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During diagnosis, a patient's medical history is obtained.

DIAGNOSING A PROBLEM

ONCE A PHYSICIAN KNOWS THE symptoms, a series of tests will help determine a diagnosis. “Diagnosis” literally means a determination of the cause of a problem, and diagnostic tests are done to find out what’s causing the symptoms. In many ways, doctors are like detectives in that they are presented with a case and have to search out culprits and causes. Diagnosing illness is an art form unto itself, and doctors use some very sophisticated techniques.

Electrocardiogram

Among the most common tests is the electrocardiogram, which is referred to as either an ECG or an EKG. EKG is short for electrokardiogram, which is a historical spelling that resulted because much of the test’s early development was done in Holland. Dr. William Einthoven, professor of physiology at the University of Leiden, received the 1924 Nobel Prize in Physiology or Medicine for his work in developing the electrocardiograph.

An ECG or EKG should not be confused with an EEG, which stands for electroencephalogram and is used to detect brain waves much as the ECG measures electrical activity in the heart.

An ECG is performed by placing electrode patches on the chest and extremities and connecting them to an ECG machine. The sensors pick up electrical activity and send the results to a printer, where they are printed on a piece of paper. Results can also be displayed on something similar to a television screen so they can be constantly monitored in an intensive care unit or other medical facility.

Much information can be obtained from an electrocardiogram, including heart rhythm, heart rate, and estimates of the level of oxygenated blood reaching the heart. If the reading is abnormal, the doctor might be able to determine what is causing the abnormality from that reading alone. The ECG can help determine if a heart attack is occurring and also reveal where in the heart the damage is located. Some forms of congenital heart disease and some forms of valvular heart disease also can be strongly suspected on the basis of an electrocardiogram.

Exercise (Electrocardiogram) Stress Test

In its simplest form, an ECG exercise stress test is performed to look for coronary artery disease or blocked coronary

arteries. Coronary artery disease is not always apparent on a resting electrocardiogram but is often visible on an ECG made while the heart is working and requires more oxygenated blood.

To perform this test, the patient is asked to walk on a treadmill while symptoms, electrocardiogram, and blood pressure are monitored. If the working heart's demand for blood is greater than the amount the coronary arteries can supply, the electrocardiogram may become abnormal, telling the doctor which areas of the heart are not getting enough blood, or are ischemic. Patients might develop angina during the test, which often correlates with changes in the electrocardiogram. Other variables, such as blood pressure and heart rate changes, can occur during the ECG exercise stress test. These might lead a physician to suspect coronary artery disease.

If patients cannot exercise for some reason, the heart is stressed with drugs that dilate the arteries (such as dipyridamole or adenosine). Sometimes drugs are used to make the heart beat faster and harder. Dobutamine is one drug of this type. Atropine is another drug that results in a faster heart rate.

Ambulatory Electrocardiographic Monitoring

Another form of ECG is ambulatory electrocardiographic monitoring, also referred to as Holter monitoring. In this test, the ECG electrodes are connected from the patient to a portable ECG machine that contains a tape recorder. The patient's ECG is monitored while the patient is performing normal daily activities over a day or two. This is usually done when **arrhythmias** or blackout spells have occurred or are suspected.

Patients are allowed to go home and asked to keep a record of their normal activities during the monitoring period. If a patient has an abnormal event, such

as a sensation that the heart rate has sped up or the feeling that an abnormal heart rhythm is occurring, he or she presses a button on the ECG recorder to mark the exact time of the symptoms.

The ECG can also be checked over the telephone. Telephone checks can be helpful in patients with pacemakers because pacemaker activity can be monitored without the need to travel to the doctor's office. To do this, an electronic device with an electrode is attached to the skin and then connected to the telephone. The physician at the other end has to have the necessary equipment so the ECG can be transmitted and printed out.

Echocardiography

Echocardiography is somewhat like the sonar used to detect a submarine under water. High-frequency sound waves are bounced off the heart to create an image of its structures. This is a relatively simple test using a sound probe placed at various locations on the chest. With this test, a doctor can image the heart while it is actually pumping. These pictures are recorded on video tape for a cardiologist to play back.

