ACTA MED PORT, Suppl 1: 17, 1980

CORONARY ARTERY SURGERY

James R. Pluth

Thoracic and cardiovascular surgery. Mayo Clinic. Rochester. Minnesota.

I doubt that there has ever been a time in medicine where a field of surgery has grown so rapidly as in the area of direct coronary revascularization. Virtually within two years following the introduction of saphenous vein bypass grafting by Favalero and Johnson the procedure was adopted across the United States and the number of coronary bypasses performed has swelled during each additional year. It is estimated that last year over 80,000 coronary revascularizations were performed and I suspect that the number will exceed that this year. The reasons for that growth are many, but prime among them is population demand. Last year over one million deaths were attributed to coronary artery disease and it is estimated that over twelve million patients per year are symptomatically affected. In addition, the ranks of cardiac surgeons have markedly swelled over the past few years and with the limited population of congenital and valvular heart disease, nearly 70% of these new surgeons found themselves engaged in noncardiac work. As a result of these two factors, the volume of saphenous vein bypass procedures increased rapidly. Added to these considerations, of course, is the fact that the procedure produced generally good results and the mortality, at least reported by the major instutions, was low. This produced confidence in the cardiologists to refer their patients to surgery since but a few years ago they had little to offer their patients in medical management.

However over the last decade, many new developments have occurred which have caused us to re-examine the procedure and to more critically assess its application. One of these was fostered by some of the cardiac surgeons who themselves were prime in the development of the procedure and who advocated that revascularization should virtually be carried out even in the smallest private hospital. In many situations this was an unfortunate attitude since we all realize that it takes more than a skillful surgeon to perform an open-heart procedure — it takes angiographic and laboratory support, good anesthesia, a well trained pump team, and a good postoperative facility and care. Unfortunately figures on mortality for these small programs were never reported until 1977 when the combined Veterans Administration report revealed their mortality which ranged between 1 and 16% virtually dependent upon the number of cases performed (Carey and Cukingnan 1979). Similar figures are available from Great Britain in their national registry of 1977 in which for ischemic heart disease mortality ranged between 4-20% and was inversely parallel to the number of cases performed by each institution. This information created a considerable stir in medical circles and for

approximately a six month period during the end of 1977 and the beginning of 1978, most centers in the United States noted a decline of 20-50% in the number of coronary revascularization cases referred for surgery. The results of surgery also became suspect since many centers were reporting that nearly 90% of the patients were either anginal free or improved despite the fact that graft patency was but 85% at one year and that somewhere between 6 and 13% of the patients had developed perioperative infarction. In addition, the cardiologists themselves had more to offer these patients in regard to medical management and in light of the not insignificant mortality rate and incidence of perioperative infarction, felt that the indications for surgery should be re-evaluated.

Unfortunately it is now difficult to provide good comparative studies to determine the effectiveness of bypass procedures. For once having obtained an arteriogram it is nearly impossible to randomly assign a patient to a medical program knowing that he has 90% lesions involving two or three vessels of his heart. This in itself has created a tremendous bias for surgery since current surgical results continue to be compared to medical management prior to the advent of revascularization procedures and actually prior to the development of the current generation of medical therapy.

Obviously before a patient reaches the surgeon, a certain degree of screening has taken place. This is done by the general practitioner or the cardiologist who has established his own criteria as to what patients qualify for further evaluation leading to arteriography and surgical consideration or whether the patient should simply be placed on a blind medical program. For example, many believe that age should be a limiting factor, but personally I feel that chronological age is irrelevant. What is important is mental and physiological age. The age range of patients in whom we have provided revascularization varies from 19-87 years and many are in the 70-80 year age group. The general health of the patient must be evaluated and the presence of co-existing terminal disease must also be carefully reviewed. I would find it difficult to advise revascularization for an individual with recently discovered small cell carcinoma of the lung, but I would not hesitate in the presence of prostatic cancer or even lymphoma if the judgement of life expectancy is reasonably three years or greater. However, many of these patients may not reach the surgeon for an opinion because of these preconceived biases by the referring physician.

