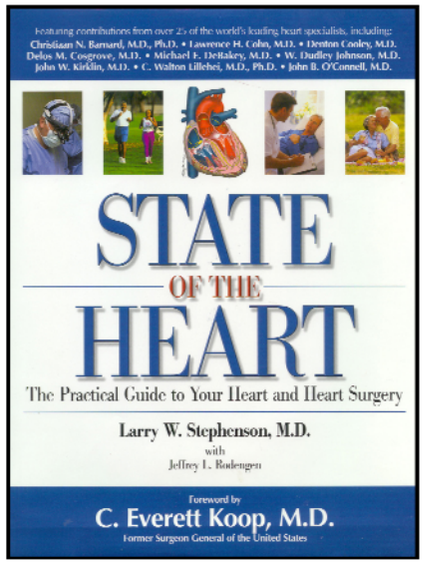

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Bypass surgery typically takes about three to five hours. After surgery, most patients remain in the hospital for four to seven days.

CHAPTER NINE

The Coronary Bypass: Operation and Recovery

THE CORONARY ARTERY BYPASS graft procedure is still the gold standard for patients suffering from left main or multiple coronary artery disease. The final determination that a coronary artery bypass graft operation is necessary is usually obtained from cardiac catheterization using coronary angiography. If the degree of blockage warrants surgery, a standard **battery of tests** is performed before surgery. These tests can be done on an outpatient basis and typically include an electrocardiogram, routine blood work studies, chest x-rays, and urinalysis.

In addition, the blood is typed (found to be type A, B, AB, or O, for example) and cross-matched with donor blood. In some centers, the patient's blood type is determined, but it is not cross-matched against a donor unit of blood in the hospital blood bank because there is about an 80 percent chance that a blood transfusion won't be needed. By avoiding the cross-match, a certain amount of work and expense is avoided. If blood is needed, it can be cross-matched relatively quickly. In other centers, blood for transfusion is actually cross-matched and available. The cross-matching issue depends on the preference of the surgeon and surgical team.

When I first became involved with heart surgery as a medical student more than thirty years ago, patients were routinely admitted for elective heart surgery about a week before the operation, and many, many tests were performed. By the time I became a faculty member at the Hospital of the University of Pennsylvania in 1978, patients were routinely admitted to the hospital one and a half days before heart surgery. Over the next several years, that policy gradually changed; patients were brought in the afternoon of the day before their heart surgery. In the past five years, this has changed further, and now more than two-thirds of the patients undergoing elective heart surgery in the United States are admitted to the hospital on the morning of their heart operation.

Although I would not have believed this was possible twenty years ago, it seems to work well, and there doesn't appear to be any adverse effect from the "admit the morning of the surgery" policy. As a matter of fact, I think if I were to undergo an elective heart operation, I would rather sleep at home in my own bed the night before the operation.

Battery of Tests: Includes blood pressure measurement, which is a common and important tool for diagnosing cardiovascular disease.

Surgeons viewing a patient's x-ray. The PA, or frontal view, is on the left, and the lateral, or side view of the patient's chest, is on the right.

However, not everyone comes in during the morning of their heart surgery. Some patients are already in the hospital for conditions related to their heart disease or have to be admitted a day or two before their heart surgery because of various pre-existing medical conditions that may need some special attention or "fine tuning" before the heart surgery.

The Choice of Conduits for Coronary Artery Bypass Grafting

During a bypass operation, the surgical team will need to "harvest" a vein or artery from elsewhere in the body to use as a graft. The most commonly used vein is the saphenous vein, which is taken from the leg. This is a superficial vein that runs from the groin to the ankle area and can be seen under the skin in many people when they stand up. It is one of the veins in the leg that may dilate over time and become varicose. In fact, not only is it a vein you can do without, but it can be a nuisance vein.

Although the saphenous vein is generally a good-quality blood vessel and can reach any coronary arteries, there is about a 3 percent to 4 percent chance per year that it will become narrow or totally blocked. Thus, the long-term patency rate (or chance of the vein staying open) is not as good as that of some other conduits.

Another very commonly used vessel is the left internal mammary artery, which is also called the internal thoracic artery (Fig. 9.1). Using an internal mammary artery is a slightly different approach because one end of it is usually left connected to a branch of the aorta. There are two internal mammary arteries: One runs under the breastbone on the right side; the other runs on the left side. The left one can usually reach the left anterior descending coronary, which generally is the most important coronary artery for bypass. It also has an excellent patency rate — there is about a 90 percent chance it will be open twenty years later.

Sometimes its size is a disadvantage. It may only be a millimeter or less in diameter (there are about twenty-five millimeters in an inch), which is smaller than the coronary artery being bypassed, and sometimes the blood flow through it is inadequate. Occasionally, the internal mammary artery will not reach the point on the coronary that it needs to access. That obstacle can frequently be overcome by disconnecting the "upstream" end and sewing one end to the coronary and one to the aorta or another artery.

The right internal mammary is also frequently used to bypass blockages in the coronary arteries. This artery usually reaches the right coronary, the left anterior descending and some branches of the circumflex. If it does not, the approach is generally the same. The upstream end of the artery is disconnected, and one end is sewn on the coronary artery and the other is attached to the aorta or to another bypass graft.

Another artery used for a bypass operation is the radial artery, which is located in the arm. Although some surgeons were using this artery for coronary

bypass twenty-five years ago, recently it has become popular again. There is a single main artery in the upper arm called the brachial artery, which divides into two main branches near the elbow. One branch, the radial artery, runs along the inner forearm toward the thumb. The other branch, the ulnar artery, runs along the outer edge heading toward the little finger. These two arteries reconnect in the hand through an artery called the palmar arch artery. If the palmar arch is intact, it is possible to take a portion of the radial artery for a bypass graft. The reported results with radial arteries so far indicate that the vessel graft has a greater chance of staying open longer than saphenous vein grafts but not quite as long as the left internal mammary artery.