Usually, echocardiograms are performed in one of two different manners. One type is called a transthoracic echocardiogram. From the patient's standpoint, it is not much different from having an electrocardiogram. The patient lies still while a technician places a probe on the chest and obtains an image, or movie, of the beating heart.

The other type is called a transesophageal echocardiogram (TEE) and is somewhat more involved. The throat is anesthetized, and a sound probe is passed through the mouth, into the throat, and down into the esophagus. The echocardiogram is obtained while the probe is slowly moved back and forth in the esophagus. In the esophagus, the probe is just a half inch from the heart and thus can

Arrhythmia:

Any abnormal heart rhythm. Also called dysrhythmia.



Echocardiograms are very useful for obtaining pictures of the moving heart to diagnose heart disease, valve malfunctions, and other abnormalities. The test, which can be done with probes moved across the chest or inside the esophagus, uses sound waves to obtain an image that can be transferred to a computer screen.

produce highly detailed images of the heart structures.

In most cases, the simpler transthoracic type of echocardiogram is all that is needed. However, a TEE yields a more detailed view of the heart and major blood vessels, which helps if the doctor is assessing the mitral valve or certain other cardiac structures.

With either type of echocardiogram, doctors can see the size of the heart chambers and how well they are functioning. They can see blood clots if present in the heart, fluid around the heart, and problems with valves, such as blockage. Using cardiac Doppler flow studies, they can also see whether heart valves are leaking or if they are narrowed (stenotic). If the patient has an artificial heart valve, doctors can determine whether the valve is functioning properly.

Echocardiograms can also be used to detect problems in the thoracic aorta,

which is the part of the aorta in the chest, and to estimate blood pressure in the pulmonary arteries. In certain heart and lung conditions, the pulmonary artery pressure can be abnormally elevated, which is something a physician needs to know.

Exercise Echocardiogram

The exercise echocardiogram is another type of stress test. This test combines exercise and echocardiogram pictures to show the contraction of the heart. After a resting test is performed, the patient is asked to walk on a treadmill. The results of this test are compared with the resting echocardiogram.

If segments of the heart are no longer contracting well, it can be concluded that these areas are not getting enough oxygenated blood. There may be a coronary artery blockage. If one is unable to exer-



The chest computed tomography scan, or CT scan, is a more sophisticated type of x-ray. This test allows three-dimensional viewing of the heart and is used to help detect abnormalities like aortic aneurysms or aortic dissections.

cise for whatever reason, drugs can be used to induce heart stress. Otherwise, the testing procedure remains the same.

The Chest X-Ray

Routine chest x-rays are typically taken from two different views. One is called a PA chest x-ray, for “posterior-anterior,” which means back to front. The patient stands facing the x-ray film plate with the x-ray machine behind him. The other routine chest x-ray is the lateral view, which is taken either from right to left or from left to right so that the doctor can look at the chest from the patient’s side. The PA and lateral views are complementary.

A chest x-ray can also be taken with the patient’s back to the x-ray film plate and the x-ray beam aimed from the front through the patient’s chest. This is called an AP chest x-ray, for “anterior-posterior.” The PA film is usually preferred because radiologists feel it gives a better picture. In an intensive care unit or a patient’s room, however, it is more convenient to put the x-ray film plate behind the patient and use a portable x-

ray machine to “shoot” the picture from the front.

A chest x-ray is a valuable tool. Doctors use chest x-rays to determine the size and shape of the heart, the shape of the arteries coming out of the heart, and to look at the lungs and other chest structures. They can also tell if the heart or one of its chambers is enlarged. With routine chest x-ray pictures, doctors can frequently tell if calcium has collected on the heart valves or in the aorta or can even see calcium in coronary arteries. Calcium deposits may suggest certain types of disease. If heart failure is present, doctors can determine if the lungs are congested and to what extent. They can also determine how effective a certain treatment is in improving heart failure and decreasing lung congestion.

The ECG and the routine chest x-ray are used as screening tests. They are simple to obtain and very useful. If heart disease is suspected, more sophisticated tests will be obtained.

