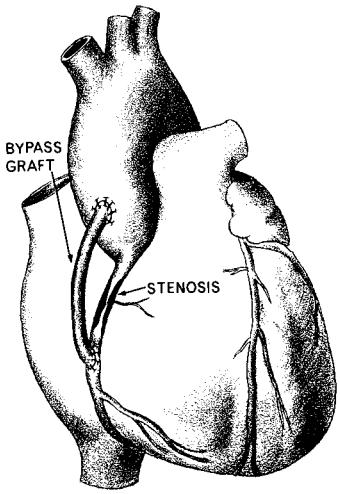

Figure 1: Sketch of an aortocoronary bypass graft.

Figure 2: The completed aortocoronary bypass. The aortosaphenous anastomosis is to the left, the saphenous right coronary anastomosis to the right.*

DIRECT CORONARY ARTERY SURGERY

Using Cardiopulmonary Bypass

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The surgical treatment of coronary artery disease has a long history. The earliest efforts were directed to relief of angina by cervical sympathectomy which did not increase myocardial blood flow and to various indirect means such as pericardial poudrage to facilitate vascular adhesions from adjacent structures.

Although postmortem injection studies with radiopaque material such as Schlesinger mass gave important information as to the extent of coronary atherosclerosis in autopsy cases, objective preoperative delineation of coronary artery disease was not adequate until Sones and colleagues [1] developed the technique of selective coronary arteriography. This technique demonstrated that coronary atherosclerosis is not greatly different from atherosclerosis in other areas of the body, i.e., the major involvement is in proximal vessels and at bifurcations. The distal vessels are usually patent and either uninvolved with atherosclerotic changes or minimally involved. Surgeons could now plan and develop operations to increase the blood supply to areas of demonstrated insufficiency. They also have an effective tool to document results.

Indirect Approaches

Sones' demonstration of long-term patency of internal mammary implants

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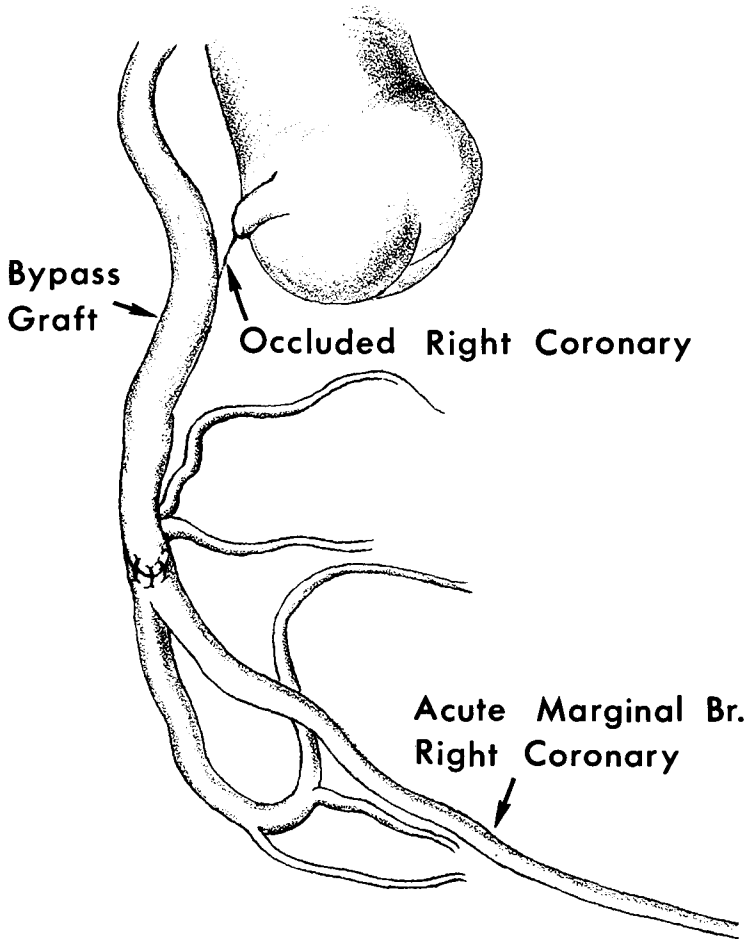