Doctors sometimes use an abdominal vessel called the gastroepiploic artery as the bypass graft. To use this artery, the abdomen must be opened. When using this artery, one end of it can be left attached to the stomach while the other end is threaded through a hole in the diaphragm, or breathing muscle, and joined to the appropriate coronary artery. The gastroepiploic artery can also be used as a free graft when both ends are disconnected. In this case, the other end is sewn to the aorta or another coronary bypass graft. The gastroepiploic artery graft seems to have a better patency rate than the saphenous vein graft but a somewhat poorer patency rate than the left internal mammary artery. The disadvantage of using this artery is that the surgeon has to make a second major incision to open the abdomen and devascularize (take part of the blood supply of) a portion of the stomach.

Over the years, doctors have found that using veins from the arms for coronary bypass grafting generally results in

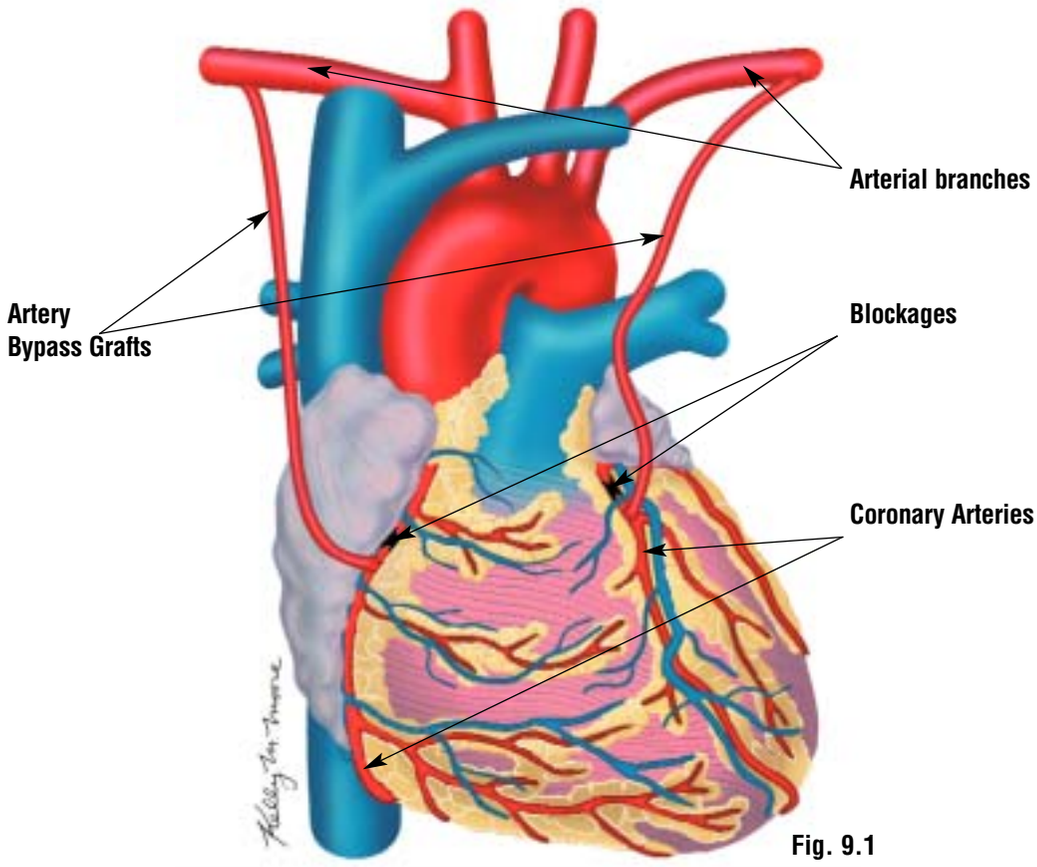


Fig. 9.1

Fig. 9.1: In a coronary bypass operation using the internal mammary arteries, one end of the vessel is left connected to a branch of the aorta, or it can be reconnected to another artery. The other end is sewn into the coronary artery beyond the blockage. This graft vessel has excellent long-term results.

poor patency rates; therefore, in most cases, they are not used unless there is no other choice. In certain other cases, veins from a human cadaver have been used, but, again, the patency rates are not very good. This may be because of a rejection process that occurs from using tissue from another human. Synthetic arteries made of Dacron or other material have also been used. These grafts generally work quite well in other areas of the body, particularly in the larger arteries and the aorta, but the patency rates for coronary artery grafting have not been very good, and these synthetic arteries are not routinely used.

The Heart Operation

We usually instruct our patients not to eat or drink anything after midnight the night before surgery. When they arrive at the hospital for surgery, patients generally report to the preoperative holding area, which is near the operating rooms. Some intravenous catheters are inserted through the skin, and a sedative is administered. At many heart centers, a local anesthetic is injected into the skin of the neck, and a larger catheter is introduced into the jugular vein and threaded through the right side of the heart into the pulmonary artery.

This catheter, called a **Swan-Ganz catheter**, can be used not only to give medicines but also to measure cardiac and pulmonary-arterial pressure and the amount of blood that the heart is pumping. Although many heart surgical teams routinely use the Swan-Ganz catheter, not all of them do. It depends on the preference of the surgeon, the anesthesiologist, and the heart surgery team.

While the patient is still in preoperative holding, another catheter is placed in one of the arteries so that the arterial blood pressure can be monitored and blood samples can be drawn to check the arterial blood's oxygenation level. This catheter is usually placed in one of the wrist arteries, often the radial artery. If a radial artery will be used for one of the bypasses, the other wrist can be used, or the catheter can be placed in the femoral artery by inserting it through the groin.

The patient is next moved into the operating room, and general anesthesia is induced.

Next, we place a plastic tube about as big as the index finger into the trachea (wind pipe). At some point, usually after the patient is anesthetized, a catheter is placed into the patient's bladder. The patient's chest and legs are swabbed with antiseptic soap solutions, and sterile operating drapes are placed on and around the patient. Now the team is ready to make the first incisions. Usually one surgical team will make one or more shallow incisions in the leg and harvest the vein for the bypass while the other team opens the chest.