Chest Computed Tomography

The chest computed tomography (CT) is a more sophisticated type of x-ray in which scanning x-ray beams are used to take pictures of the chest from several different angles and provide a two- or three-dimensional view of the heart, lungs, and chest. Chest CTs are very useful for evaluating various abnormalities. In general, the test can be particularly helpful in evaluating conditions like aortic aneurysm, aortic dissection, and fluid around the heart.

There’s a form of computed tomography called ultrafast computed tomography that has been used to evaluate the coronary arteries. In this case, as many as seventeen scans are performed per second. These scans are helpful in determining whether a person has clinically significant coronary calcifications. Ultrafast computed tomography is relatively new,

and currently the resolution is generally not as good as that of the pictures obtained with a cardiac catheterization, during which radiopaque dye is injected through a catheter directly into the coronary arteries.

Magnetic Resonance Imaging (MRI)

Magnetic resonance images are produced by the interactions of radio waves and magnetic fields. A computer transforms the signal from these interactions into pictures. There is no exposure to x-rays. The magnet is shaped like a large doughnut within which the patients lie. Unlike CTs, MRI can depict blood vessels and heart chambers without the need for injecting a contrast agent (x-ray “dye”) and can picture them in three dimensions or from any angle. Images can also be obtained in movie format to show heart motion and blood flow.

MRI is superior to CTs when differentiating abnormalities next to the heart from abnormalities of the heart itself. Unlike echocardiography, which shares some of these advantages, MRI is not

limited by the distance of the organ from the skin or by intervening bone structures and air. In children with complex congenital heart disease, MRI is an important supplement to echocardiography both for diagnosis and for assisting in surgical planning.

For other forms of heart disease, MRI is very helpful in assessing tumors or blood clots in the heart, pericardial disease, and diseases of the aorta such as aneurysms and dissection, and in supplementing echocardiography. MRI can determine cardiac anatomy, how well the heart pumps, and perfusion (blood actually getting to the heart muscle) but cannot adequately picture the coronary arteries. Technological advances should make this possible in the near future, at which time MRI may be able to provide information that is currently obtained from a combination of echocardiography, **radionuclide** studies, and cardiac catheterization.

Nuclear Perfusion Tests

Another kind of testing uses one of two radioactive agents, thallium or tech-

Radionuclide:

A small amount of a nuclear substance that is used during diagnosis of heart disease to help physicians better see the heart and blood vessels.



During MRI, or **magnetic resonance imaging**, radio and magnetic waves are used to obtain very detailed images of the heart from any angle. It is especially helpful in diagnosing congenital heart disease in children and problems with arteries and veins.

netium-99m, to study blood flow in patients suspected of having coronary artery disease. Sometimes these tests are used to monitor the progress of disease in patients whose condition has already been diagnosed.

In this test, a tiny amount of radioactive substance, referred to as a radionuclide, is injected into the body, and pictures are produced as the radiation escapes. These substances in the bloodstream are called "tracers" and are detected by a camera similar to a Geiger counter.

Thallium scanning is usually done in conjunction with an exercise stress test. The patient is asked to either walk on a treadmill or pedal a stationary bike. After a vigorous exercise period, radioactive material is injected into the bloodstream, and the patient is asked to exercise for about another minute. Scanning is done with a device that measures ra-

dioactivity. The resulting picture will show any areas of the heart that suffer from poor blood flow or no blood flow. With a thallium scan, the patient has a second scan four hours later.

If both tests show adequate blood flow, the heart and coronary arteries are probably normal. If both sets of scans show a "defect," or an area of the heart where there is no uptake of thallium, this indicates that the muscle has probably been replaced by scar tissue from a previous heart attack. If the scan shows faint uptake of thallium during exercise but more normal uptake at rest, it indicates that the heart muscle in that area is probably still alive but the coronary artery may be blocked. In this case, a cardiac catheterization can identify the exact area of blockage.

Technetium-99m is gaining popularity for obtaining similar information because it tends to yield higher quality pictures and more information than thallium. Technetium-99m is commonly used in a form called Sestamibi. With Sestamibi, the resting scan is usually performed before the stress test.

If a patient is unable to exercise on a treadmill, either the thallium or the technetium test can be done by using drugs that cause the heart to mimic its blood flow during exercise.

