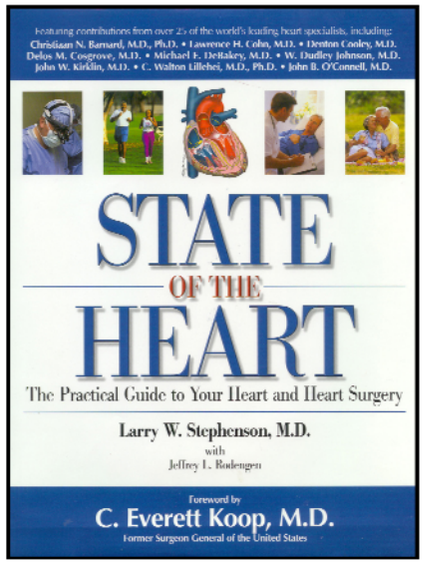

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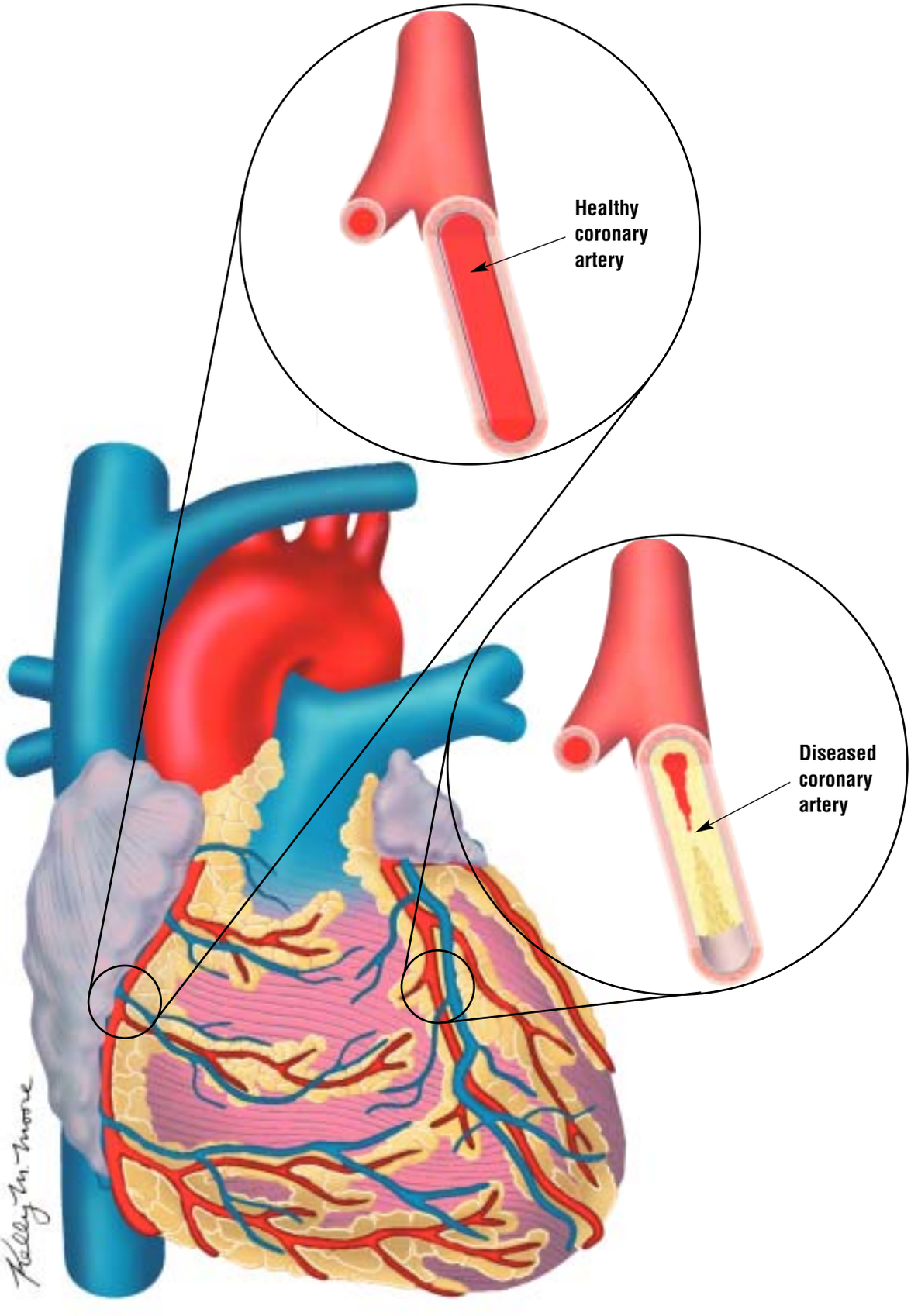


Fig. 8.1: Coronary artery disease is caused by atherosclerosis. During this process, plaque builds up in healthy arteries and gradually clogs them.

Fig. 8.1

CHAPTER EIGHT

CORONARY ARTERY DISEASE AND TREATMENT OPTIONS

IN THE EARLY PART OF THIS CENtury, Nobel Prize–winning surgeon Dr. Alexis Carrel attempted what may have been the first bypass of a coronary artery. Without a heart-lung machine, however, his animal trial met with limited success.

Little else happened in the dawning field until 1930, when a French surgeon named Dr. Rene Leriche developed a method to attach skeletal muscle to the heart in animals, in hopes that new blood vessels would form. This line of research was pursued by Dr. Claude Beck in Cleveland, who confirmed that new blood vessels did indeed grow into the heart muscle from tissues wrapped around the heart. In his first attempt to treat coronary disease in a human patient, Beck roughened the outer surface of the heart with a burr and sutured a graft of skeletal muscle from the chest to the heart. New vessels formed, and the patient recovered. The patient's angina also disappeared. Beck went on to perform variations of this operation in sixteen patients.

In 1946, a Canadian surgeon named Dr. Arthur Vineberg performed an operation on a patient with a coronary artery blockage. He tunneled the internal mammary artery from the chest wall into the patient's heart muscle but did not directly connect it to one of the heart's arteries. He was hoping new blood vessels would sprout from the mammary artery and connect with the blocked blood vessels in the heart. Over the next several months, new vessels formed, giving the heart a new blood supply. Although the Vineberg operation enjoyed some popularity in the following decades, the chief drawback, as with Beck's operation, was that it took months for new blood vessels to form — if they formed at all.

At about the same time, surgeons began to perform a procedure called **endarterectomy**, which basically meant cleaning out atherosclerotic material from the coronary arteries. Endarterectomies were often quite extensive and sometimes involved almost the entire length of the artery. Although the results were good with larger arteries in the body, the early results with coronary arteries were not good. Some patients survived for years, but in many cases the coronary arteries clotted off soon after the surgery. The high mortality rate was considered unacceptable, and doctors continued searching for new and better ways to treat coronary artery disease. Today, coronary endarterec-

Endarterectomy: A surgical procedure in which atherosclerotic material in an artery is removed and the artery is either sewn back together or a patch is placed over the surgical incision.

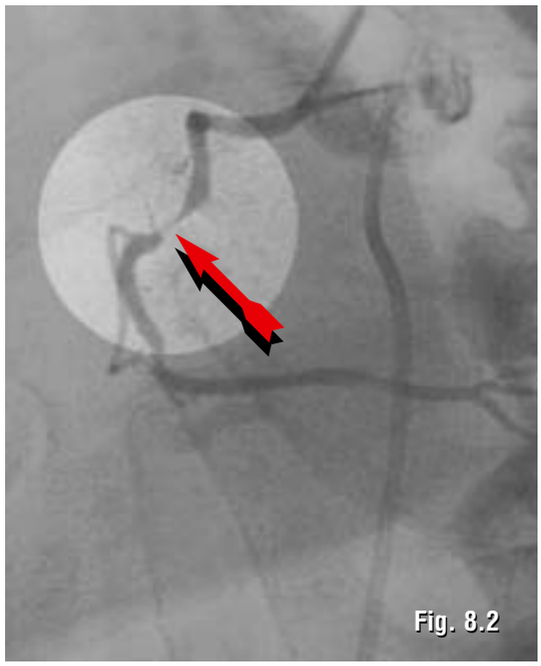


Fig. 8.2: **Coronary Arteriography:** The process of obtaining a coronary arteriogram or an x-ray picture of the arteries of the heart. This is done by injecting a radiopaque dye that shows up on x-ray film.