To open the chest, an incision is made in the skin. The subcutaneous tissue is divided — this is a layer of fat usually a quarter- to a half-inch thick. In more obese people, however, it can be quite thick. Beneath that, a layer of muscle that is attached to the breastbone is cut through to expose the sternal bone. A saw is used to open the entire length of the sternum. Then a metal retractor is used to separate the sternal edges and hold the chest open.

With the chest open, I free up one or both internal mammary arteries and open the sac around the heart, or pericardium. A powerful anticoagulant, or blood thinner, called heparin is administered directly into the bloodstream to prevent the blood from clotting while the circulation is supported by the **heart-lung machine**. To hook a patient up to a heart-lung machine, stitches are placed so plastic tubes can connect the patient's circulation to the machine. A tube about the size of the index finger is placed into the ascending aorta about three inches above where the

Swan-Ganz Catheter: A catheter that is guided into the heart and the pulmonary artery, where it can be used to measure pressures in the heart and pulmonary artery, as well as take blood samples, administer intravenous drugs, and measure cardiac output.

Heart-Lung Machine: A machine used to bypass the function of the heart and lungs.

aorta comes out of the heart. This tube delivers oxygenated blood from the heart-lung machine to the patient.

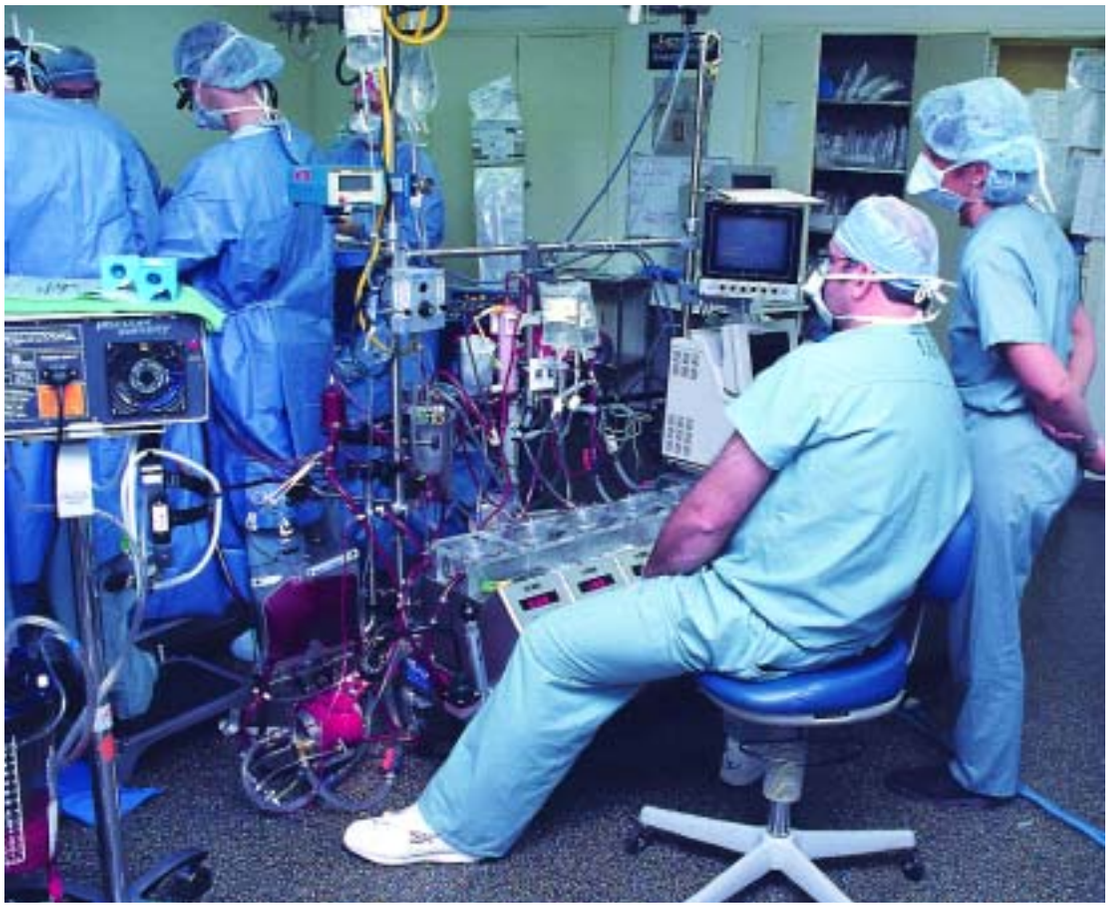
Another catheter is placed through the right atrium. Some doctors use a two-stage **cannula**, with one part going through the right atrium into the inferior vena cava and a second drainage system remaining in the right atrium. In other patients, two separate venous catheters are inserted into these same areas. This depends on whether additional heart surgical procedures might be done and also on the preference of the surgeon. The tube or tubes in the right atrium return unoxygenated blood from the patient's venous system to the heart-lung machine.

Frequently, an additional catheter is placed through the right atrium and manipulated into the coronary sinus. The coronary sinus is a vein that returns blood to the right atrium from the heart itself. This catheter is called a **retrograde coronary perfusion catheter** and is used to give part or all of the solution that will "turn off" the heart during the procedure.

After these catheters are in place, I will begin cardiopulmonary bypass by telling my technician or perfusionist running the heart-lung machine to turn on the machine with a command such as "on bypass." The heart-lung machine then takes over the function of the heart and lungs. After it is activated, most surgeons will cool the patient's body temperature to some level, but not all surgeons do this. There are advantages and disadvantages to cooling. The major advantage is that it adds an additional level of safety to the heart and the brain if some problem were to temporarily develop with the heart-lung machine.

Retrograde Coronary Perfusion Catheter:
A catheter that is inserted through the right atrium into the coronary sinus, a vein that drains the heart itself. This catheter is usually used to administer cardioplegia solution, which stops the heart from beating during surgery.

