Overview of Coronary Artery Disease

Coronary artery disease is a condition in which the blood supply to the heart muscle is partially or completely blocked.

The heart muscle needs a constant supply of oxygen-rich blood. The coronary arteries, which branch off the aorta just after it leaves the heart, deliver this blood. Coronary artery disease can block blood flow, causing chest pain (angina) or a heart attack (also called myocardial infarction, or MI).

Coronary artery disease was once widely thought to be a man's disease. On average, men develop it about 10 years earlier than women because, until menopause, women are protected by high levels of estrogen. However, after menopause, coronary artery disease becomes more common among women. Among people aged 75 and older, a higher proportion of women have the disease, because women live longer.

In developed countries, coronary artery disease is the leading cause of death in both men and women. Coronary artery disease, specifically coronary atherosclerosis (literally "hardening of the arteries," which involves fatty deposits in the artery walls and may progress to narrowing and even blockage of blood flow in the artery), occurs in about 5 to 9% (depending on sex and race) of people aged 20 and older. The death rate increases with age and overall is higher for men than for women, particularly between the ages of 35 and 55. After age 55, the death rate for men declines, and the rate for women continues to climb. After age 70 to 75, the death rate for women exceeds that for men who are the same age.

Coronary artery disease affects people of all races, but the incidence is extremely high among blacks and Southeast Asians. The death rate is higher for black men than for white men until age 60 and is higher for black women than for white women until age 75.

Causes

Coronary artery disease is almost always due to the gradual buildup of cholesterol and other fatty materials (called atheromas or atherosclerotic plaques) in the wall of a coronary artery. This process is called atherosclerosis (see Atherosclerosis) and can affect many arteries, not just those of the heart.

Occasionally, however, coronary artery disease is caused by spasm of a coronary artery, which can occur spontaneously, or from use of certain drugs such as cocaine and nicotine. Rarely, the cause is a birth defect, a viral infection (such as Kawasaki disease), systemic lupus erythematosus (lupus), inflammation of the arteries (arteritis), a blood clot that traveled from a heart chamber into one of the coronary arteries, or physical damage (from an injury or radiation therapy).

As an atheroma grows, it may bulge into the artery, narrowing the interior (lumen) of the artery and partially blocking blood flow. With time, calcium accumulates in the atheroma. As an atheroma blocks more and more of a coronary artery, the supply of oxygen-rich blood to the heart muscle (myocardium) can become inadequate. The blood supply is more likely to be inadequate during exertion, when the heart muscle requires more blood. An inadequate blood supply to the heart muscle (from any cause) is called myocardial ischemia. If the heart does not receive enough blood, it can no longer contract and pump blood normally.

An atheroma, even one that is not blocking very much blood flow, may rupture suddenly. The rupture of an atheroma often triggers the formation of a blood clot (thrombus). The clot further narrows or completely blocks the artery, causing acute myocardial ischemia. The consequences of this acute ischemia are referred to as acute coronary syndromes (see Coronary Artery Disease: Acute Coronary Syndromes (Heart Attack: Myocardial Infarction: Unstable Angina)). These syndromes include unstable angina and several types of heart attack, depending on the location and degree of the blockage. In a heart attack, the area of the heart muscle supplied by the blocked artery dies.

Sometimes an acute coronary syndrome is caused by coronary artery spasm or another type of coronary artery disease.

Risk Factors

Some factors that affect whether a person develops coronary artery disease cannot be modified. They include

- Advancing age
- Male sex
- Family history of early coronary artery disease (that is, having a close relative who developed the disease before age 50 to 55)

Other risk factors for coronary artery disease can be modified or treated. These factors include

- High blood levels of low-density lipoprotein (LDL) cholesterol
- High blood levels of lipoprotein a
- Low blood levels of high-density lipoprotein (HDL) cholesterol
- Diabetes mellitus
- Smoking
- High blood pressure
- Obesity
- Physical inactivity
- Dietary factors

Smoking more than doubles the risk of developing coronary artery disease and having a heart attack. Secondhand smoke appears also to increase risk.