Coronary Artery Bypass Grafting (CABG): A surgical technique in which one's own veins or other arteries are used to route blood around a blocked area in a coronary artery.

Dr. Rene Favaloro, below, performed early saphenous vein bypass graft operations to treat coronary artery disease.

tomy is still used by some surgeons, but it's done in conjunction with **coronary artery bypass grafting**.

The Coronary Bypass Evolves

Even while endarterectomy was being tested on patients, teams of surgeons were approaching the first successful modern coronary artery bypass graft surgery. The story of the bypass begins as early as 1952, when the renowned Soviet surgeon Dr. Vladimir Demikhov was joining the internal mammary artery, which is under the breast bone, to the left coronary artery in dogs. Other surgeons soon began to study coronary artery bypass grafting in experimental animals.

In 1962, the technique received a major boost when Dr. Mason Sones at the Cleveland Clinic reported on a technique called selective **coronary arteriography** (Fig. 8.2). In this procedure, a catheter is threaded up through an artery in either the groin or the arm and used to inject radiopaque contrast material directly into the coronary arteries. This technique supplied the road maps for the surgical treatment of coronary artery disease. For the first time, chest surgeons were able to see the exact location of blockages and plan their surgery.

Meanwhile, the idea of using a piece of the patient's own vein for a bypass graft of a blocked artery was gaining acceptance. During the Korean War, surgeons were more commonly using the saphenous vein from the leg, which is a superficial vein that runs from the groin to the ankle area and is totally expendable (Fig. 8.3), to bypass arteries in the leg that were injured and blocked. As the concept gained widespread acceptance, some doctors began to envision using vein grafts to bypass blocked coronary arteries, and sporadic attempts were made throughout the early part of the decade.

In 1967, at the height of the Cold War, a Soviet surgeon, Dr. V.I. Kolessov from Leningrad, reported in an American surgical journal his experience with internal mammary artery–coronary artery anastomosis for the treatment of coronary artery blockages in six patients. Operations were performed through an incision in the left chest without the heart-lung machine. The following year, Dr. Charles Bailey and Dr. Teruo Hirose from New York published a report on surgery in which the internal mammary artery was used to bypass blockages in the right coronary artery in two patients. In 1968, Dr. George Green, also from New York, used the heart-lung machine to bypass a patient's left anterior descending coronary with the internal mammary artery.

That same year, Dr. Rene Favaloro, a surgeon from the Cleveland Clinic, used the saphenous vein technique to bypass blockages of the coronary arteries in fifteen patients. This group had also had the Vineberg operation, in which a mammary artery was tunneled into the heart to increase blood flow. The saphenous vein bypass graft was inserted between the aorta and the right coronary artery. The bypass was performed by dividing the coronary artery and sewing

the vein graft end-to-end beyond the blockage in the right coronary artery. In an addendum to the published paper, fifty-five more cases were added — fifty-two for blockages of the right coronary artery and three others for diseases in the left circumflex coronary artery.

Most surgeons, however, remained extremely skeptical of the coronary bypass operation, especially that in which the saphenous vein was used. This was because, although the saphenous vein bypass grafts worked relatively well for bypassing arterial blockages in the legs, it was not uncommon for these bypasses to clot off and require urgent surgery to save the leg. It was feared that if saphenous veins were used to bypass coronary arteries, particularly those supplying the left ventricle, a blood clot would result in instant death.

By May 1969, all of this was about to change. At the annual meeting of the American Surgical Association, a young surgeon who had recently completed his heart surgery training, Dr. W. Dudley Johnson from Marquette University in Milwaukee, reported on a series of 301 patients who had undergone various operations for coronary disease since February 1967. Many of the techniques he described are still used today. In that report, which was published later that year in a major surgical journal, Johnson stated:

"The vein graft technique was expanded and used in all major branches (of the coronary arteries). Vein grafts to the left-sided arteries run from the aorta over the pulmonary artery and down to the appropriate coronary (blood) vessel. Right-sided grafts run along the atrial-ventricular groove and also attach directly to the aorta. There is almost no limit to the potential (coronary) arteries to be bypassed. Veins can be sutured into the distal (far end) anterior

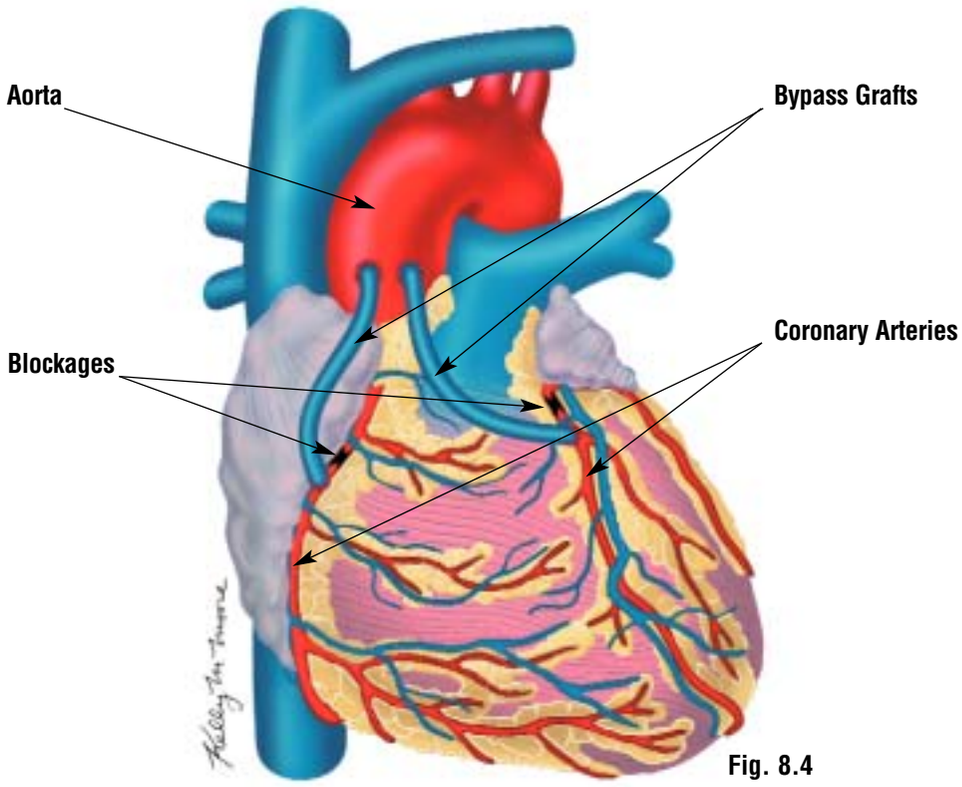


Fig. 8.4

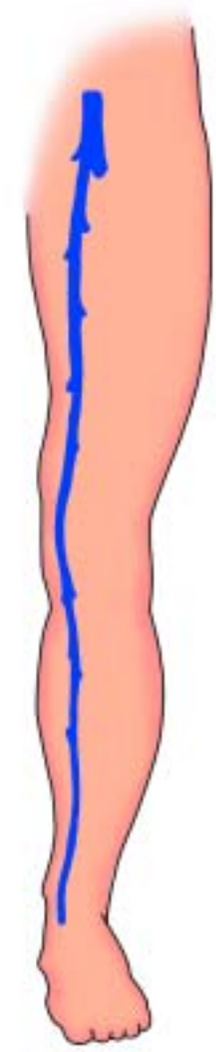


Fig. 8.3 (above): The saphenous vein runs from the groin to the ankle.