Cannula:
A hollow tube that is inserted into a blood vessel, the heart or other body cavity.



The heart-lung machine is a complex-looking machine that includes pumps with a blood oxygenator to simulate the action of the heart and lungs.

During surgery, heart surgeons wear full operating gowns and 2x or 4x magnifying glasses to help them see the very small coronary arteries and the bypass grafts.

Cardioplegia Solution: A solution that stops the heart from beating and reduces its oxygen consumption, thus allowing surgery to take place.

After the patient's circulation is supported by the heart-lung machine, most surgeons will "cross-clamp" the aorta by placing a clamp on the aorta between the heart and the catheter bringing oxygenated blood back from the heart-lung machine. This isolates the heart from the body's main artery. At this point, most surgeons administer a solution called a **cardioplegia solution**, which stops the heart from beating. This is frequently injected into the coronaries through the aorta and also through the retrograde coronary sinus catheter into the veins of the heart.

This stops the heart and cuts down on the oxygen consumption of the heart muscle, as does the cooling of the heart. Once again, not all surgeons use these techniques, but the vast majority do.

With the heart stopped and the body supported by the heart-lung machine, the coronary arteries that are to be bypassed are identified. I usually have a mental picture of exactly where I want to put the bypasses and know where the blockages are. Frequently, the last thing I do before scrubbing in, gowning up, and putting on sterile gloves is look again at the movies of the patient's coronary arteries. The images are individual frames from x-rays, which, when shown sequentially at high speed, look like a movie of blood flowing through these arteries. During surgery, most surgeons wear powerful magnifying glasses that increase the size of the relatively small coronary arteries at least two to four times. Some surgeons use a special type of microscope that magnifies the arteries even more.

I next isolate the obstructed coronaries, which tend to be on the surface of the heart. Sometimes they are hidden in a layer of fat on the heart and have to be located. Other times they're in the heart muscle. The coronary arteries are opened beyond the obstruction and measured. The internal diameters tend to be in the range of from one millimeter to two millimeters, which is about the size of a straw from a broom.

Placing the Graft

With the coronary opened beyond the area of obstruction, I am ready to place the bypass graft. To do this, I join one end of the vessel conduit to the coronary artery with small stitches usually made out of polypropylene. The needle itself is joined to the stitch, and if you hold the needle and suture in your hand, you may have to squint to see them because they are so small.

After all the bypasses, which can range from one up to eight or nine grafts (but

typically three or four), are sewn to the coronaries, the other ends are joined to the aorta or, in some cases, to other veins or arteries. If I've decided to use an internal mammary artery, one end is already connected to the arterial system.

The bypasses are now complete, and any air that might have gotten into the heart is removed, and the patient's body is rewarmed. The heart usually restarts on its own but sometimes needs the help of a temporary pacemaker or an electrical shock. It might have to be paced a while with a temporary pacemaker until its natural rhythm kicks in. Temporary pacing wires are usually connected to the heart and can be removed a few days after the surgery by pulling them out. Some surgeons choose to leave them in, cut them off at the skin level, and let them retract.

After the heart has started, our patient is weaned from the heart-lung machine by slowly turning the heart-lung machine off as the patient's own heart and lungs take over. In some cases, the heart is too weak to take over for whatever reason, and another attempt or two will be made at letting the heart take over. If these are unsuccessful, I may use an **intra-aortic balloon pump**, which is a pump that is threaded through an artery, usually through the groin, and connected to an external power source. There is a balloon on the tip of a long, thin tube that inflates and deflates in synchrony with the heart, helping the heart to pump blood as the patient gets through the early postoperative period.

In more severe cases when the heart does not take over, some form of ventricular assist device may have to be used. This is relatively uncommon. Most patients are weaned from bypass without the use of any type of mechanical support on the first attempt.

After I check the operative field to make sure that all bleeding has stopped, drainage tubes will be placed, and the sternum will be closed, usually with stainless steel wires that are left in permanently. The layers of the tissue are sewn together, and the skin on both the chest and the leg wound may be closed with sutures or metal staples. When stainless steel staples are used to close the skin, they are usually removed a week or two later, although the timing of the removal is the surgeon's preference and may depend on other pre-existing medical conditions.

The Postoperative Intensive Care Unit

Patients are not yet awake when they leave the operating room and are transferred to an intensive care unit. A portable monitoring system usually accompanies patients so the surgical team, while in transit, can continually read the electrocardiogram and the arterial blood pressure. After the patient arrives in the intensive care unit, various monitoring lines including an **ECG** are connected, and the patient slowly wakes up over the next hour or so. Today, we tend to remove the breathing tube from most patients

Electrocardiogram (ECG or EKG): A recording of your heart's electrical activity. At left, a patient is shown undergoing an ECG test.

Intra-Aortic Balloon Pump: A pump that is threaded into the aorta, usually through an artery in the groin, and connected to an external power source. There is a balloon on the tip of a catheter that inflates and deflates in synchrony with the heart, helping the heart to pump blood through the early postoperative period.

within the first several hours after the heart surgery. Sometimes, if the patient's breathing has not taken over sufficiently, it may be left in a little longer.

Most patients stay in the intensive care unit overnight and are discharged from intensive care to the step-down unit the next day. Being transferred from the intensive care unit to a step-down unit depends on a few factors. The patient must not need the ventilator. It may also depend on how well the heart and lungs are working, and sometimes it is also related to the surgical team's preference.

When the patient gets to the step-down unit (also referred to as the "floor" or "ward"), he is already drinking liquids and sometimes eating semisolid food. Within a day or two, the diet will rapidly progress to regular food. Patients also often walk up and down hallways, with some assistance, after a day or two on the ward. Discharge from the hospital can be as early as three days after the surgery but is usually about four days to a week after heart surgery, although this can be extended for various reasons. Interestingly, although everybody's pain threshold is different, the midline incision through the breastbone is not very painful. Most patients are sent home with only a mild pain medicine.

Bypass patients are often able to walk with assistance a day or two after surgery.