Dietary risk factors include a diet that is low in fiber, vitamins C and E, and phytochemicals (which are present in fruits and vegetables and are thought to promote health). For some people, a diet low in fish oils (omega-3 polyunsaturated fatty acids) increases risk.

Having one or two drinks of alcohol a day appears to slightly reduce the risk of coronary artery disease (while slightly increasing that of stroke). However, having more than two...
drinks a day increases the risk, and the larger the amount, the greater the risk.

Certain metabolic disorders, such as hypothyroidism, hyperhomocysteinemia, and a high level of apoprotein B (apo B), also are risk factors.

Whether infection with certain organisms contributes to the development of coronary artery disease is uncertain. The organisms suspected include Chlamydia pneumoniae (which can cause pneumonia), Helicobacter pylori (which can contribute to stomach ulcers), and a virus (as yet unidentified). One example of the relationship between infection and premature coronary artery disease is the finding that people who have poor dental health, particularly periodontal disease (infection of the gums), appear somewhat more likely to have a heart attack. Nonetheless, inflammation, whether caused by infection or not, appears to contribute to the development of acute coronary syndromes. If an atheroma becomes inflamed, it softens and is more likely to rupture, and blood clots are more likely to form.

**Prevention**

Modifying risk factors can help prevent coronary artery disease. Some of these factors are interrelated, so that modifying one also modifies another.

**Smoking:** Quitting smoking is most important. People who quit smoking decrease their risk of developing coronary artery disease by half compared with those who continue to smoke. How long people smoked before quitting does not matter. Quitting also decreases the risk of death after coronary artery bypass surgery or after a heart attack. Avoiding secondhand smoke is also important.

**Diet:** Limiting the amount of fat to no more than 25 to 35% of daily calories is recommended to promote good health. However, some experts believe that fat must be limited to 10% of daily calories to reduce the risk of coronary artery disease. A low-fat diet also helps lower high total and LDL (the bad) cholesterol levels, another risk factor for coronary artery disease. The type of fat consumed is as important as the amount of fat. Thus, eating oily fish, such as salmon, which are high in omega-3 fats (good fats), regularly and strictly avoiding the more harmful trans fats are recommended. Trans fats are being removed from ingredients in many fast food sites and restaurants.

Eating at least five servings of fruits and vegetables daily can decrease the risk of coronary artery disease. Such foods contain many phytochemicals. Whether the phytochemicals are responsible for the risk reduction is unclear because people who consume such diets also tend to eat less fat, more fiber, and more foods containing vitamins C and E. One group of phytochemicals called flavonoids (found in red and purple grapes, red wine, and black teas) appears to be particularly protective.

A high-fiber diet is also recommended. There are two kinds of fiber. Soluble fiber (which dissolves in liquid) is found in oat bran, oatmeal, beans, peas, rice bran, barley, citrus fruits, strawberries, and apple pulp. It helps lower high cholesterol levels. It may decrease or stabilize high blood sugar (glucose) levels and increase low insulin levels. Thus, soluble fiber may help people with diabetes reduce their risk of coronary artery disease. Insoluble fiber (which does not dissolve in liquid) is found in most grains and grain products and in fruits and vegetables such as apple skin, cabbage, beets, carrots, brussels sprouts, turnips, and cauliflower. It helps with digestive function. However, eating too much fiber can interfere with the absorption of certain vitamins and minerals.

The diet should contain the recommended daily requirements of vitamins and minerals. Vitamin supplements are not considered an acceptable substitute for a healthy diet. The role of supplements in reducing the risk of coronary artery disease is somewhat controversial. Taking supplements of vitamin E or vitamin C does not seem to prevent coronary artery disease. Taking folate or vitamins B₆ and B₁₂ may lower homocysteine levels, but studies have not shown that taking these supplements decreases the risk of coronary artery disease.