Fig. 8.4 (left): The saphenous vein bypass graft, a common bypass technique, using saphenous veins from the legs, is used to bypass blocked portions of the coronary arteries. A double bypass is shown.

THE FIRST CORONARY ARTERY BYPASS SURGERY

DR. DUDLEY JOHNSON, WHO was one of a handful of doctors who popularized the modern coronary bypass operation, first knew he wanted to practice medicine while in seventh or eighth grade — but he didn't know he wanted to be a surgeon until he got into medical school.

"And then I didn't really have any illusions about being a heart surgeon," Johnson said in a 1999 interview. "But I figured if I had experience in the chest, I could get a little better job in a clinic somewhere, so I also trained to do lung surgery along with general surgery. As it turned out, the doctor in Milwaukee, Dr. Derward Lepley, Jr., who was in charge of the heart surgical realm, which was really in its infancy in the middle sixties, asked me to join him in practice, so I ended up staying in heart surgery."

Dudley Johnson

It was a fortunate decision for the field of heart surgery. At the time, surgical teams across the country were experimenting with various treatments for arteriosclerosis in the coronary arteries. Endarterectomy, or stripping plaque from the coronary arteries, was an accepted treatment. Bypass grafts, which were being placed into the coronary arteries of animals, remained a controversial procedure that many surgeons thought wouldn't work. Various attempts were made, including one in 1962 by Dr. David Sabiston, who probably performed the first bypass in a human. Unfortunately, his patient died only days later of a stroke.

Meanwhile, a team of doctors in Houston under the leadership of Dr. Michael DeBakey was developing its own bypass program. "If you go back to that period, you will find there was a great deal of work being done in the experimental laboratory on coronary bypass and other types of coronary surgery," DeBakey said. "In 1961, we wrote our last article on our experimental work with animals. We came out with the conclusion that we had about a 50 percent rate at the end of six months with the bypass graft staying open. We said that was very encouraging and we felt that more experimental work ought to be done."

DeBakey's team did continue its animal research — until a historic moment in 1964. The surgical team, having already heard about Sabiston's unsuccessful bypass, was in the midst of an endarterectomy for a patient when an unforeseen opportunity arose. DeBakey recently told the story:

"This fellow had total blockage of the right coronary, and the only thing he was living on really was his left anterior descending (LAD) coronary artery and a little diagonal branch, and he had a blockage in the left main coronary, right where the LAD began. It was a complicated lesion. When we got in and tried to do the endarterectomy, we kept trying to find the cleavage plane, but we couldn't find it. We knew we couldn't get this fellow off the table unless we restored circula-

tion in the one artery that was supplying all the blood to his heart. So we decided right then and there to do what we had been doing in animals. We got a little piece of vein out of his leg and put it in, and it worked."

This was probably the first successful coronary artery bypass graft surgery. Drs. H. Edward Garrett, Edward W. Dennis, and DeBakey, however, didn't report this success in the medical literature until eight years after the procedure. "In the final analysis, I don't think we deserve all that great a credit for having done the first coronary bypass in a patient," he recently said.

Michael DeBakey

"It was an accident! I think the most important thing to point out about this was the fact that we were doing experimental work, and if we had not been doing the experiments, we wouldn't have thought of doing it in a patient.... I think that's about as good an example as you can provide for the usefulness of animal laboratory experimental work."

Johnson Shows the World

While this first successful graft remained pretty much unknown throughout the mid-1960s, other surgeons at various heart centers continued their work. Johnson, by then a heart surgeon himself, remembered visiting the Cleveland Clinic to watch early coronary patch grafts, which only widened the narrow and diseased portion of the artery. After seeing the technique, he went home and "promptly did two such patches."

Johnson, however, did not like sewing a patch onto the most diseased portion of the artery when the disease had obviously spread beyond the patch. "It occurred to me that the diseased area could be avoided completely by opening the artery beyond the disease. A vein could be attached like a patch, and the other end of the vein simply attached to the aorta."

But there was much controversy surrounding a complete bypass procedure, beginning with the technique used to connect the vein graft to the coronary artery and the aorta. Surgeons also debated if more than one vein graft could be placed, or how many "bypasses" were practical.

In 1969, Johnson introduced the modern saphenous vein bypass with the end-to-side sewing technique. He helped settle many of these controversies with his string of successful operations and the multiple-bypass technique he developed, including the double, triple, and quadruple bypass. Since then, he has performed more than ten thousand coronary bypass operations.

"The long-term results of coronary artery bypass graft surgery have been evaluated in several centers. In many subgroups of patients, life expectancy has returned to normal or even better than normal," Johnson said. "Coronary artery bypass graft surgery has stimulated more than nine thousand published reports in the medical literature. It does more to change quality and length of life than what medicine can do for most other major chronic diseases. The coronary artery bypass graft operation does nothing for the basic cause of the disease, however, and prevention is, of course, the ultimate answer."

descending or even to the posterior margin branches.

"Double vein grafts are now used in over 40 percent of patients and can be used to graft any combination of arteries.... This direct approach to coronary flow immediately improves heart function and alleviates most clinical symptoms."

In discussing Johnson's presentation, a prominent New York surgeon named Dr. Frank Spencer commented: "I would like to congratulate Dr. Johnson very heartily. We may have heard of a milestone in cardiac surgery today.... If the exciting data by Dr. Johnson remains valid and the grafts remain patent [i.e., open] over a long period of time, a total revision of thinking will be required regarding the feasibility of direct arterial surgery for coronary artery disease."

Coronary Artery Disease Today

Since its development, the coronary bypass operation has evolved into the leading surgery to treat clogged heart arteries. Patients who have bypasses are often relieved of angina immediately, and their bypass grafts usually stay open for years to come. Hundreds of thousands of bypass operations are performed every year.

Almost fourteen million Americans alive today have a history of heart attack, angina pectoris, or both. In 1999, it was estimated that more than one million Americans will have a new or recurrent heart attack. It will be fatal in about one-third of these cases. At least 250,000 people a year in the United States die of a heart attack within one hour of the onset of symptoms — even before they can reach the hospital. Based on the Framingham Study in Massachusetts, 5 percent of all heart attacks occur in people under age forty years, whereas 45 percent occur in people under age sixty-five years (statistics released by the American Heart Association for 1998).

Coronary Artery Anatomy

Although each person's coronary artery system is somewhat different, most people have two coronary arteries that come off the aorta: the right coronary and the left main coronary. The left main coronary artery is like a short tree trunk, and it usually divides after a half inch or so into two major branches — the left anterior descending coronary and the left circumflex coronary (See Chapter Two).

When physicians talk about coronary arteries, they are usually referring to these three: the right coronary, the left anterior descending, and the left circumflex. Many of my patients wonder how it's possible to have a quadruple or quintuple bypass if there are only three major coronary arteries. As it turns out, the coronary arteries are like branches on a tree. The main trunks split into major branches, which split into smaller branches and on and on until the arterial branches become so small they cannot be seen by the naked eye. Any one of these many, many arterial branches can be blocked, meaning that as many as eight or nine, and perhaps even more, bypasses may be necessary.

What Causes Coronary Artery Disease?

The most common cause of coronary artery disease is atherosclerosis, sometimes referred to as "hardening of the arteries." In this condition, fatty buildups develop on the arterial lining (Fig. 8.1). These buildups are soft and almost look like cottage cheese. In fact, the word atherosclerosis comes from the Greek "athero" meaning porridge, and "sclerosis" meaning hardening.