With routine coronary bypass operations, the chances of surviving the heart operation and walking out of the hospital are better than 99 percent.

Factors that can increase the risk of the surgery include the relative health of the left ventricle. If it's fairly normal, the risk of the surgery can be very low. If it's badly damaged from previous heart attacks, the risk could be greatly increased. Patients who are in the middle of having a major heart attack and/or in cardiogenic shock during the surgery are at increased risk. Other risk factors include lung disease and other important medical conditions, previous strokes, obesity, and additional heart surgery, like valve replacement, during coronary bypass surgery. Risk is also increased in patients who have had previous heart surgery and in the elderly, particularly in those more than eighty years old.

Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) Surgery

As medicine and surgery advance, newer techniques are constantly being developed. MIDCAB procedures are coronary artery bypass operations done without the aid of a heart-lung machine and that use novel devices and techniques. Coronary bypass surgery has been performed by some surgeons without the use of the heart-lung machine since the beginning, but the vast majority have used, and still use, the heart-lung machine.

New technology, however, has prompted many heart surgeons to take a long, hard look at performing coronary bypass grafts in selected patients without the use of the heart-lung machine.

Some surgeons now are performing surgery, particularly when only one or two bypasses are needed, through a small incision in either the left or right side of the chest, depending on where the bypass graft is to be placed. This is done without the use of the heart-lung machine. There are certain advantages to performing the surgery without the aid of the heart-lung machine, yet there are many advantages to performing heart surgery with the heart-lung machine. Nonetheless, these techniques are being evaluated at many centers around the world.

If everything goes well and the heart-lung machine is not used, you can have the breathing tube removed sooner after the surgery and may be able to go home a day or two earlier. Some of the surgeons doing the surgery without a heart-lung machine have used videoscopes with remote TV cameras to perform portions of the operation, such as freeing up the internal mammary artery. Some have used videoscopes with special instruments to join the coronary artery to the internal mammary artery. Some surgeons use the routine midline incision through the breastbone but then perform the coronary bypass procedure without the heart-lung machine. Again, there are advantages and disadvantages to doing this.

Not all patients undergoing heart surgery at this time are eligible for these MIDCAB procedures. At one center in California, where the surgeons are prepared to do this in any eligible patient, they have found that over the last three years about 6 percent of the coronary bypass surgeries have been done without the use of the heart-lung machine. In another center in New York that is well known for this type of coronary bypass surgery and has had a lot of self-referrals especially for this type of surgery, the percentage of cases done without the use of the heart-lung machine is about 16 percent of the total number of patients undergoing coronary bypass grafting.

Although the initial results with MIDCAB surgery have been positive, it is probably too early to tell whether the number of MIDCAB operations will continue to grow. After surgeons gain more experience, some may decide to go back to doing most or all of their cases with the aid of the heart-lung machine. Time will tell whether these efforts are worthwhile.

Complications from Coronary Bypass Surgery

There are complications that can occur during even "routine" coronary bypass surgery. A patient can have a heart attack during or shortly after the heart operation. It may be related to one of the bypass grafts clotting up or possibly to other events related to the heart surgery. The heart may fail even without a heart attack, requiring an intra-aortic balloon pump or mechanical assist device to be placed.

A patient may develop **respiratory insufficiency** or pneumonia and require prolonged stays including treatment with a respirator. Kidney failure may develop. This is more likely in people who have some degree of pre-existing kidney failure and in those with low cardiac output for prolonged periods. Wound infections are another risk with any major surgery. Fortunately, most patients undergoing coronary bypass surgery are at a very small risk, only a few percent, for any serious complications.

Respiratory Insufficiency: When the lungs are not functioning normally.

Less serious side effects are not so rare, however, and can range from the annoying to something that needs to be fixed with surgery. One of these is excessive blood loss from the chest drainage tubes, which can happen for a variety of reasons. To stop the blood loss, the patient has to be taken back to the operating room. This happens about 2 percent to 4 percent of the time.

Heart arrhythmias, or irregular heartbeats, are fairly common after heart surgery. Most are not serious and are more

Atrial Arrhythmias: Irregular heartbeat originating in the atrium.

Atrial Fibrillation: The atria no longer contract in synchrony with the heart but rather contract in a chaotic fashion so they no longer pump blood into the ventricles.

of a nuisance than anything else. About 20 percent to 30 percent of my patients develop **atrial arrhythmias**, sometimes **atrial fibrillation** or atrial flutter. Also, the ventricles may beat faster than normal. Again, these are usually not serious conditions but may require treatment with medicines. Sometimes, the heart even has to be shocked electrically back into a normal rhythm. The likelihood of these irregular rhythms decreases in the first few days after the surgery, and, by about a month after the surgery, most additional medicines prescribed to treat these abnormal heart rhythms can be discontinued.

Strokes during or after Coronary Artery Bypass Surgery

Patients may suffer a stroke during or shortly after heart surgery. The chances are about 1 percent in a person who has never had a stroke before but can be as high as 5 percent or 10 percent in patients who have had a previous stroke. Sometimes strokes can be very severe. The patient may be in a coma and never wake up after the surgery. Fortunately, most strokes are much less severe, and most patients who have a problem with their speech or a weakness in an arm or a leg either totally recover or recover to some degree.

Discharge often happens between four and seven days after coronary bypass graft surgery, although complete recovery will take up to three months in routine cases.

One of the causes of strokes is related to blockages in the arteries that deliver the oxygenated blood to the brain. The two major arteries are called the carotid arteries, and they can develop atherosclerotic disease just as the coronaries can.