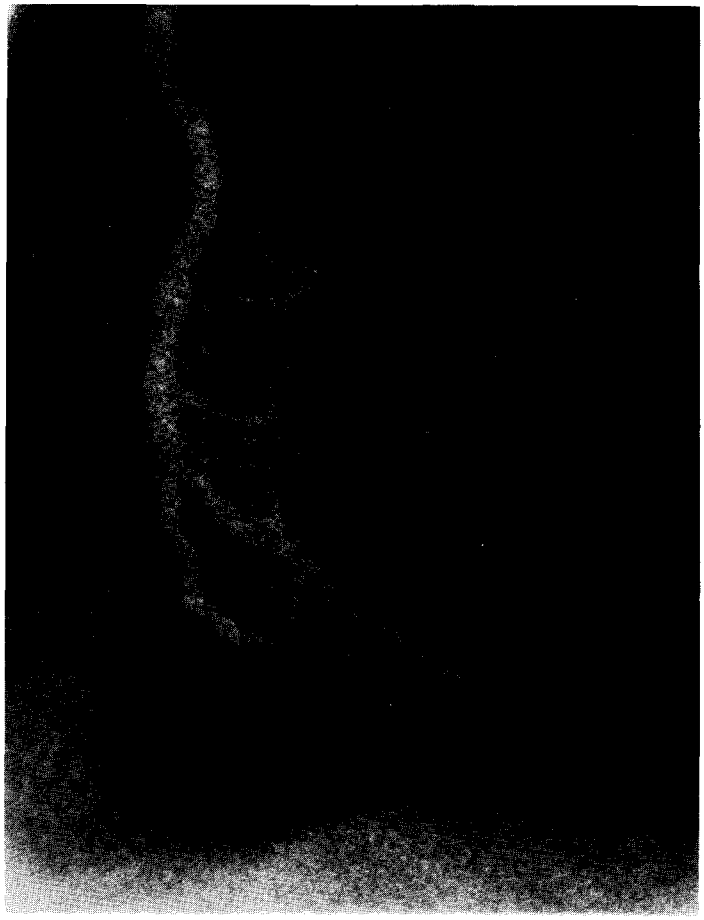

Figure 3: (A) Schematic of postoperative injection of the aortocoronary bypass (the aortic root is included for orientation).*
(B) Postoperative injection of the aortocoronary bypass showing excellent flow.*

with effective revascularization via collateralized coronary vessels stimulated Effler and others [2, 3] to re-evaluate and establish on a firm objective basis the effectiveness of internal mammary artery implantation. This was accomplished for single anterior implants and later for bilateral anterior and posterior internal mammary artery implants.

Although these indirect approaches were shown to increase total myocardial blood flow, the maximum effect is not obtained for from nine to twelve months following operation. It takes considerable time for the implant to form effective anastomotic channels with the pre-existing coronary system. In addition indirect methods of revascularization may not be effective in carrying a large amount of extra coronary blood to the myocardium.

Direct Approaches

Further efforts were made to improve direct surgical procedures. Longmire et al.[4] had begun such direct coronary procedures before the advent of selective coronary arteriography and during the early phases of cardiopulmonary bypass. Effler's group[5] with their vast experience in coronary arteriography and coronary surgery made two significant contributions to direct coronary artery surgery. One was the clarification of the balance of coronary circulation in patients with intractable angina. They demonstrated that in the living human with symptomatic coronary insufficiency, the right coronary artery is dominant, that it supplies a very significant amount of blood to the posterior left ventricle in 60% of the patients.

They also developed a concept of endarterotomy and patch grafting as opposed to endarterectomy. In the former technique the intima is not disturbed and a stenotic vessel is opened by a longitudinal incision in the artery and widened by closing the artery with a gusset of vein or pericardium. This technique avoids the "snow plow" effect on collateral vessels, an effect which at times follows endarterectomy due to shearing off the intima of the small branches in the endarterectomized segment leading to their subsequent thrombosis. The endarterotomy technique, however, is limited in application to stenotic vessels only, not occluded ones, and to arteries where only a short segment is involved.