As these fatty buildups become larger, they damage the artery wall, and a scar forms. This scar is then infiltrated with calcium, which further hardens the atherosclerotic material. At some point,

the arteries become very brittle and calcified, and the buildups gradually narrow the opening until blood has difficulty getting past the blockages.

Symptoms of Coronary Artery Disease

When the heart does not get enough oxygen, portions of it may become **ischemic**, which results in a type of pain called angina pectoris. This pain is often described as pressure, and it usually occurs over the breastbone. It can feel like a band tightening around the chest. Some of my patients have described it as a pile of bricks or heavy weights that has been placed on their chest. This could be a pain that goes from the chest to the neck and lower jaw or a numbness down the arm, particularly the left arm. Sometimes it can manifest itself as a discomfort in the upper portion of the abdominal wall. It may be mistaken for heartburn, a gall bladder attack, or even an upset stomach.

Chest pain does not always accompany hardened arteries. Some patients have what is called an angina equivalent. This could be a form of shortness of breath or other symptoms that, after appropriate testing, turn out to be caused by a lack of oxygenated blood getting to the heart muscle.

Diabetic patients, especially those who have been taking insulin for a long time, often lack this angina warning system. These people may have what is called diabetic neuropathies, or diseases related to their nervous system, and may not have the same sensitivity and same warnings that other people would have. This is especially dangerous. People who have a defective warning system could be playing tennis or doing some other strenuous activity with no sign that the heart is not getting enough blood. They could then suffer a heart attack without any warning. Angina alerts people to immediately stop whatever they are doing and rest.

As atherosclerotic material builds up, it may actually starve the heart muscle for blood. Heart attacks occur not only when the plaque on the arterial wall blocks blood flow but also when the artery breaks or ruptures. When this happens, platelets, which are designed to begin blood clotting, attach to the raw surface of the crack and form a growing clump. This further blocks the coronary artery and may result in a heart attack. Even a temporary clumping of platelets can result in a heart attack.

Coronary arteries themselves can also go into spasm and block off. This is believed to be genetically related as some people are more prone to have coronary arteries that will go into spasm. If this happens, the blood flow beyond the spasm is severely compromised, which can cause angina or even a heart attack.

Ischemia:
When a portion of the body, an organ or tissue, is not getting enough oxygenated blood. It is usually related to a blockage in one of the arteries delivering blood to that area.

Heart Attack and Heart Failure

The medical term for heart attack is **myocardial infarction**. During a heart attack, a portion of the heart muscle dies. Patients usually survive small heart attacks. If the heart attack involves a significant portion of the heart, however, the victim will usually die due to arrhythmias during the beginning of the heart attack.

Myocardial Infarction:
When a portion of the heart muscle dies. Also referred to as a heart attack.

In the event a patient survives a large heart attack, a considerable portion of heart muscle will turn into scar tissue and no longer contract. This can lead to heart failure. The patient will become short of breath and frequently fatigued because of the reduced amount of blood being pumped by the heart, resulting in a relative lack of oxygen and other nutrients getting to the body's tissues. The patient may develop swelling in the ankles or in the legs or abdomen as the heart fails and fluid backs up into the tissues.

Dissolving Blood Clots During Heart Attacks

By
James Marsh, M.D.
Professor of Medicine and Chief, Division of Cardiology
Wayne State University

IN MOST CASES, HEART ATTACKS are caused by atherosclerosis, which slowly narrows the coronary arteries, and a blood clot that suddenly forms and blocks off the coronary artery completely, thus limiting blood flow to the heart. When a patient comes into a hospital emergency room early in the course of a heart attack, physicians may administer a clot-dissolving drug.

The most common clot-dissolving drug is tPA (tissue plasminogen activator). During the first ninety minutes, this drug will dissolve the clot that is blocking the coronary in about 75 percent of patients, restoring blood flow to the heart and limiting the amount of heart damage.

Because this is a very potent drug that dissolves clots anywhere in the body, bleeding is one possible side effect of tPA. Therefore, patients must be carefully selected to have minimal risk for bleeding. It cannot be used in patients who have had a recent stroke, in patients with severe high blood pressure, or in patients with bleeding stomach ulcers. However, when it is given to carefully selected patients in the first six to twelve hours after the onset of a heart attack, it can definitely improve their outcome.

Medical Treatment of Coronary Artery Disease

If you develop angina pectoris or what's thought to be an angina equivalent, your physician probably will start with an electrocardiogram. If it's abnormal or in certain cases even if it's normal, your physician may decide to do some form of stress testing. Depending on the results, and sometimes even without testing, your physician may decide to do a type of cardiac catheterization called coronary arteriography, in which catheters are used to inject the coronary arteries with radiopaque dye. This helps doctors see if blockages are present, where they are located, and how severely the artery is blocked.

In most angina cases, the treatment is medication, dietary changes, and exercise. Several medications are popularly prescribed to treat angina:

- ♥ Nitrates dilate coronary arteries. They do not necessarily dilate the area with the blockage, but they can dilate beyond the blockage and lower the overall resistance to blood flow.
- ♥ Beta blockers work directly on the heart muscle. Beta blockers cause the heart to contract more slowly and with less vigor, reducing the amount of oxygen demanded by the heart muscle.
- ♥ Ace inhibitors dilate arteries throughout the body, which lowers the resistance to blood flow. The heart does not have to work as hard to deliver

the same amount of blood to the body, allowing the heart itself to get by with less oxygenated blood.

♥ Calcium channel blockers are particularly helpful in patients who have some degree of coronary artery spasm. They prevent the arteries from going into spasm or at least decrease the incidence and severity of the spasm.

Interventional Therapy

If a severe blockage is present, more aggressive measures may be needed to get oxygenated blood to the heart. One option is interventional therapy, or the use of catheter-based therapies.

When a coronary artery has a severe degree of blockage — more than 70 percent but usually less than 100 percent — cardiologists may be able to dilate the artery with a balloon catheter (Fig. 8.5). Sometimes even arteries that are totally blocked can be reopened with catheters.

In this procedure, a catheter, which looks like a long piece of spaghetti, is threaded through the arterial system, usually through an artery in the groin or arm. The catheter is tipped with a tiny sausage-shaped balloon that is deflated and guided into the coronary artery and positioned directly opposite the narrowed area. The balloon is inflated, crushing the plaque material against the arterial wall and opening up the artery. It may have to be inflated several times.

A disadvantage to using a balloon is restenosis. Doctors have found that in about 40 percent of patients who undergo this procedure, within a year or less the artery begins to close again, or restenose, which can occur for various reasons. This means another catheter procedure is necessary, or perhaps open heart surgery.

Recently, a device called a stent has been developed to combat restenosis. It is used with the balloon. Stents look like wire or mesh tubes, and they are usually flexible. In this procedure, the stent is placed over the balloon, and both are guided to the obstruction. When the balloon is inflated, the stent expands and is lodged in the artery (Fig. 8.6A). The stent remains in place after the balloon and catheter are withdrawn (Fig. 8.6B). Its major advantage lies in its ability to lessen the chance that the artery will become obstructed again, although it does require placing a foreign object into the coronary artery.

Balloon catheters are not the only interventional option. Another is a tiny drill called a rotablator. This device literally shaves atherosclerotic material off the arterial wall. Under certain conditions, a laser can be used to carve out, or vaporize, some of the atherosclerotic material. These devices are usually not used in a coronary artery that is totally blocked, particularly if that blockage has been present for a long time.