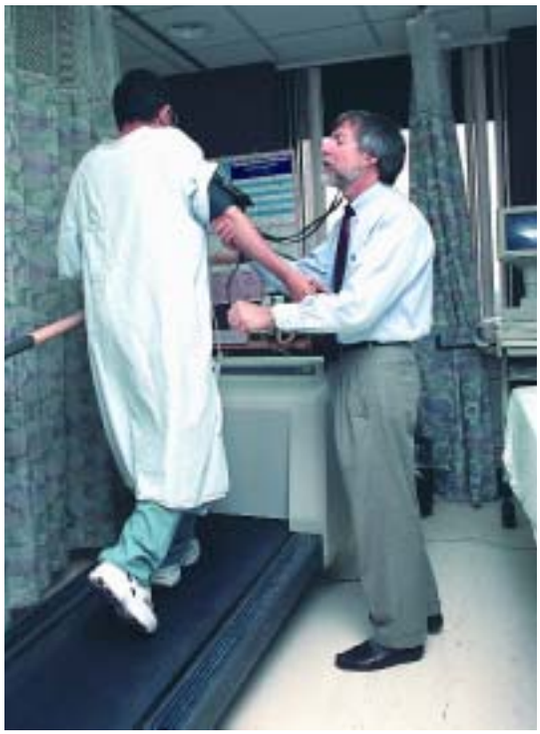
When both the coronary artery and the carotid artery blockages are severe, the surgeon will most likely treat both problems at the same time. On the other hand, if one of the two problems is less severe, surgeons tend to first operate on whichever problem is more severe. The preference for which operation to do first or whether to do both at the same time varies with surgeons, and there is a certain amount of information to support one approach versus the other in specific situations.

Discharge

When the patient is discharged from the hospital, depending on the circumstances, he may have a visiting nurse come to his house for a week or two. This depends on the surgical team's preference and the patient's condition.

If the patient goes home between three and five days after the surgery, he may need to come back to the hospital to get staples removed from the skin of the leg and chest, or a visiting nurse can remove the staples at home.

In most cases, the patient's cardiologist, who has referred the patient to the heart surgical team, will see the patient within the first few weeks or so after heart surgery and may readjust prescription medications. The heart surgeon will



usually see the patient three to six weeks after surgery. If the patient is doing well, the patient will usually be transferred back to the care of the cardiologist or internist at that time.

From a surgical standpoint, the only medicine that I routinely recommend is an aspirin a day. Some physicians choose a baby aspirin, and others choose a regular aspirin. Aspirin probably helps keep the coronary bypass grafts open longer, but this has not been proven conclusively. Because aspirin is relatively benign, however, it's worth the effort.

When the patient is discharged from the hospital, the biggest restriction is that the patient should not lift anything heavier than about twenty pounds for the first couple of months while the breastbone is healing. After three months, the patient can generally resume vigorous activity. This could even mean playing professional sports such as ice hockey or other strenuous contact sports. Before attempting any type of vigorous activity after heart surgery, however, you must first clear it with your cardiologist.

Although patients gain confidence while walking around the hospital ward, once they return home, my patients often realize they're weaker than they think they are. However, they are usually still able to go outside for brief walks. Within a month, most patients are able to walk a mile or two. If the weather is bad or unusually cold, patients often choose to walk inside a shopping mall. Some cardiologists prefer to enroll all of their patients in cardiac rehabilitation programs, whereas others only enroll some, particularly those who get little exercise.

The Postoperative Exercise Stress Test

Three weeks to two months after the surgery, the cardiologist may prescribe an **exercise stress test.** Some cardiologists order an exercise stress test for all of their patients who have recently undergone coronary artery bypass surgery, whereas other cardiologists are more selective. These cardiologists do stress testing of patients with unusual symptoms, those who are going to do vigorous exercise such as jogging and playing tennis, or people who have jobs that require extra caution, such as commercial airline pilots. If the exercise test result is normal, most cardiologists allow the patient to go back to any type of normal vigorous activity.

Exercise Stress Test: A test in which patients are connected to an electrocardiogram machine. They are usually asked to walk on a treadmill or possibly pedal a stationary bicycle while their electrocardiogram, blood pressure, and sometimes other vital signs are being monitored.

Common Postoperative Complaints

I hear several common complaints when I see patients four or five weeks after coronary bypass surgery. One is poor appetite. In virtually all patients, this improves anywhere from three weeks to two months after the surgery, and in most cases, they will regain weight to their presurgery level. If, on the other hand, they are overweight, they may prefer not to get back to that level, and diet counseling is

normally done not only in the hospital but by the patient's own cardiologist. This also applies to special diets recommended by a cardiologist.

Another complaint I frequently hear three to five weeks after the surgery is trouble sleeping. I'm not sure why many of my patients have unusual problems with not being able to sleep. It may be that during heart surgery or time in the intensive care unit, the clock in the patient's brain, or circadian rhythm, gets reset, and it may take awhile to revert to a normal routine. Most patients return to their normal sleep patterns five to seven weeks after surgery.

My patients sometimes complain about night sweats. This problem usually resolves itself, although occasionally night sweats can indicate a serious problem, particularly if they are associated with high fevers. In most patients, however, it is a side effect that seems to be unique to either the heart surgery or a major operation. The condition gets better in a month or two.

Numbness is another complaint, particularly if it is located in the left chest area or left breast in women. It seems to be more common in patients in whom the left internal mammary artery was used for a bypass graft. Some patients notice some numbness along the vein harvest site in the leg, particularly around the ankle area. This can be related to damage to the small branches of the nerve that intertwine with the saphenous vein. These problems usually subside over a couple of months.

Some patients have numbness or tingling in their little finger and the finger or two next to it, either in one or both hands. This common complaint is thought to be related to the fact that when the chest retractor is opened, it stretches the ulnar nerve as it comes out of the spinal cord, loops over the first rib, and goes into the arm. This problem, when it occurs, almost always subsides, sometimes taking five or six weeks or longer.

Occasionally, patients say their eyeglasses are a bit out of focus. This seems to be a problem that is not specific to heart surgery but occurs following all types of major surgery. I am unclear why this occurs, but ophthalmologists usually say patients should wait a couple of months after a major operation before getting their eyeglass prescriptions changed because their visual acuity tends to return to what it was before the surgery.