Nuclear perfusion scans are useful tests and are sometimes used as screening tests to determine whether a person ought to undergo a cardiac catheterization with coronary angiography, which is a more invasive but more accurate test to show coronary artery blockages. Nuclear tests and coronary angiography give somewhat different information and, in many cases, can be complementary. The information taken together may help determine whether a cardiologist will recommend more invasive procedures such as balloon dilatation of the coronary artery, stent placements, or even coronary artery bypass surgery.



Prior to the actual nuclear scan, patients are often asked to exercise vigorously. During the scan, they lie still while their circulation is watched for signs of abnormality.



The **positron emission tomography** scan, or PET scan, is a very advanced form of nuclear scanning that reveals circulation of blood through the heart.

Pyrophosphate Technetium-99m Scanning

The pyrophosphate technetium-99m scan also uses technetium, but a different form than is used in the Sestamibi scan. The pyrophosphate scan is used to determine if a patient has had a heart attack and, if so, how much damage has occurred. Damaged heart muscle will take up this form of technetium within twelve hours after a heart attack. Normally, the propensity for damaged heart muscle to take up pyrophosphate disappears within a week after a heart attack. This test can also be used to determine whether there is ongoing damage from the heart attack and whether the damage is confined to one area. Although this test is useful, it is slowly being replaced with other tests that can each yield some of the same information.

MUGA Scan (Multigated Acquisition Study)

The MUGA scan is done to determine how well all four chambers of the heart are functioning and how big they are. The results obtained from this test are similar to some of the information obtained from the echocardiogram.

For this test, blood is withdrawn into a syringe containing the radionuclide technetium combined with pertechnetate. The technetium attaches to the red blood cells. About ten minutes later, the blood is reinjected, and a resting scan is taken. If a stress MUGA has been requested, the patient performs stationary exercise, and the heart is scanned at regular intervals.

Positron Emission Tomography, or PET Scanning

Positron emission tomography, or PET, is currently the gold standard test using radioactive particles and the most accurate noninvasive way to measure blood flow to the heart muscle. In addition to measuring blood flow, it can measure metabolic activity, which means it can determine whether heart muscle cells are alive and functioning. Active heart muscles consume oxygen and glucose, and PET measures this activity.

During a PET test, the patient is injected with a chemical that gives off subatomic particles as it degenerates. The subatomic particles, called positrons, are detected by the PET scanner, and this in-

formation is stored in a computer. The computer reconstructs an image of the heart at work, showing which areas are not performing normally. This tells the physician that the coronary artery leading to that area is blocked and may need to be opened with a balloon catheter or surgical bypass grafting.

PET can also tell if an area of the heart is not performing normally because it has been damaged during a heart attack and has now turned to scar tissue. In that case, there would be no need to place a bypass graft to an area that is never going to function normally anyway.

PET is not available at many medical centers because of the cost. Radioactive agents used in this test have a very short lifetime, and therefore a cyclotron, which costs several million dollars, needs to be present at the PET scanning facility to produce these agents. Hospitals without PET scanning use other perfusion tests that also yield adequate information.

Doppler Ultrasonography

This test is used to measure blood flow through the veins and arteries in the

legs or through the carotid arteries that supply blood to the brain. Doppler ultrasound works on the same principle as echocardiography. High-frequency sound waves are bounced off the soft tissue and converted into electrical impulses that are displayed on a screen. In the legs, these tests can be used to determine if there's a blood clot in a vein or blockage of the arteries, which is typically caused by atherosclerotic material.

Blood Tests

There are scores of different blood tests that can be performed at a hospital, and all of them yield information about various functions of the human body. Some of these are obtained specifically to learn various information about the human heart. If a person is admitted to a hospital emergency room because of chest pain, doctors may draw blood from a vein in the arm to measure what are called cardiac enzymes. The blood is sent to the hospital laboratory for a test to help determine, along with the electrocardiogram, whether the patient is having a heart attack. If heart muscle is damaged, certain enzymes or chemicals



During diagnosis of heart disease, blood samples are often drawn. They can be used to determine whether a heart attack is in progress.

will leak from the damaged or dying heart muscle. Some of these enzymes are very specific to the heart and help determine whether a patient is having a heart attack. One of these is called creatine kinase, or CK. Another is called lactate dehydrogenase, or LDH. Troponin is a type of protein that leaks from the damaged heart muscle and can also help diagnose a heart attack.