The feasibility of using catheters depends on the severity of the blockage. In some cases, when catheters are forced beyond total blockages, they may perforate the wall of the coronary artery and cause

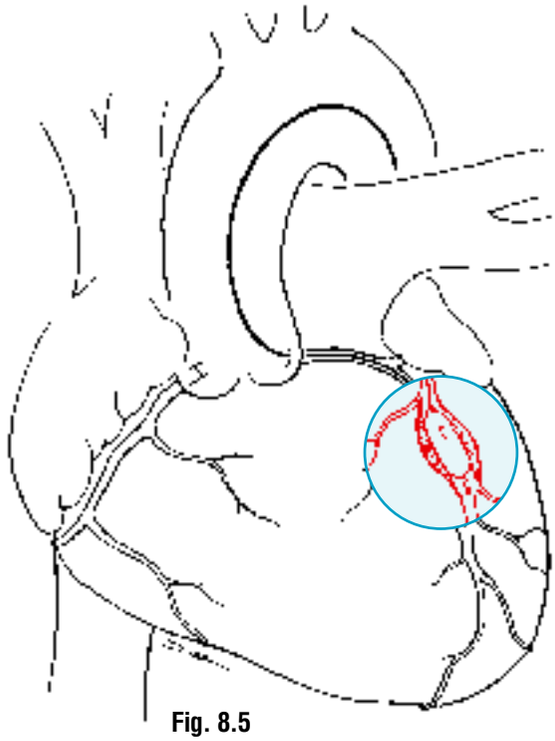


Fig. 8.5

Fig. 8.5: Coronary arteries that are blocked with atherosclerotic material can be opened with a balloon-tipped catheter in a procedure called percutaneous transluminal coronary angioplasty.

Fig. 8.6: Recently, a device called a stent has come into use. This device is placed on the balloon (A) and remains in the artery after the dilatation (B).

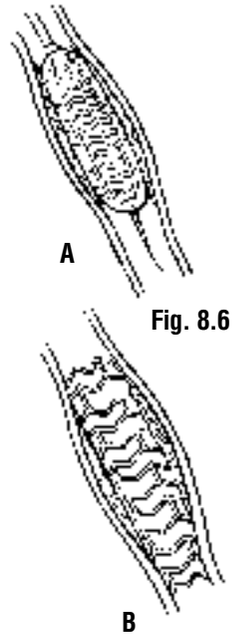


Fig. 8.6

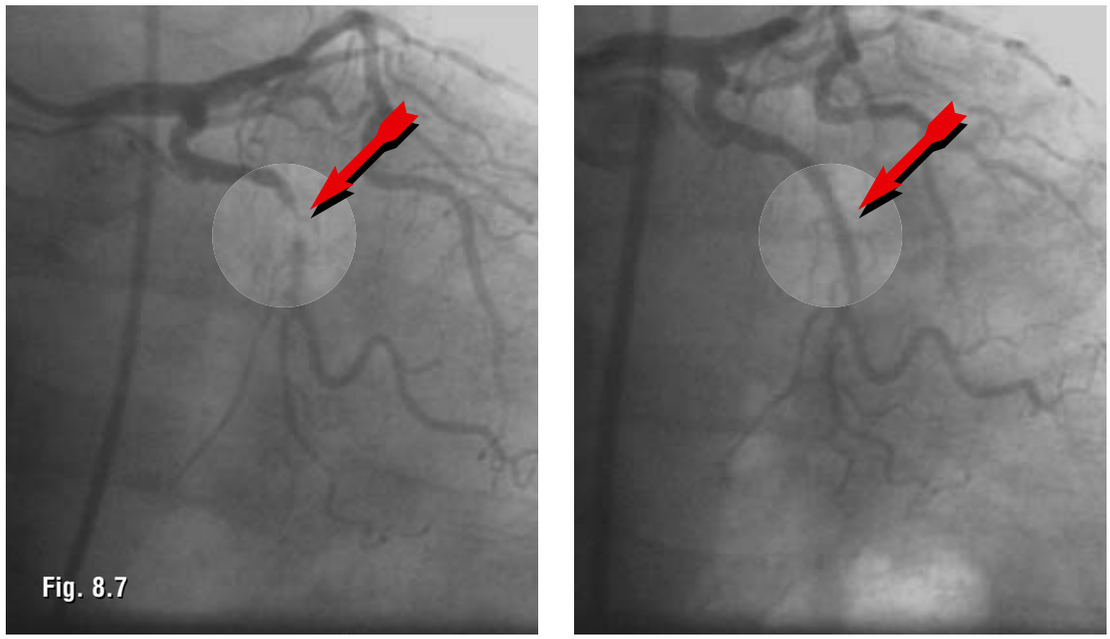


Fig. 8.7: These coronary angiography films were taken before and after a stenting procedure. The blocked artery, left, is contrasted with the open artery, right, after a stent was put in place with a balloon-tipped catheter. Introduced in the early 1990s, coronary stents are designed to hold open a blocked coronary artery after a balloon widening.

severe complications. In the most important coronary artery, the left main coronary, cardiologists are usually reluctant to dilate blockages or attempt other catheter procedures to open the artery because some of the material could suddenly break off, possibly blocking the blood flow to the left ventricle and causing a fatal heart attack. There are centers, however, where research is being done on using balloons and related techniques in the left main coronary under special conditions.

Transmyocardial Laser Revascularization

If interventional catheter techniques aren't viable, doctors usually turn to the coronary bypass graft. There are cases, however, when the coronary artery disease is so severe and so widespread, or diffuse, that there's really nowhere to place the bypass graft.

For these patients, a relatively new procedure called transmyocardial laser revascularization may be considered. In this operation, a laser, used either through a catheter or directly through a surgical incision, is used to burn tiny holes in the heart muscle itself. It is hoped these channels will, over time, connect with some of the smaller blood vessels and form new circulation.

In a September 1999 issue of *The New England Journal of Medicine*, Dr. O. Howard Frazier from the Texas Heart Institute reported on a multicenter study in which ninety-one patients were randomly assigned to undergo transmyocardial laser revascularization and another one hundred one patients were randomly assigned to continued medical treatment.

After twelve months, the study group found that the patients who underwent transmyocardial laser treatment had much better control of their angina than their medicine-treated counterparts. Seventy-two percent were improved compared with only 13 percent of the patients who were receiving continued medical treatment. The group also found that the quality of life was significantly improved in the laser-treated group.

In the group that underwent laser treatment, 3 percent died in the hospital after the surgery. At twelve-month follow-up, 85 percent of the patients who had undergone laser treatment were alive as compared with 79 percent in the medically treated group.

Frazier's report, therefore, indicates that at least up to the first twelve months after the laser procedure, the patients who had the procedure are improved over a similar group treated only with medicines.

Coronary Bypass Grafting

In patients with substantial left main coronary artery disease, physicians typically choose coronary bypass graft surgery instead of catheter techniques or leaving the disease untreated.

Studies have shown that people who undergo the surgery will, on average, live longer than a similar group who forgo the operation. Patients with triple-vessel coronary disease, in which all three of their major coronary arteries have severe blockages, and particularly those who also have left ventricular dysfunction (perhaps related to a previous heart attack), also benefit from coronary artery bypass grafting and on the average live longer than those who do not have the surgery. Patients with severe double- or single-vessel coronary disease can also be candidates for coronary bypass grafting, depending on the circumstances.

A doctor would often consider recommending bypass surgery if the patient had a substantial blockage of the left anterior descending coronary artery, particularly if the blockage were where it is attached to the left main coronary. Doctors are frequently reluctant to dilate the artery there or put a stent there because it could interfere with the left main coronary.

If the left anterior descending coronary artery is totally blocked upstream but is a good vessel beyond that, as determined by the number of collateral blood vessels feeding it, and the heart muscle is alive beyond this blockage, bypass surgery is often a good choice if angina is bothersome.

