenous vein or arterial conduits, notably Buffolo, with almost 1,300 cases in Brazil and mortality of 2.5%,17 and Benetti, with more than 1,400 cases in Argentina; cost reduction was the primary stimulus in both series. The technique can be used for elective, emergency, and reoperative CABG surgery. Through a thoracotomy incision, the requirement of a bloodless field for the anastomosis can be achieved by temporary coronary occlusion on a beating heart. Surgical skill in the ability to anastomose the conduit to a moving target of about 2 mm in diameter is obviously an essential prerequisite. Extubation is possible in the immediate postoperative period. Not all the results of non-pump CABG surgery have been trouble-free. Gundry described an unacceptable number of anastomotic stenoses, and these, together with unexpected late deaths, have led the Loma Linda center to abandon the procedure.20 The future may hold some promise of an increase in non-pump CABG surgery in very selected patients, notably with single-vessel disease. Nevertheless, completeness of revascularization is a major concern in all cases of CABG surgery; and CPB, together with myocardial protection, safely provides a bloodless and motionless field for the insertion of multiple grafts if necessary, and in combinations of lesions that pose a high risk.

Which bypass conduit confers the best results?22 The question is as old as the bypass procedure itself. Autologous saphenous vein, easy to harvest and tolerant of the preparation required, rapidly established itself as the universally utilized conduit, but with increasing years of follow-up the drawbacks began to emerge. Vein grafts are prone to occlusive disease, and 10 years after surgery 50% have closed, principally of atherosclerosis. Maintenance of saphenous vein graft patency with a variety of pharmacological agents has generally been disappointing, and aspirin alone is still the drug of choice.26 Metallic mesh stents may be implanted into the coronary arteries at the time of surgery to maintain patency, 27 but they have their own complications, principally thrombus formation.

The left internal mammary artery (LIMA) presents a convenient substitute to the saphenous vein and has now replaced the latter as the primary conduit of choice, accompanied by saphenous vein grafts, or the right internal mammary artery, for multiple bypass. Other autologous arterial grafts have also been tried, including the right gastroepiploic and inferior epigastric arteries (though as part of the splanchnic arterial bed they are prone to reactive spasm) and the radial artery as a free arterial graft,28,29 but these are not in the mainstream of arterial conduits. An acceptable artificial conduit material would have enormous attraction for the surgeon, being readily available and consistent in size and quality, but at this time there has been no breakthrough in such a development. All the synthetic or biological substitutes for arterial or autologous saphenous vein have proved disappointing. Whichever conduit is used, the Coronary Artery Surgery (CASS) Registry showed that good revascularization in patients with triple-vessel disease appears to produce the most benefit to patients with severe angina and left ventricular dysfunction.

The amount of blood loss sustained in CABG surgery and the subsequent need for transfusion of blood and blood products have been the focus of attention for a variety of reasons, including difficulty in obtaining blood donors, but more recently, as the result of current views concerning the risks of homologous transfusion. Blood conservation, utilizing pharmacological and non-pharmacological means, has been actively pursued, with positive results.31,32 The use of prophylactic aprotinin (Trasylol), administered either in a low- or high-dose regimen, has become a popular method of reducing bleeding associated with CABG surgery.33 Blood loss can be significantly reduced by as much as 42%. In Europe the use of this antiprotease drug has become popular in CABG surgery; reports of increased
peroperative myocardial infarction and postoperative pericardial effusions associated with high-dosage use must be taken into account, however, when assessing its overall value. In the United States there is less enthusiasm for its use.35,36 Other pharmacological agents, namely tranexamic acid and epsilon-aminocaproic acid, have also been successfully used to reduce blood loss and consequently blood transfusion. The use of allogenic red blood cell transfusion is growing.37

Removal of autologous heparinized blood before bypass, to be retransfused at the conclusion of the extracorporeal circulation, and returning the volume remaining in the extracorporeal circuit have also been practiced.38 Collection and autotransfusion of shed mediastinal blood in patients undergoing uncomplicated CABG grafting have been reported to halve the number of patients requiring homologous transfusion. These simple and inexpensive methods have been widely used, in addition to the utilization of the more complex "cell-saver" blood-cell processing devices. There is no doubt that the drive towards the reduction of homologous blood transfusion will continue.

Mechanical support of perioperative cardiogenic shock by a variety of devices is now firmly on the agenda of CABG surgery. The most widely adopted is the intra-aortic balloon pump (IABP); its use preoperatively has been directed toward improvement of the patient's hemodynamic status. Deployment of the IABP will produce some improvement in myocardial perfusion, but only revascularization can provide the potential for optimal recovery of ischemic myocardium. Intra- or postoperative insertion of the IABP in CABG surgery has improved the outlook in selected cases, but the severity of the pump failure will determine the ultimate outcome. The same remarks apply to the implantable or external, left or right, ventricular-assist devices that have been increasingly used in the past decade in circumstances where the IABP alone is insufficient to maintain a satisfactory hemodynamic status and also to left heart bypass pumps. Some of these devices are being used successfully as a bridge to cardiac transplantation.41

This review would be incomplete without mention of some of the other factors that also have contributed to the present position of CABG surgery. Cardiac surgery is a team event and the improvements in cardiac anesthesiology and cardiorespiratory and arrhythmia intensive-care management, both pharmacological and mechanical, have been fundamental to the speedy and safe recovery of those who undergo such procedures.42 The selection of patients who may benefit from bypass has inevitably become wider, as the perioperative management has improved, yet the results continue to improve. Appropriate timing of the procedure in relation to recent myocardial infarction and better preoperative preparation of the patients have played their part in the overall improvement.

The next decade will, no doubt, be as exciting as the last in bringing forward new developments. One that is already being applied to congenital heart lesions is the use of thoracoscopic, video-assisted techniques through small "port access," without sternotomy or thoracotomy. Already there are reports of animal studies in which the internal thoracic artery has been anastomosed to the LAD coronary artery using the thoracoscope, with cold-blood cardioplegia and femoro-femoral bypass. Benetti has reported successful revascularization in 30 patients using the thoracoscope to harvest the LIMA for anastomosis to the LAD coronary artery without extracorporeal circulation,43 and Aeuff and his colleagues describe similar thoracoscopic anastomoses in 3 patients.44

So long as coronary artery disease exists, so will the need for its surgical treatment, and so will the ingenuity with which cardiac surgeons and their colleagues pursue in their determination to make these procedures safer and more successful. Giant steps such as the introduction of cine coronary arteriography, CPB, and cardioplegia are infrequent, but the continuing, future developments will make their own contributions in the decades to come toward the further improvement of this most successful procedure.

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References