This endarterotomy and patch graft procedure was performed in a sizable

number of patients with lesions of a dominant right coronary. The early mortality was in the range of five percent and the results encouraging. However, coronary arteriography performed in the late postoperative period showed that approximately 40% of cases had restenosis or occlusion of the vessel. This was thought to be due to platelet and fibrin deposition in the roughened sclerotic wall of the reconstructed vessel and perhaps also to a contraction of the pericardial onlay graft.[6]

Our group[7,8] had a similar incidence of late stenosis and occlusion in a much smaller series of right coronary endarterotomy and patch graft procedures. We also saw a larger number of patients with complete obstructon of the right coronary artery and subsequently devised another procedure—aortocoronary bypass. See Figure 1.

This technique has several advantages over the endarterectomy alone, and endarterotomy and patch grafting. These are:

1) It can be used for occlusive as well as stenotic lesions.

2) Long areas of stenosis are no more difficult to manage than short areas of stenosis.

3) Only a short segment of distal right coronary artery need be isolated.

4) The distal anastomosis of the reversed saphenous vein bypass can be made quickly on total cardiopulmonary bypass.

5) The proximal anastomosis is essentially a large vessel anastomosis to a segment of the ascending aorta isolated by a side-biting vascular clamp and can be made after bypass has been discontinued.

Patient Selection

Patients with significant intractable angina usually of more than a year's duration are candidates for a complete evaluation of the coronary circulation. In our unit, in addition to the routine cardiac roentgenograms, electrocardiograms and blood studies, this involves an exercise treadmill electrocardiogram to demonstrate or document ischemic changes during exercise, selective coronary arteriography to confirm and document the coronary pathology and coronary anatomy, and a left ventriculogram and right heart catherization to study cardiac hemodynamics.

Patients with severe stenosis (more than 80% narrowing) or occlusion of a dominant right coronary artery are then candidates for a right aortocoronary bypass. In most instances there is an additional significant stenosis of the left main, left anterior descending coronary artery or the left circumflex coronary artery. In these instances an internal mammary artery implanation is frequently done at the same operation.

Operative Technique

As a median sternotomy incision is being made to expose the heart, one of the saphenous veins, usually the left, is exposed and removed. Cannulation for cardiopulmonary bypass with two caval cannulas and an aortic perfusion cannula is accomplished. A left atrial or left ventricular vent is inserted.

Mild hypothermia is employed to quiet the heart action and to protect the myocardium from ischemic damage. The right coronary artery is isolated and encircled with two heavy braided silk sutures which are tightened to occlude blood flow. A short longitudinal arteriotomy is then made distal to the obstruction and the reversed saphenous vein draft sutured with an oblique end-to-side technique. The occluding sutures around the coronary artery are then removed and flow is reestablished through the right coronary vessel.

A side-biting aortic clamp is then applied to the ascending aorta and the proximal anastomosis is made during the short period of rewarming, or following termination of cardiopulmonary bypass if heart action is strong. See Figure 2.

In cases where a concurrent internal mammary implantation is planned the artery is dissected from the chest wall from its origin to the sixth intercostal space and then detached and implanted while the patient is still on the cardiopulmonary bypass.

Comments

Direct coronary artery surgery is coming of age. Early efforts of Longmire and others carried a high risk due to the lack of precise pathological diagnosis and the early state of the art of cardiopulmonary bypass.

Selective coronary arteriography permits accurate pathological diagnosis and a better understanding of anatomical considerations. These factors permit direct coronary artery surgery at a low risk. The vessel most frequently approached by direct surgical techniques now is a dominant right coronary artery. By opening this vessel, or preferably bypassing the obstructing lesion, the posterior left ventricle can be effectively revascularized. Also via collaterals, coronary perfusion of the anterior left ventricle may be improved by this technique.

We have now performed seven such aortocoronary bypasses with no operative deaths. The clinical course has been good in most patients. One patient with a postoperative coronary arteriogram showed not only excellent filling of the entire dominant right coronary but also a significant contribution of flow to the distal branches of the anterior descending and left circumflex coronary vessels. See Figure 3.

Aortocoronary bypass appears to be an improvement over other forms of direct coronary artery surgery. It is probable that this procedure can be extended to the left coronary as well.

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