Over the years, I have also noticed patients may come in for their heart surgery taking a certain antihypertensive (blood pressure) medication, and go home taking less of that medicine or none. A month later, however, they need that medicine again and don't know why they were not sent home taking it. While patients are in the hospital, particularly while in bed for two to four days, the tone in their blood vessels tends to relax somewhat. When they are up and around again, the tone may not return as quickly, and their blood pressure may be a little lower than it was before the heart surgery. This explains why they may not need the antihypertensive medicines they previously took. However, after about a month or six weeks, when the blood vessel tone returns, they often need to take the same blood pressure medication they took before the surgery.

Patients with diabetes often go home with different insulin requirements than they had before the heart surgery. Sometimes diabetic patients who were not taking insulin go home taking insulin, and sometimes those that are taking insulin, particularly lower doses, will go home and not need insulin. In general, I find that after five to seven weeks, patients tend to require whatever dose of oral antihyperglycemics or insulin they had been taking before the heart surgery.

My patients frequently tell me that when they lie on their side, particular-

ly their left side, they notice their heart beating more than they did preoperatively, and they think perhaps this is dangerous. This is a common complaint and is generally caused by adhesions that have formed around the heart in the healing process. They are feeling the tug of these adhesions as the heart beats. Over time, however, the adhesions stretch, and most patients become used to it and no longer notice it.

Some patients notice a lump at the top of their breastbone that wasn't there before the surgery. If the lump is red and tender, it could signal an infection, but usually the lump appears because there is a layer of fat under the skin that does not hold stitches too well, and the consistency of this fat is somewhat like cottage cheese. To get stitches to hold, we have to place them deeper into the tissue, which tends to wad the tissue up around the stitch. Also, we place deeper stitches because the skin along the middle of the breastbone tends to pull away toward the arms. Over time, the lump will usually even out and return to normal.

Fortunately, over the last ten years, we have seen a decrease in the death rate from coronary artery disease in the United States. This is probably due to a number of factors, including better education of the general public, particularly about diet, cigarette smoking, and, in some cases, changes in life style.

This decrease is probably also due to relentless campaigns by the American Heart Association, the National Institutes of Health, and other groups, including national medical and surgical societies that deal with heart disease. They not only educate the public but also fund research in these areas. We also have better medications, and, certainly, the invasive cardiology field has come a long way, including the use of balloon dilatation and stents to treat various forms of blockages in the coronary arteries. Despite all of this, it appears that coronary artery bypass graft surgery will be around for the foreseeable future and continue to play a major role in the treatment of patients with advanced forms of coronary artery disease.

Strokes, Carotid Artery Disease, and Coronary Bypass Surgery

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THE MOST DREADED COMplication of coronary artery bypass grafting, other than death, is the occurrence of stroke during the surgery. Unfortunately, as the average age of patients having bypass surgery has risen during the past twenty years, so has the chance of having a stroke. For patients less than age fifty years, the risk of stroke after coronary artery bypass grafting is less than 1 percent; for those patients more than age eighty years, the risk approaches 8 percent to 10 percent.

The causes of a stroke during surgery are many, but they can be grouped under three general headings.

Problems with Blood Flow to the Brain

Although cardiopulmonary bypass with the heart-lung machine rarely causes poor blood flow to the brain, certain unusual circumstances can occur.

Each time the left ventricle contracts, it ejects blood from the

heart and causes a pulse in the arteries throughout the body. The brain, however, is sensitive to the loss of regular pulse, and the heart-lung machine provides a more continuous flow than the normal pulsing flow from the heart. Because there is a lack of pulsation, it is particularly important that an adequate blood pressure be maintained when the patient is receiving assistance from the heart-lung machine to ensure the brain gets enough blood. Partial or complete obstruction of one or both carotid arteries, which supply blood to the brain, can lead to compromised blood flow to the brain while the heart-lung machine is working.

Bleeding into the Brain

One of the startling and very fortunate findings in heart surgery is that, despite the high doses of very potent blood thinners (anticoagulants) required when the heart-lung machine is used for coronary artery bypass grafting, bleeding into the brain is extremely rare. In fact, it almost never occurs during the operation and thus can be discounted as a cause of stroke during the operation.

Embolus to the Brain

An abnormal clump of material traveling through the blood vessels is called an embolus. The possible sources of material traveling to the brain include blood clots from inside the heart, debris from plaque in the aorta or the carotid arteries, and

particles of material or air from the heart-lung machine.

Surgeons have recently focused their attention on atherosclerosis in the aorta and in the carotid arteries.

Physicians currently have numerous strategies to deal with atherosclerosis when it occurs in the aorta near the heart. This area is of great importance to the surgeon because it is where the blood-return tubes from the heart-lung machine are usually inserted, where coronary bypass grafts may be sewn, and where other clamps and tubes may need to be placed to protect the heart muscle during the operation.

Atherosclerosis in the Carotid Arteries

In the carotid arteries, the accumulation of atherosclerotic plaque is unfortunately quite common in older patients. When more than half of the carotid artery is obstructed with atherosclerotic material, the risk of stroke begins to climb.

In patients with at least 60 percent obstruction of their carotid artery, a carotid endarterectomy, or surgical clearing of the artery, yields much greater freedom from subsequent strokes than continued medical therapy. A carotid endarterectomy is performed through an incision in the neck. During the procedure, the atherosclerotic accumulation can be removed directly and the artery incision closed.

The subsequent freedom from strokes is obtained not only by patients who have symptoms from their carotid obstructions but also by those who do not have symptoms from them. Thus, the mere presence of a substantial carotid artery blockage can justify a carotid endarterectomy even if the patient does not have symptoms. Unfortunately, the first symptom of advancing carotid artery blockage may be a full stroke.

Carotid and Coronary Artery Disease

Patients who have substantial carotid artery disease in addition to coronary artery disease are at a much higher risk of stroke during coronary artery bypass grafting if nothing is done to correct the carotid artery disease.

The issue for surgeons in the last several years has been timing the two operations (carotid endarterectomy and coronary artery bypass graft) when a patient has both forms of artery disease. Several approaches have been tried, including performing one of the operations first, followed by the other. In some situations, this may seem to be an acceptable choice, particularly if the disease in one of the arterial systems is very severe and that in the other system is not.