When a patient does present who appears to be a good physiological candidate, one must have some preconceived concept as to the indications for arteriography. The selection that we use is as follows: (1) chronic incapacitating angina, (2) unstable angina, (3) angina of recent onset, (4) subendocardial infarction, (5) myocardial infarction in patients younger than 45 years of age, (6) a positive treadmill exercise test in an asymptomatic patient, (7) strongly positive treadmill exercise test, (8) angina that is refractive to medical therapy, (9) valvular heart patients with angina, and (10) complicated infarcts.

These are the indications therefore for angiographic assessment and, to put it into perspective, approximately 40% of patients with angina eventually get referred for arteriography. At the Mayo Clinic this represents about 2,000 angiograms per year and yet of that selected group only approximately 35% are scheduled for surgery. Of the remaining about 10% have normal arteriograms and many of these were studied merely to rule out angina as a cause of chest pain. Another 10% have such extensive disease or left ventricular failure that they are not candidates for surgery. Approximately 10-15% are studied because they are undergoing other open-heart procedures and are in that age group in which coronary artery disease is likely and the symptoms suggest co-existing disease. The remaining patients are those in whom the lesions suggest they might be best handled medically or who are returning for follow-up evaluation.

Our indications for surgery can be divided into two general groups: (1) Those patients with certain anatomical lesions in whom surgery is known to have superior results and (2) Clinical criteria.

Certainly the condition that leads the list of clinical indications is that of chronic incapacitating angina. It should be stressed that incapacitation should not be defined by the physician but by the patient. If the patient feels that his life style is sufficiently impaired after a good medical program so that he is desirous of an operation with known and expressed risks, I believe he has identified for himself the status of incapacitation. For this category of patients the results of surgery have been good with approximately 60% of the patients relieved of anginal pain and an additional 30% considerably improved.

A second indication is in patients who have had crescendo or incapacitating angina. Here the indication is not that one is preventing the developmemt of an infarct since only about 14% of these patients do progress to a transmural infarct on that admission with medical management. Comparing that figure with the 6% preoperative infarction rate plus the surgical risk of death, there is no significant statistical indication for surgery. (In our own series the mortality was not markedly different within the first one month after the development of crescendo angina, although after eighteen months a small difference in mortality was noted.) However, if one looks as to how these patients fare subsequently, 64% of the patients treated medically continue to have angina at the end of two years as compared to only 18% of those surgically treated.

A third criteria is in those patients who have incurred a subendocardial infarction. A few years ago one of our cardiologists reviewed the fate of these individuals and found that 25% were readmitted within one month with a full transmural infarct. We have therefore adopted an aggressive attitude to study and revascularize these patients as soon as they are hemodynamically stable.

Other indications include patients in whom cardiac surgery is otherwise indicated. I might add that not all patients with valvular heart lesions are routinely studied. In fact, unless the patient has symptoms of angina, a study is not advised. Similarly in patients 70 years of age or older with aortic valve disease in whom angina is only a mild problem, study might not be recommended. This is justified on two bases — (1) the increased risk of surgery when revascularization is additionally performed and (2) the fact that longevity even after five years does not appear to be changed by concomitant bypass procedures.

Another indication might be considered nearly prophylactic; that is, in those individuals who face a major surgical procedure, such as prosthetic hip replacement or peripheral vascular reconstruction in whom angina previously had been a major symptom. In these patients it appears that preliminary revascularization may allow a smoother convalescence at less risk. In over 110 surgical procedures performed on patients with previous revascularization, the operative mortality has been zero compared to an all time 6% risk in those patients who have had previous myocardial infarctions.

Within the anatomical conditions for which saphenous vein bypass grafting is indicated, we would consider left main coronary lesions predominant. Takaro (1976) and Bloomer and Ellestad (1979) have shown a doubling in survival rate for this group of patients as compared to medically treated patients. It must be noted, however, that the surgical risk in this group of patients has been relatively high ranging between 5 and 7% and I suspect that this may be due in part to poor myocardial protection at the time of surgery. The Veterans Administration study has similarly shown a marked difference in survival rates between those treated medically and those treated surgically.