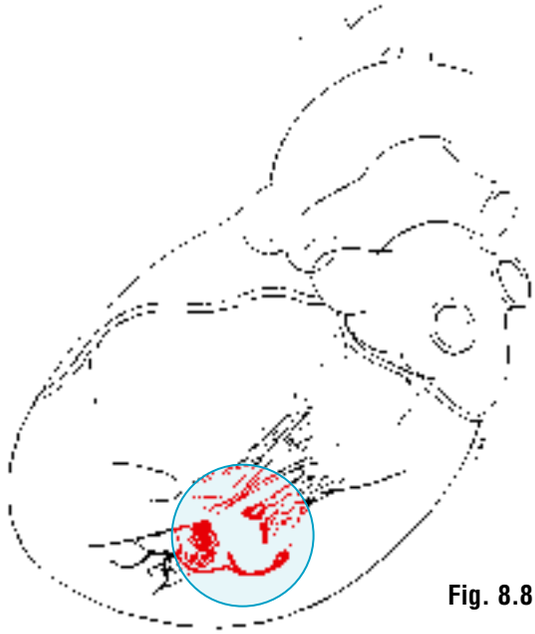


Fig. 8.8

Fig. 8.8: The papillary muscles, which connect the valve leaflets to the interior wall of the heart, can sometimes rupture during a heart attack. This condition usually results in valve replacement.

Complications of Heart Attacks Requiring Heart Surgery

If a heart attack has occurred, there are possible complications. These include left ventricular aneurysm, which may require surgery, and post-myocardial infarction ventricular septal defect and papillary muscle rupture, both of which almost always require surgical repair.

Left Ventricular Aneurysm

When a coronary artery such as the left anterior descending is blocked, a portion of the heart muscle may die and turn into scar tissue. Sometimes, however, as it's turning into scar tissue, the dying or dead tissue stretches and forms a sac (Fig. 8.9A). Later, as the living portions of the heart muscle contracts, some blood may be pushed back into the sac so it actually absorbs part of the heart's pumping energy, thus contributing to heart failure.

These sacs or aneurysms can also be the source of certain types of serious irregular heart rhythms. In addition, blood clots can form in them that can occa-

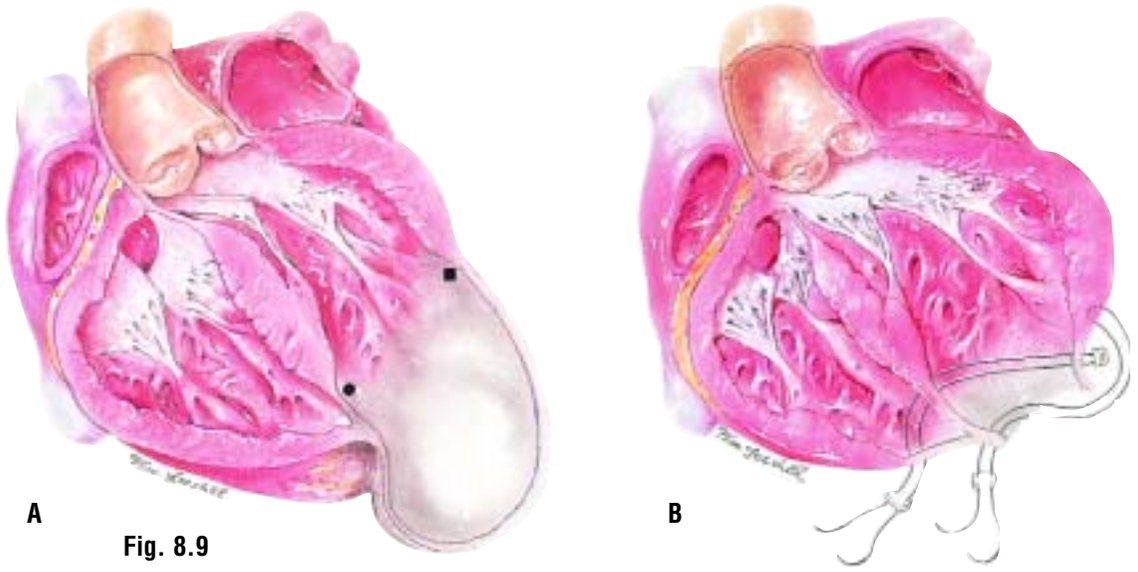


Fig. 8.9

Fig. 8.9: A left ventricular aneurysm occurs when a portion of the left ventricle, the heart's main pumping chamber, balloons out (A), often as a result of a heart attack. It can be corrected surgically by removing the sac-like portion of the ventricle (B) and sewing it back together (C).

sionally break off and travel to the brain and other areas in the body.

Removing a left ventricular aneurysm requires using the heart-lung machine. Much of the scar tissue sac is removed (Fig. 8.9B), and the remaining heart muscle is repaired or sewn back together by using one of several techniques (Fig. 8.9C).

Frequently when performing surgery to remove a left ventricular aneurysm, I will also bypass blocked coronary arteries. A patient who needs coronary bypass surgery may also happen to have a left ventricular aneurysm. In most cases, patients undergoing aneurysm removal, with or without additional coronary bypass grafting, have a good chance of surviving the operation — usually in the range of 90 percent to 95 percent.

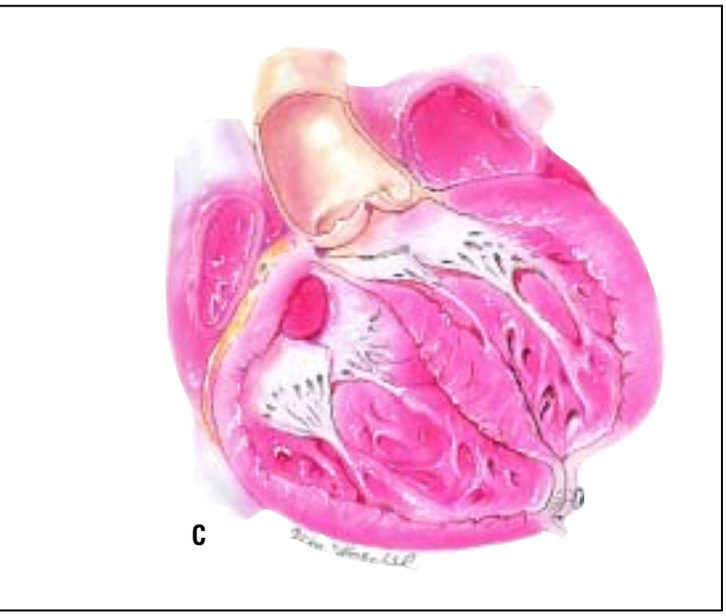
Post–Myocardial Infarction Ventricular Septal Defect

Another complication of coronary artery disease that requires heart surgery is called post–myocardial infarction ventricular septal defect. This happens when the common wall between the right and the left ventricle (the ventricular septum) ruptures after a heart attack.

This is different and a much more serious problem than the congenital type of ventricular septal defect. The postmyocardial infarction ventricular septal defect needs to be repaired relatively soon after it occurs, and the risk of death for this surgery is higher than that for congenital surgery. These patients can be very unstable and sometimes are in cardiogenic shock. This surgery usually requires placement of the intra-aortic balloon pump to assist the heart before the patient is taken to the operating room.

When the surgeon opens the heart to repair the hole, he may find that the heart muscle tissue around the hole is also dying or dead, which makes the hole technically challenging to repair. Nonetheless, the majority of the patients who undergo the repair survive. In some cases, coronary bypass grafting or other heart surgery procedures are done at the same time. Depending on the circumstances, about 70 percent or 80 percent of the patients undergoing this operation survive the procedure and do well.

In many cases, it is a life-saving surgical procedure, and, without the surgery, death may occur within a few days.