Limiting the amount of simple sugar carbohydrates (such as refined white flour, white rice, processed foods) and increasing the amount of whole grains may help reduce the risk of coronary artery disease because it reduces the risk of obesity and possibly of diabetes, which are also risk factors for coronary artery disease.

Overall, people should maintain a healthy weight and eat a variety of foods. The Mediterranean diet, which consists of large portions of fruits, vegetables, nuts, and olive oil, appears to reduce the risk of coronary artery disease.

**Types of Fat**

There are three types of fat: saturated, monounsaturated, and polyunsaturated.

“Saturated” refers to the number of hydrogen atoms in a molecule of fat. Saturated fats contain as many hydrogen atoms as they can. They are usually solid at room temperature. Saturated fats are present in meats, dairy products, and artificially hydrogenated vegetable oils. The more solid the product, the higher is the proportion of saturated fats. A diet high in saturated fats promotes coronary artery disease.

Unsaturated fats (monounsaturated and polyunsaturated) do not contain as many hydrogen atoms as they could. Monounsaturated fats could contain one more hydrogen atom. They are usually liquid at room temperature but start to solidify in the refrigerator. Olive oil and canola oil are examples. Polyunsaturated fats could contain more than one additional hydrogen atom. These fats are usually liquid at room and refrigerator temperatures. They tend to become rancid at room temperature. Corn oil is an example. Other polyunsaturated fats include omega-3 fats, contained in deep-sea fatty fish (such as mackerel, salmon, and tuna), and omega-6 fats, contained in vegetable oils.

In a process called hydrogenation, hydrogen atoms are artificially added to polyunsaturated oils so that these oils may be used to make food products that do not become rancid and to make solid fat products, such as margarine. Trans fats result from this process. (“Trans” refers to where the hydrogen atoms are added to the fat molecule.) Trans fats are particularly common in commercial baked and fried foods, such as cookies, crackers, doughnuts, french fries, and other similar foods.

Trans fats increase low-density lipoprotein (LDL—the bad) cholesterol levels and decrease high-density lipoprotein (HDL—the good) cholesterol levels, and these effects appear to increase the risk of coronary artery disease. Avoiding products that contain trans fats is wise. Trans fats are now listed on food labels. Also, if hydrogenated fat or partially hydrogenated fat is the first fat on the list of ingredients, the product contains trans fats. Some restaurants also provide information on which menu items contain trans fats. Several cities in the United States have barred restaurants from using trans fats in their food, and more cities are likely to follow this
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...been disappointing. A good candidate for the procedure. Not be suited to PCI because of its location, its length, the amount of calcium that accumulates, or other conditions. Thus, doctors carefully determine whether a person is a 

...inserted. If the artery becomes blocked again, whether from a clot or other causes, doctors may do a second PCI. 

...atheromas by cutting, shaving, crushing, or dissolving them. Some of these techniques are still being evaluated, but so far, the results, especially over the long term, have 

...certain drugs can help reverse atherosclerosis. 

...have a drug-releasing stent are given an antiplatelet drug for at least a year after the stent is 

...high in monounsaturated or omega-3 fats and low in trans fats is probably desirable. 

**Physical Inactivity:** People who are physically active are less likely to develop coronary artery disease and high blood pressure. Exercise that promotes endurance (aerobic exercise such as brisk walking, bicycling, and jogging) or muscle strength (resistance training with free weights or weight machines) helps prevent coronary artery disease (see Exercise and Fitness: Type of Exercise). Walking just 30 minutes each day can be beneficial. People who are out of shape or who have not exercised in a long time should consult their doctor before they start an exercise program. 

**Obesity:** Modifying the diet and engaging in physical activity can help control obesity. Decreasing alcohol consumption can also help because alcohol is high in calories. A loss of even 10 to 20 pounds (4½ to 9 kilograms) can reduce the risk of coronary artery disease. 