If the doctor suspects someone might be having a heart attack, particularly from the symptoms and also from the ECG changes, the patient is usually admitted to the hospital's cardiac care unit for observation. The levels of serum enzymes, such as the CK and the LDH, may not initially be elevated but during the next day or two may become elevated, indicating not only that the heart has been damaged but that portions of it may be dying. The levels of these enzymes suggest how large or how clinically significant the heart attack is. Also, these enzyme levels should start to return to normal levels in a day or two. If they continue to be elevated, the heart attack may be continuing or damage may be occurring over several days. This can be of great concern to the physicians caring for the patient and may indicate that something invasive will have to be done such as obtaining a **coronary arteriogram** in the cardiac catheterization laboratory. It could also mean the patient may need a catheter procedure to open the blocked coronary artery or even require coronary bypass surgery.

Arterial and Venous Oxygen Levels

Blood samples are used to determine both arterial and venous oxygen levels. Arterial oxygen content can help determine how well the lungs are working. Blood arterial samples are most frequently obtained from an artery in the wrist or the groin (Fig. 5.1). They can be obtained during cardiac catheterization or in the cardiac care unit.

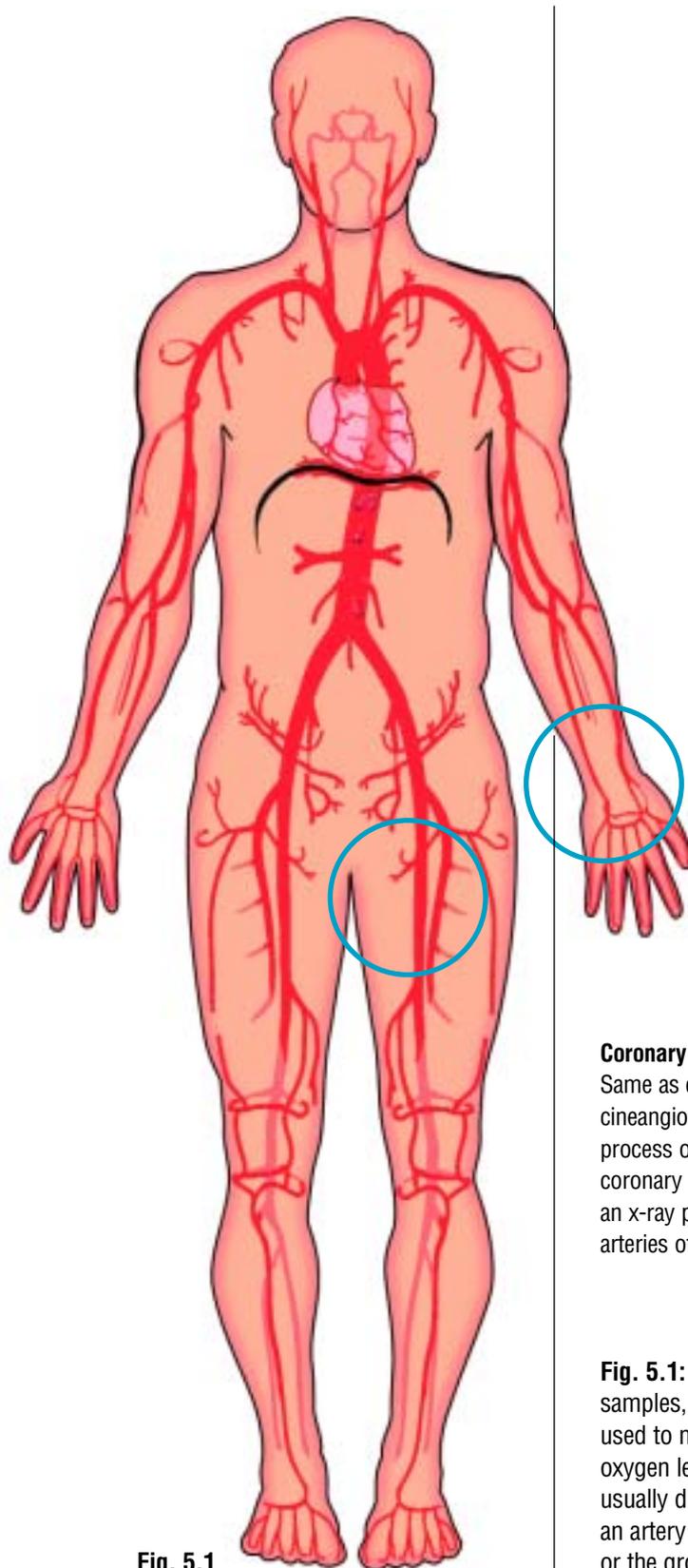


Fig. 5.1

Coronary Arteriography: Same as coronary cineangiography. The process of obtaining a coronary arteriogram or an x-ray picture of the arteries of the heart.

Fig. 5.1: Arterial blood samples, which are used to measure blood oxygen levels, are usually drawn from an artery in the wrist or the groin.

In adults, venous blood oxygen levels are used to determine how well the heart is functioning. A venous oxygen probe can also be part of an indwelling monitoring catheter that's used either during heart surgery or in the intensive care unit (ICU). This monitor provides continuous information that helps physicians determine how well the heart is pumping.

Children who have congenital heart disease have blood samples obtained during the cardiac catheterization procedure. The blood oxygen levels in various cardiac chambers provide clues as to what type of congenital heart defect the child has and even where the defects are located in the heart.

Cholesterol Level

Cholesterol and triglycerides are substances that can be measured by obtaining a blood sample. Also, the various sub-types of cholesterol such as high-