A second anatomical indication is the presence of two or three vessel coronary artery disease with moderately impaired left ventricular function. Three vessel disease in the presence of a good ventricle does not in itself as yet appear to be an indication for surgery provided symptoms can be controlled medically and the patient is not disabled by angina. In a prospective randomized study by Dr. Vlietstra, from our institution, we found that patients with normal ventricles did equally well treated either medically or surgically and even at 3 years no difference in survivorship could be demonstrated.

Similarly patients with extremely poor left ventricular functions with ejection fractions of less than 25% (E. F.+25-49%) did very poorly irrespective of the type of management. In fact, only when left ventricular function was moderately compromised did surgery appear to have any beneficial effect.

I know that in some ways this conflicts with the prevailing opinion that surgery is vastly superior to medical management for three vessel disease. Unfortunately a good deal of that discrepancy has arisen from the Cleveland Clinic review of medically treated patients between 1962 and 1967 in which a 10% yearly mortality was reported for three vessel disease and a 6% yearly mortality for two vessel disease (Bruschke et al 1973). Similar figures for currently treated surgical groups is approximately 1/2 of that percentage; however, we must remember that in comparisons of this type we are really comparing two series at two different time intervals. Recently the Veterans Administration released figures of longevitys for patients treated medically for angina in whom all current medical treatment was provided. In essence this demonstrated no difference in survival at four years with single vessel or two vessel disease whether treated medically or surgically. There was a considerable difference in patients with three vessel disease which favored the surgical approach, but when the left main coronary patients were removed from this group the difference was not significant.

These then are our principle indications for surgery. We do not feel that patients with acute transmural myocardial infarctions should be operated upon and we are indeed reluctant to offer surgery for patients with cardiogenic shock, although this is occasionally done. Revascularization procedures for control of arrhythmias has not provided relief of arrhythmia in the majority of instances except when localized aneurysms have been present. It is important to study these patients on the table with His bundle recordings in order to determine the site of excitation and to include that area which frequently borders the aneurysm in the resection or to perform subendocardial incision to include that area.

Equally important to the selection of patients for surgery is the care provided to them prior and during the surgical procedure. The majority of patients that are operated upon have been on beta blocking agents in an attempt to control their angina. In the past when these drugs were discontinued prior to surgery, a relatively high incidence of myocardial infarction seemed to occur probably related to the increased sensitivity of these patients to catecholamines. In the United States only Propranolol is employed and at present we feel that surgery can be safely undertaken if the patient is receiving 160 mg. or less per day. Higher doses may well be tolerated, but we are reluctant to proceed in the presence of total beta blockade. In addition, the patient should be well sedated to avoid the stress of anticipated surgery and personally I prefer to avoid the use of morphine because of its nonpredictable influence on catecholamine released. During anesthesia both hypotension and hypertension must be avoided. Although monitoring the electrocardiogram seems to be of help in order to observe pattern changes, hemodynamic monitoring appears of even greater value. The use of a Swan-Ganz catheter especially in the presence of left main coronary lesions is of tremendous value as elevations in pulmonary artery pressure signifying left ventricular failure preceed electrocardiographic changes. Afterload reduction in these patients who develop pulmonary pressure elevations may prevent infarction and reduce the operative mortality. Currently cold cardioplegia is nearly universally employed to provide myocardial protection during the procedure and we are hopeful that this adjunct may reduce the incidence of perioperative infarction. Cardioplegia alone as infused through the coronaries may not be adequate in patients with severe stenotic lesions and bathing the heart with cold or iced saline may additionally be necessary. Postoperatively the patients are now started on a program employing antiplatelet agents as soon as extubation is accomplished. In patients with previous graft occlusion, Persantine should probably be started even before operation.