**High Cholesterol Levels:** High total and LDL (the bad) cholesterol levels can be lowered by exercising and by quitting smoking as well as by reducing the amount of fat in the diet. Drugs that lower levels of total and LDL cholesterol in the blood (lipid-lowering drugs) may be used (see Cholesterol Disorders: Dyslipidemia). The benefits of lowering cholesterol levels are greatest in people with other risk factors, such as smoking, high blood pressure, obesity, and physical inactivity. 

Increasing the level of HDL (the good) cholesterol also helps reduce the risk of coronary artery disease. The same lifestyle changes that lower total and LDL cholesterol levels can help increase HDL cholesterol levels, as can certain drugs. For people who are overweight, losing weight can also help. 

**High Blood Pressure:** Lowering high blood pressure reduces the risk of coronary artery disease. Treatment of high blood pressure begins with lifestyle changes: eating a healthy diet that is low in salt and, if needed, losing weight and increasing physical activity. Drug therapy (see Antihypertensive Drugs) may also be necessary. 

**Diabetes Mellitus:** Good control of diabetes reduces the risk of some complications of diabetes, but the effects of such control on the development of coronary artery disease are less clear. Good control of diabetes may also reduce the risk of complications of coronary artery disease. 

**Treatment** 

Doctors try to do three things for people with coronary artery disease. They try to reduce the heart's workload, improve coronary artery blood flow, and slow down or reverse the buildup of atherosclerosis. The heart's workload can be reduced by controlling the person's blood pressure and using certain drugs such as beta-blockers or calcium channel blockers that keep the heart from pumping as hard. Coronary blood flow can be improved by percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG). A coronary artery blood clot may sometimes be dissolved by drugs (see Coronary Artery Disease: Opening the Arteries). Modifying the diet, exercising, and taking certain drugs can help reverse atherosclerosis. 

**Percutaneous Coronary Intervention** 

In PCI (also called percutaneous transluminal coronary angioplasty—PTCA), doctors insert a large needle into the main artery of the thigh (femoral artery). Then a long guide wire is threaded through the needle, into the artery, and up through the aorta into the narrowed coronary artery. A catheter with a balloon attached to the tip is threaded over the guide wire and into the narrowed coronary artery. The catheter is positioned so that the balloon is at the level of the narrowing. The balloon is then inflated for several seconds. The inflated balloon compresses the atheroma that is narrowing the artery and widens the artery. Inflation and deflation may be repeated several times. In 80 to 90% of people, the narrowed arteries that are reached are opened. 

To help keep the coronary artery open, doctors usually insert a tube made of wire mesh (a stent) into the artery. About 75% of the time, doctors use stents that are coated with a drug. The drug is released slowly to help prevent the coronary artery from becoming blocked again, a common problem with bare-metal stents. However, although these drug-releasing stents are very helpful in keeping the artery open, people who have a drug-releasing stent have a slightly higher risk of developing a blood clot in the stent than do people who have a bare metal stent. To decrease the risk of such clots, people who have a drug-releasing stent are given an antplatelet drug for at least a year after the stent is inserted. If the artery becomes blocked again, whether from a clot or other causes, doctors may do a second PCI. 

Generally, PCI is preferred to bypass grafting because it is a less invasive procedure. However, the affected area of the coronary artery may not be suited to PCI because of its location, its length, the amount of calcium that accumulates, or other conditions. Thus, doctors carefully determine whether a person is a good candidate for the procedure. 

**Other Techniques:** Doctors have tried other techniques to remove atheromas. These include the use of tiny blades, burners, or lasers to remove thick, fibrous, and calcified atheromas by cutting, shaving, crushing, or dissolving them. Some of these techniques are still being evaluated, but so far, the results, especially over the long term, have been disappointing. 