However, recent surgical research has indicated that for the majority of patients with severe disease in both arterial systems, a combined operation is probably the best approach. During such an operation, the blocked coronary arteries are bypassed, and the diseased carotid artery is treated. This approach in our institution and other surgical centers has yielded lower operative death and stroke rates while providing better long-term relief from stroke. One study has demonstrated that doing the two procedures after the same anesthesia induction rather than as separate operations is much more cost effective.

In summary, evidence is accumulating that patients with severe disease in both their coronary and carotid arteries are generally better treated with a combined operation. Continuing studies are being performed that will test whether this combined approach is more effective than the staged approach in all surgical centers. The goal remains lowering the incidence of stroke during surgery, still the most devastating nonfatal complication of coronary artery bypass surgery.

Minimally Invasive Coronary Artery Revascularization

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One of the major causes of surgical trauma is the method of entry into the body. Large incisions tend to result in greater trauma, whereas the pain and some complications associated with surgery can possibly be lessened if the physician gains entry through a smaller incision. This approach has led to the concept of "less invasive surgery," a relatively new method of surgery that is accomplished through a few small "keyhole" incisions using a video camera attached to a telescope.

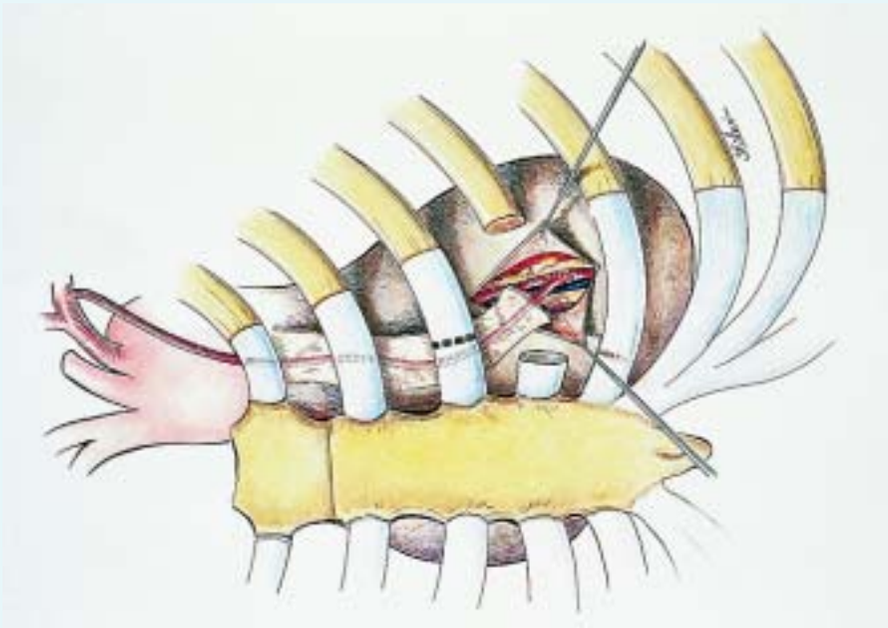
Because of the unique complexities of heart surgery — including the necessity of the heart-lung machine, operating on a moving organ, and the need to sew tiny blood vessels together — cardiac surgery was the last surgical specialty to adopt these new concepts. Starting in 1995, however, a few surgeons began performing coronary artery bypass grafting (CABG) through a three-inch incision between the ribs on the left side of the breast bone. The procedure was performed on a

beating heart rather than on a stopped heart, and the minimally invasive direct coronary artery bypass (MIDCAB), or "keyhole" form of cardiac surgery, was born. The "direct" in the acronym means that although the bypass was performed through a small incision, it was done while viewing the heart directly rather than with a scope.

This form of surgery has two benefits for postoperative recovery: Patients do not undergo as much discomfort as a large incision would cause, and the heart-lung machine, which can contribute to the undesirable side effects of heart surgery, is not used.

At first, the MIDCAB operation was basically limited to a single bypass on the front surface of the heart and, because the heart was still moving, the connection of the bypass was technically challenging, and the results of the procedure were appropriately questioned. This issue was largely solved by the introduction of "stabilizers," which are mechanical feet placed against the surface of the heart. This produces a local area of immobilization and allows for precise sewing while the remainder of the heart continues to beat and support the circulation.

In 1995, the Port-Access™ device was introduced by Heartport, Inc., of Redwood, California. This device allows the surgeon access to the heart through a smaller incision while still using the heart-lung machine. It allows not only CABG operations but also surgery on the mitral valve inside the heart. Both are performed through a



New surgical techniques are allowing surgeons to access the heart through much smaller incisions on the side of the chest. Commonly called "keyhole" surgery, this is possible for a number of different heart operations.

three-inch incision on either the left (CABG) or right (mitral valve) side of the sternum. In addition to the ability to use the heart-lung machine without opening the chest, this procedure offers the ability to safely stop the heart with a balloon catheter placed in the aorta just above the heart.

In 1998, there were about forty-five thousand beating-heart operations performed in the United States (7 percent of all CABGs) and four thousand Port-Access procedures. Findings being published in early 1999 in the medical literature give some early indication that acceptable results may be obtained by these new approaches.

Currently, most of the focus in the field of minimally invasive cardiac surgery is on the off-pump coronary artery bypass (OPCAB) procedure. In the OPCAB operation, multiple coronary arteries can be bypassed. Although the breastbone is still divided, the heart-lung machine is not utilized, and newer generation stabilizers are used to immobilize each artery to be bypassed in turn while the heart continues to beat. Many experts in the field predict that within five years, more than 50 percent of all CABG surgery will be performed by using this approach.

The field of minimally invasive cardiac surgery is less than four years old, and the early results are promising. However, the results have not yet withstood the test of time. Accurate measurement of its role in managing heart disease will require further comparison, not only with conventional bypass surgery, but also with the "least invasive" form of coronary bypass, percutaneous transluminal coronary angioplasty (PTCA).