The results of saphenous vein bypass surgery are susprisingly good and the vast majority of the patients do find improvement. However, the degree of symptomatic improvement appears to be related to the degree of completeness of revascularization. In a group of patients with three vessel disease only 12% of the patients were free of pain if none of the bypass grafts remained open, as compared to nearly 95% of the patients when all bypass vessels were patent. Not only are symptoms relieved by surgery, but ventricular function is also improved. Ejection fractions develop a normal response with exercise when revascularization is complete as compared to their preoperative status. We therefore believe that there is little question about the benefits of saphenous vein bypass graft procedures when proper indications for surgery are present.

Unfortunately graft failure still occurs with resultant recurrence of symptoms. The rate of graft failure varies considerably depending upon the reporting institution, but review of those reported in the literature as compiled by the Veteran's study indicated graft patencies to be between 60 and 80%. Generaly the failures fall into four groups — (1) technical, (2) inadequate native vessels with poor run-off, (3) new atherosclerotic disease, and (4) graft closure. The latter can be subdivided into iatrogenic and pericardial disease. Generally technical problems can be reduced by optical magnification and experience. The difficulties of an inadequate native vessel or severe atherosclerotic involvement of the vessel to be grafted is not as easily overcome. We know that we underestimate the anatomical pathology by at least 30% angiographically as compared to pathological examination. There is also a tendency with angiographic magnification to depict a better vessel than is actually present. Perhaps newer angiographic methods, such as employing steroscopic views or dimensional spacial reconstruction, will help to identify these problems. New atherosclerotic lesions distal to the site of grafting are not uncommon. It is an interesting phenomenon that once a significant lesion develops in a vessel or the vessel is totally occluded the distal segment of vessel rarely develops further disease. On a few patients with homozygous hyperlipidemia in whom the progress of the disease is so rapid that they can be followed easily, the primary lesions always appear proximal, but after subsequent bypass new lesions again develop just distal to the anastomotic junction. In other patients a similar process is frequently noted and it would appear that revascularization stimulates or predisposes the development of new lesions because the vessel is again subjected to systemic pressure. Intrinsic graft failures appear to be of two types. We can nearly exclude those failures secondary to pericarditis in which some type of inflammatory process appears to involve the body of the graft. However, other than this etiology, other grafts continue to show narrowing of the lumen that may progress to ultimate occlusion. In the experimental animal this process can be noted as early as two weeks after implantation and in the earliest phases, at one day, is simply a thrombotic occlusion. Later the process becomes more mature with ingrowth of media and endothelium and ultimate occlusion (Fig. 1). The etiology of this process appears related to the action of platelets which adhere to the endothelium. A clot subsequently forms and mitogenic factors from the platelets are then released creating medial cell hypertrophy. The process is not dissimilar to the pathology which we believe is basic to the atheromatous lesion where a break in the endothelium calls forth platelet deposition, medial hypertrophy, and eventually the typical atheromatous plaque. What evidence do we have to support this concept? In a group of dogs in which the femoral vein was used to bypass an occluded left anterior descending vessel, Indium ^{111} tagged platelets were administered and with a gamma-counter localization of these platelets in the site of the graft could be visualized within a few hours. With the use of antiplatelet drugs, such as Dipyridamole, adherence of the platelets was completely abolisfhed (Fig. 2). Can this process be prevented by other means? This seems unlikely for in the process of harvesting veins the endothelium appears to be at least partially destroyed. Dr. Kaye and Dr. Josa from our institution have demosnstrated the loss of endothelium when simply the branches of the vein are

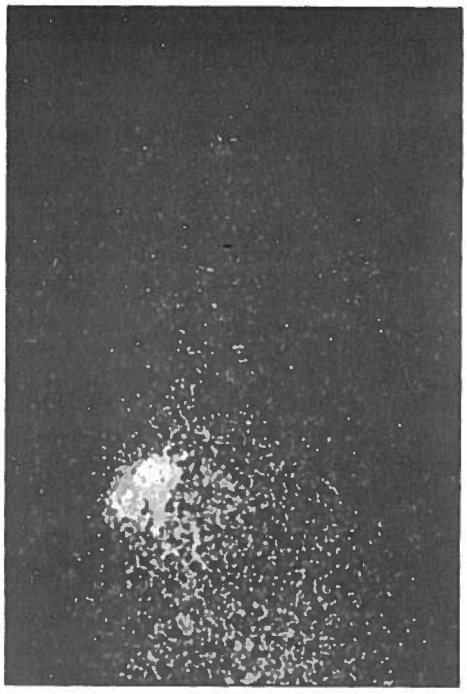

Fig. 1 — *External gamma scan of the canine heart demonstrating the accumulation of Indium*^{111} *tagged platelets (center of photograph) which have accumulated in the saphenous vein graft.*