Mitral Valve Replacement for Papillary Muscle Rupture

Another complication of a heart attack is that one of the papillary muscles, which is inside the left ventricle and helps control the mitral valve, may be involved in the heart attack. The entire muscle may become detached from the ventricular wall (Fig. 8.8). If this happens, the mitral valve will no longer function effectively, blood will flow backwards into the lungs, and they will fill with fluid. The person will suffer from congestion of the lungs and be very short of breath and may go into heart failure or cardiogenic shock.

This is often a surgical emergency that requires the intra-aortic balloon pump to help stabilize the patient's condition while being prepared for mitral valve replacement surgery. This is a high-risk surgical procedure, but it must be done and hopefully will be life saving.

Unfortunately, because this condition is associated with heart attacks, we may be doing several operations at once. We might be placing coronary artery bypass grafts and, in some cases, may even have to remove a left ventricular aneurysm.

The chance of surviving emergency mitral valve replacement for papillary muscle rupture is about 70 percent, and most of the survivors do well providing the left ventricle has not been too badly damaged by the heart attack.

Transmyocardial Laser Revascularization

By
Lawrence H. Cohn, M.D. *(pictured)*
Professor of Surgery
Harvard Medical School
Chief, Cardiothoracic Surgery
Brigham and Women's Hospital
Boston, Massachusetts
&
Sary Aranki, M.D.
Associate Professor of Surgery
Harvard Medical School
Boston, Massachusetts

IN RECENT YEARS, A TREATment called transmyocardial laser revascularization, or TMLR, has been introduced for coronary artery disease that is so advanced that bypass surgery, balloon catheters, and stents by themselves are not effective. In this new treatment, physicians use a very powerful laser to bore a hole through the surface of the heart into the left ventricular cavity. Until recently, it has been experimental.

Clinical studies under the supervision of the U.S. Food and Drug Administration were performed simultaneously at multiple U.S. centers. Recently, one type of laser (carbon dioxide) was approved as a treatment option for certain patients. Other types of laser are currently in the study phase. Ours was one of the original U.S. sites pursuing carbon dioxide laser treatment.

The Laser in Medicine

The laser has been used in medicine for more than twenty years. Its primary use in medicine is in treating disease. Many eye conditions are successfully treated with a laser, and a laser has been used to dissolve kidney and gall bladder stones. These are but a few of the many applications of lasers in medicine, aside from heart disease, and many more applications are being introduced.

Who Is a Candidate for TMLR?

Not every person with coronary artery disease is a candidate for TMLR. In many cases, bypass surgery and balloon angioplasty produce good short-term and long-term results. However, in an increasing number of persons, coronary artery disease has progressed to such an advanced and severe form that surgery is no longer possible. These patients typically acquire coronary artery disease at a younger age, are more likely to be diabetic with multiple risk factors, and are more likely to have already had numerous bypass and balloon procedures.

In addition, candidates for TMLR must suffer from severe symptoms, like angina or chest pain, that interfere with their quality of life. Maximal medical therapy must have already failed, and any additional medications must be contraindicated. Also, TMLR treatment is not beneficial for heart failure.

How Does TMLR Work?

No one has yet determined how the laser treatment improves symptoms and the blood supply

to the heart. It was initially thought that the holes created by the laser infuse the heart muscle with a new blood supply directly from the heart cavity (such a system exists in animals such as crocodiles or snakes). However, these channels do not stay open for long, and their role in long-term blood supply is minimal, if any.

Other possibilities include damage to the heart muscle and its nerve supply that eliminates the origin of chest pain. Also, a placebo effect has been postulated, meaning that patients mistakenly believe they should get better because a supposedly very useful treatment was performed. These reasons may explain the improvement of symptoms. Nevertheless, because the symptoms take weeks or sometimes months to improve, the above mechanisms are highly unlikely.

However, it is now believed, although not yet proven, that the laser energy stimulates the heart muscle to sprout new blood vessels that supply blood to deprived parts. This is called angiogenesis and can also be stimulated by certain body proteins.

The Surgical Procedure

TMLR is performed through an incision in the left side of the chest just underneath the left breast. The heart-lung machine is not required, and the operation is performed on a beating heart. Because the overwhelming majority of these patients have had previous coronary artery bypass operations, it is unsafe to perform this operation through the sternum, or breastbone. In addition, the back of the heart is more accessible from the left side of the chest without the need to apply too much tension to the heart, which could lower blood pressure during the operation.

Because it takes some time for a new blood supply to the heart muscle to develop after TMLR, the possibility of a reduction in blood supply as a result of the stress of anesthesia and surgery is increased. Therefore, extra vigilance is needed after the procedure to deal with these problems before they become more serious. Aggressive preventative measures include noninvasive monitoring and mechanical and pharmacological support. In addition, all patients are sent to the intensive care unit after surgery for close monitoring.

The operation lasts between one and a half and two hours on an average. Patients can be disconnected from the respirator and their breathing tube removed either in the operating room or as soon as they wake up in the intensive care unit.

The Results of TMLR

The chance of surviving the operation in the first thirty days after surgery is greater than 95 percent. This risk was initially higher but has improved with more intensive support. The long-term survival after one and two years is comparable to that of those patients who did not undergo surgery.

The major impact of TMLR has been in relief of angina, reduced need for hospital admissions, and an improvement in the quality of life. About three out of four patients have experienced these benefits. The need for hospital admission because of unstable angina was also substantially reduced. Even more encouraging, there has been no deterioration in heart function and no damage to the heart muscle resulting in heart failure symptoms.

In Summary

We continue to offer TMLR to patients with severe and advanced coronary artery disease in whom conventional treatment either has failed or is no longer possible. It is only offered for symptomatic angina and not for heart failure. The operation is performed through the left side of the chest without the need for the heart-lung machine. The risk of dying from the operation is comparable to that of coronary bypass surgery because of the potential for complications under stressful conditions. Despite this early risk, the survival after one or two years is similar to that of patients who did not undergo surgery. The majority of patients (75 percent) responded with a marked improvement in symptoms and quality of life and less need for hospital admissions. Intensive research on the exact reason for these results continues.

Women, Race, and Coronary Artery Surgery

By
Reneé S. Hartz, M.D.
Cardiothoracic Surgeon
Professor of Surgery
Tulane University
Tulane Xavier Women's Center of Excellence
New Orleans, Louisiana

CORONARY ARTERY BYPASS grafting (CABG) is the most commonly performed surgical procedure in the United States. There are approximately 325,000 CABG procedures performed every year, and patients who receive this surgery benefit from more than thirty years of experience and published medical data on its relative safety.

Just as CABG is the most commonly performed surgery, more health care dollars are spent treating arteriosclerotic conditions (such as coronary artery disease and stroke) than any other illness in America. These expenditures will dramatically increase as the life expectancy of the U.S. population continues to rise. Currently, men live on average to age seventy-two years and women to age eighty years.

At the same time, the number of female patients undergoing treatment for coronary artery disease is increasing much more rapidly than the number of male patients. In less than fifty years, it is expected,

more cardiovascular health care dollars will be spent on women than on men.

Likewise, the medical community has begun to look at the impact of race on CABG, and this is a topic that deserves attention.

When studying the outcome of CABG in large populations, including mortality and incidence of complications, we have found that females and non-Caucasians fare less good. Moreover, women and non-Caucasian patients stand a greater chance of having several other conditions, each of which on its own increases risk.

Applications of CABG

In the early 1980s, the number of women undergoing CABG almost doubled before beginning to level off. Today, about 25 percent of patients undergoing CABG are women. In surgical centers that accept high-risk referrals (such as those that regularly admit 80-year-olds), the percentage of women having CABG may approach 50 percent.