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**Understanding Percutaneous Coronary Intervention (PCI)** 

Doctors insert a balloon-tipped catheter into a large artery (usually the femoral artery) and thread the catheter through the connecting arteries and the aorta to the narrowed or blocked coronary artery. Then doctors inflate the balloon to force the atheroma against the arterial wall and thus open the artery. Usually, a collapsed tube made of wire mesh (a stent) is placed over the deflated balloon at the catheter's tip and inserted with the catheter. When the catheter reaches the atheroma, the balloon is inflated, opening up the stent. Then the balloon-tipped catheter is removed, and the stent is left in place to help keep the artery open.
People are usually awake during the procedure, but doctors may give a drug to help them relax. People are closely monitored during PCI because balloon inflation momentarily blocks blood flow in the affected coronary artery. This blockage can produce chest pain and changes in the heart's electrical activity (detected by ECG) in some people. Fewer than 1 to 2% of people die during PCI, and 3 to 5% have nonfatal heart attacks. Coronary artery bypass surgery becomes necessary immediately after PCI for fewer than 3% of people.

Coronary Artery Bypass Grafting

Coronary artery bypass grafting (CABG) is also called bypass surgery or coronary artery bypass surgery. In the procedure, doctors take an artery or vein from another part of the body to connect the aorta (the major artery that takes blood from the heart to the rest of the body) to a coronary artery past the point of its blockage. Blood flow is thus rerouted, skipping over (bypassing) the narrowed or blocked area. Veins are usually taken from the leg. Arteries are usually taken from beneath the breastbone (sternum) or from the forearm. Artery grafts rarely develop coronary artery disease, and more than 90% of them still work properly 10 years after the bypass surgery. However, vein grafts may gradually become narrowed by atheromas, and after 5 years, one third or more may be completely blocked.

The operation takes 2 to 4 hours, depending on the number of blood vessels to be grafted. A numeric modifier (for example, triple or quadruple) before bypass refers to the number of arteries (for example, 3 or 4) that are bypassed. The person is given a general anesthetic. Then, an incision is made down the center of the chest from the neck to the top of the stomach, and the breastbone is parted. This type of surgery is called open-heart surgery. Usually, the heart is stopped so that it is not moving and thus easier to operate on. A heart-lung machine is then used to put oxygen into the blood and pump the blood through the bloodstream. When only one or two blood vessels require grafting, the heart may be left pumping. The hospital stay is typically 5 to 7 days, usually less if a heart-lung machine was not used during surgery.

The risks from surgery include stroke and heart attack. For people who have a normal-sized and normally functioning heart, have never had a heart attack, and have no additional risk factors, risk is less than 5% for a heart attack during surgery, 2 to 3% for stroke, and less than 1% for death. Risk is somewhat higher for people with reduced pumping ability of the heart (poor left ventricular function), damaged heart muscle from a previous heart attack, or other cardiovascular problems. However, if these people survive the surgery, their prospects for long-term survival are improved.

Other Techniques: With new techniques, chest incisions can be much smaller, resulting in minimally invasive bypass surgery. One technique involves robotics. While sitting at a computer console, a surgeon uses pencil-sized robotic arms to do the operation. The arms hold specially designed surgical instruments that can do intricate movements, mimicking those of the surgeon's hands. Through a viewing scope, the surgeon watches a magnified three-dimensional image of the operation. The operation requires three 1-inch (about 2 1/2-centimeter) incisions—one for each of the two robotic arms and one for a camera, which is connected to the scope. Thus, the surgeon does not need to split open the person's breastbone. The operating time and hospital stay are usually shorter with the newer procedures than with open-heart surgery.
Coronary artery bypass grafting consists of attaching an artery or part of a vein to a coronary artery, so that the blood has an alternate route from the aorta to the heart muscle. As a result, the narrowed or blocked area is bypassed. An artery is preferred to a vein because arteries are less likely to become blocked later. In one type of bypass grafting, one of the two internal mammary arteries is cut, and one of the cut ends is attached to a coronary artery beyond the blocked area. The other end of this artery is tied off. If an artery cannot be used or if there is more than one blockage, a section of a vein—usually, from the saphenous vein, which runs from the groin to the ankle—is used. One end of the section (graft) is attached to the aorta, and the other to a coronary artery beyond the blocked area. Sometimes a vein graft is used in addition to the mammary artery graft.