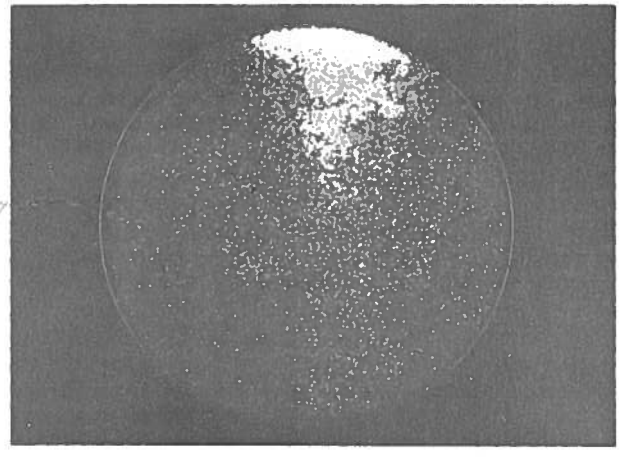

Fig. 2 — *Gamma scan of the intact canine heart demonstrating absence of accumulation of platelets in the vein graft following pretreatment of the animal with aspirin and Persantine. The accumulation of material to the left of the photo is the left ventricular chamber.*

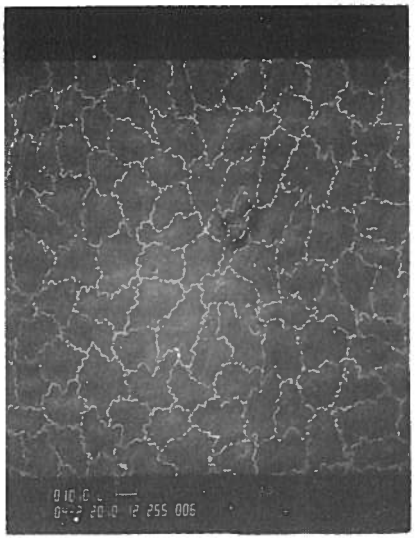

Fig. 3 — *Normal intact endothelium of a canine femoral vein. Endothelium was preserved by in situ perfusion with glutaraldehyde.*

Fig. 4 — *Disruption of the endothelium in the canine femoral vein following careful removal of the vein in preparation for coronary implantation.*

ligated in an in situ situation (Fig. 3 and 4). This appears to be due to the loss of the vasovasorum and probably accounts for the improved patency of internal mammary artery grafts since they are removed en bloc with the accompanying vein.

Therefore, if we cannot prevent endothelial destruction, we must combat the secondary changes by employing antiplatelet drugs and this is the rationale for their use. However, these agents must be administered prior to the surgical procedure in order to prevent platelet adherence and it would appear that they should continue to be used postoperatively to prevent the development of further atheromatous lesions if indeed platelet activity is the underlying factor initiating this condition. Recently we have become interested in the experimental clinical evaluation of the prostacyclines, or E2A prostaglandin. This drug blocks platelet ADP and in doses of one nannogram/kilogram appears to prevent the exuberant platelet buildup noticed in these grafts. Perhaps small doses of this drug for the first few days after surgery will prevent these changes until endothelial outgrowth can cover the denuded areas.

In summary therefore coronary artery surgery appears to be an excellent procedure for the relief of symptoms in chronic incapacitating angina, crescendo angina, and in patients with left main coronary disease or three vessel disease with impaired left ventricular function it appears to prolong longevity. In addition, improvement in clinical function can be documented; however, some unresolved problems remain and these involve the ultimate fate of the grafts and the reasons for late graft failures. Further investigation may lead us closer to a solution so that the ultimate results of this procedure can be improved.