The Society of Thoracic Surgeons (STS) Database is one of the most authoritative sources for statistics on who is having CABG surgery. The largest database for coronary bypass surgery in existence, the STS Database contains records of almost five hundred thousand CABG operations. This study found that between 1994 and 1996, 8.5 percent of CABG-only operations (not including other types of heart operations) were performed on non-Caucasian pa-

tients, and 28.2 percent were performed on women.

Medicare statistics also shed light on CABG surgery. In the United States, these figures show that in 1986, the overall national rate of CABG was 25.6 per one hundred thousand people. For Caucasians, the number was 27.1 per one hundred thousand, in contrast to a rate of 7.6 per one hundred thousand for African Americans.

Risk Factors for CABG in Women

When comparing men and women, several factors have been examined to determine the outcome after surgery. These include age; the presence of risk factors like diabetes, hypertension, and renal failure; body size as it relates to the size of the blood vessels (especially the coronary arteries); and race (Caucasian or non-Caucasian).

Age: Because women develop coronary artery disease later than men, women undergoing CABG are often older than men undergoing CABG. For example, although the average age of all patients enrolled in the STS Database remained remarkably constant from 1991 to 1995 (64.5 years), the age of the women in 1995 averaged 66.9 years and that of the men, 63.6 years.

Contributing Factors: When undergoing CABG, women are more likely than men to be diabetic or hypertensive or to have pre-existing kidney failure or be experiencing congestive heart failure. They are also statistically more likely to have advanced symptoms of coronary artery disease like severe angina, unstable or changing angina, or angina at rest.

These factors increase the risk of any type of treatment, especially coronary artery bypass surgery. Furthermore, women are more likely to have their operation on an urgent or emergency basis. All of these factors increase the chance of having a poor outcome after CABG.

On the other hand, women undergoing surgery typically have had fewer previous heart attacks and have fewer diseased arteries than do men.

Body Size and Diameter of Coronary Arteries: It has often been said that women have worse outcomes after coronary intervention because they are smaller and their arteries are harder to work with. However, there has been no proven relation between size of the arteries and success in surgery.

Risk Factors for CABG in Non-Caucasians

Although the risk profiles for Caucasians and non-Caucasians have not been examined as thoroughly as those of men and women, the STS Database shows clear differences between the two racial groups.

Age: We found that non-Caucasian patients having CABG are somewhat younger (age sixty-two years) than Caucasian patients (almost age sixty-five years).

Severity of Cardiac Disease: Fewer non-Caucasian patients have had previous cardiac operations, although statistically significantly more have severe symptoms that result in urgent or emergency operations. There are no differences in the number and type of diseased arteries in Caucasian and non-Caucasian patients.

Contributing Factors: Non-Caucasian patients have a greater chance of having diabetes and kidney failure than Caucasian patients. However, they are much less likely to have emphysema.

The Operation

Preparing for Surgery

For all patients, every attempt should be made to stabilize symptoms and decrease the work load on the heart. In women and non-Caucasians, who are more likely to have severe and unstable symptoms, this may mean early hospital admission or even time in an intensive care unit.

In women, a class of drugs called calcium channel blockers may also be useful because they

Table 8.1: Characteristics of women and non-caucasian patients undergoing CABG*

Preoperative	Postoperative	Procedural
More renal (kidney) failure	More strokes	Less elective surgery
More diabetes	Longer time on ventilator	Less use of LIMA
More hypertension	More kidney failure	
More serious symptoms	More dialysis	
	Higher 30-day mortality	

*All differences are statistically significant.

have been shown to decrease arterial spasm, a condition that occurs more commonly in female patients.

It is crucial that patients in high-risk categories attempt to lower their operative risk. The lowest priority is an elective operation for which the patient is admitted on the same day of their surgery. An urgent operation is one that is performed on an inpatient basis and within twenty-four hours of a heart catheterization.

The highest-risk operation, and that of the highest priority, is an emergency operation — the patient must go immediately from the catheterization laboratory to the operating room. Caucasian men are more likely to have elective CABG than any other patients.

Choice of Grafts for the Bypasses

It is more often a problem to find good conduits (arteries and veins used as bypass grafts) in women needing CABG because they are more often obese and diabetic and more likely to have varicose veins (or even to already have had their leg veins removed or stripped), and more often have serious arterial blockages in their legs (poor circulation).

Despite this, fewer women have the left internal mammary artery (LIMA) used as a bypass graft during their surgery. Since the LIMA has profound influence on long-term health and has been associated with lower mortality in some studies, attempts should be made to use this vessel as a bypass graft when feasible.

In the past, it was often said that using the LIMA is technically difficult and takes longer, so women and elderly patients (who more often have an emergency operation) usually receive leg vein grafts. These issues are less relevant today because all competent surgeons can rapidly harvest the LIMA (remove it from the chest wall) and because anesthetic techniques have been improved to the degree that almost all patients can be stabilized.

Use of the LIMA has increased dramatically over the previous decade, and the LIMA is currently used in more than 80 percent of CABG operations. Still, a substantial difference persists in its use in men and women and in Caucasian and non-Caucasian patients.

Results of CABG

Operative Mortality

Because of all the involved issues, it is not surprising that overall risks of death in women are somewhat higher than in men. In studies published in the late 1970s and early 1980s, this difference became evident. More recent reports have noted similar results.

In the Coronary Artery Surgery Study of more than eight thousand patients, mortality was 5.3 percent for women, compared with 2.5 percent for men. Moreover, even though mortality has fallen in both genders because of improvements in equipment and techniques, for the almost five hundred thousand patients in the STS Database, the mortality was 4.5

Women and Coronary Disease

THE MOST IMPORTANT thing to know about women and coronary artery disease (CAD) is that CAD is the number one killer of women in the United States.

About half of the patients who suffer from heart attacks each year are women. Thus, one should be just as suspicious of coronary artery disease in a woman as in a man. About five hundred thousand women in the United States die each year from all forms of cardiovascular disease. Almost twice as many women die in the United States from cardiovascular disease as from all forms of cancer.

The incidence of CAD increases after menopause. It's felt this is because patients are not only older, but also because of a lack of estrogen (a female hormone) that gives some protection against atherosclerotic disease.

With estrogen replacement therapy, atherosclerotic disease probably increases at a slower rate.

percent for women and 2.76 percent for men. At the same time, the mortality was 3.9 percent for non-Caucasian patients and 3.3 percent for Caucasian patients.

Complications of CABG

Both female and non-Caucasian patients have a significantly greater likelihood of having a stroke or kidney failure after surgery. Women have a greater chance of being treated with a respirator longer than men, despite having a lower incidence of emphysema before surgery. There are almost no differences in the rate of bleeding complications and serious chest infections between the gender and racial groups.

Postoperative Estrogen in Women Patients

Women undergoing CABG are likely to be postmenopausal because coronary artery disease is more prevalent in postmenopausal women (young diabetic women are the exception). Many studies suggest that women at high risk for coronary artery disease or those who already have the disease will benefit from estrogen therapy. This group includes women who have undergone CABG or angioplasty.

Hormone therapy is a secondary intervention (as opposed to a primary intervention, in which hormones are used to prevent coronary artery disease). There are seven published studies showing that hormone therapy results in a lower rate of death or complications in women who already have coronary artery disease. One study of 1,091 women, 92 of whom took estrogen after surgery, showed that survival at five and ten years was statistically significantly better in the group who took the hormones.

Another large study is currently testing these results, but, in the meantime, physicians should strongly consider treating all of their postmenopausal CABG patients with estrogen unless they are at very high risk for breast or uterine cancer.

Conclusions

Even though the risk may be higher for women and non-Caucasian patients, their long-term benefit from CABG is excellent, and they are likely to experience years of event-free survival (no heart attacks, death, angioplasty, or repeated hospitalization). Women with known or suspected coronary artery disease should discuss CABG with their physicians because the benefit of this powerful intervention outweighs the risk of the surgery for many.