RESUMO

CIRURGIA DAS CORONÁRIAS

Nenhum campo da cirurgia cresceu tão rapidamente como o da revascularização coronária directa. De facto, desde a introdução da portagem aorto-coronária por Favaloro e Johnson, este processo foi adoptado nos E.U.A. e o número destas operações tem aumentado anualmente. Pensa-se que, no último ano, foram feitas cerca de 80000 revascularizações e parece que este número vai aumentar no presente ano. As razões deste aumento são várias mas, acima de tudo, parece estar ligado à procura por parte da população. Contudo, os resultados estão directamente ligados à experiência dos grupos cirúrgicos e à mortalidade, dependendo deste factor varia entre 1% e 16% conforme o trabalho da «Veterans Administration». Semelhante variação é relatada na Grã-Bretanha. É difícil obterem-se bons resultados comparativos acerca da eficiência das portagens coronárias. Tem sido dito que a idade é um factor limitante mas, segundo o autor, a idade cronológica é irrelevante. O que é importante é a idade mental e fisiológica como se demonstra pelo facto de se terem operado doentes entre os 19 e os 87 anos de idade. A selecção de doentes candidatos a cinecoronariografia deverá seguir as regras seguintes: 1) angina crónica incapacitante, 2) angina instável, 3) angina de início recente, 4) enfarte subendocárdio, 5) enfarte de miocárdio em doentes com menos de 45 anos de idade, 6) prova de esforço positiva em doentes assintomáticos, 7) prova de esforço fortemente positiva, 8) angina refractária ao tratamento médico, 9) doentes valvulares com angina, 10) enfartes complicados. Na Mayo Clinic estas indicações representam cerca de 2000 cineangicos por ano. Porém, neste grupo de doentes só 35% têm indicação cirúrgica. Dos restantes, cerca de 10% têm angiogramas normais e outros

10% têm doença extensa ou insuficiência ventricular esquerda e não são candidatos a cirurgia. Cerca de 10% 15% são estudados porque têm outras indicações para cirurgia do coração aberto. Os doentes restantes tem lesões em que o tratamento médico é preferido ou então os que se apresentam para follow-up. Tão importante como a selecção dos doentes é o tratamento pré e per-operatório (beta bloqueantes, sedação, anestesia, monitorização, cardioplagia, prevenção da agregação plaquetária). Os vários resultados cirúrgicos podem ser considerados em quatro grupos: 1) erro técnico 2) más artérias coronárias com deficiente *rum-off* 3) doença aterosclerótica 4) obstrução da portagem. A continuação dos estudos comparativos e do aperfeiçoamento técnico deverão levar-nos à solução deste problema de modo a melhorar os resultados à distância.

REFERENCES

CAREY JS, CUKINGNAN RA (by invitation), GRONER GF (by invitation), SKOW JR (by invitation): Probability of Survival After Coronary Bypass Surgery in Veterans Administration and Community Hospitals. *The Journal Of Thoracic and Cardiovascular Surgery,* Volume 77, Number 1, January, 1979.

BRUSCHKE AVG, PROUDFIT WF, SONES FM: Progress Study of 590 Consecutive Nonsurgical Cases of Coronary Disease Followed 5-9 Years. I. Arteriographic Correlations. *Circulation,* Volume XLVII, June, 1973.

TAKARO T, HULTGREN HN, LIPTON MJ, DETRE K, and participantes in the study group: The VA cooperative randomized study of surgery for coronari occlusive disease. II. Subgroup with significant left main lesions. *Circulation* 54 (Suppl. III): III-107, 1976.

BLOOMER WE, ELLESTAD M: Uptade on Surgery for Coronary Artery Occlusive Disease. Cardiovascular Diseases, *Bulletin of the Texas Heart Institute,* Special Supplement, Volume 6, Number 2, June, 1979.

Adress for reprints: *J. R.Pluth*
Thoracic and Cardiovascular Surgery
Mayo Clinic. Rochester. Minnesota 55901
USA.