density lipoprotein (HDL) cholesterol and low-density lipoprotein (LDL) cholesterol can be determined from a blood sample. These important tests reflect how one's body controls the levels of these particular substances, which, if too high or too low, may indicate that one is more prone to develop blockage of the coronary arteries feeding blood to the heart, blood vessels going to the brain, and arteries in other areas of the body. Patients may have to change their diet or take medication to lower the concentration of these substances and thus reduce the chances of a heart attack or stroke.

Second Opinions

Second opinions are obtained from another doctor, usually one of the same specialty, about a patient's specific medical problem. Obtaining a second opinion is quite common, and, in fact, many insurance companies require a second opinion before important surgery. Sometimes patients feel that they are offending a doctor if they tell a doctor that they would like to get a second opinion. They shouldn't. Most doctors encourage patients to seek a second opinion if they feel the patient is not quite comfortable with the diagnosis.

Obviously, having a cardiac catheterization or a heart operation is a major event in one's life, and patients should feel that they have received informed recommendations about having such a procedure. You should not hesitate to obtain a second opinion unless you are comfortable with the advice you have received. However, sometimes in emergency situations a second opinion is impractical.

In some respects, many patients have actually obtained second or third opinions and may not realize it. For example, the patient's internal medicine doctor or cardiologist may refer the patient to a cardiologist who specializes in cardiac catheterization procedures. After evaluating the pa-



It can be a good idea to obtain a second opinion. Heart surgery and heart catheterizations are major events, and patients should be satisfied with the information about their condition and treatment.

tient and obtaining results from a cardiac catheterization and other studies, the doctors talk with each other and decide whether or not to recommend heart surgery. If the surgery is recommended, the patient is referred to a heart surgeon, who discusses the case with the patient as well as the referring doctor and then makes his or her recommendation for or against heart surgery. From that standpoint, two or three opinions have already been obtained.

How does one go about obtaining an additional opinion or a second opinion from another cardiologist or from another heart surgeon? One way to do it is to simply ask a cardiologist or heart surgeon to recommend another heart surgeon or cardiologist for a second opinion. Usually if you're going to get a second opinion, you would want to get it from somebody other than the doctor's partner because the partner may have a vested interest in agreeing with the first opinion. Also, you would probably feel more comfortable obtaining an opinion from somebody who is perhaps less likely to share exact views with the doctor.

Patients can also ask a family doctor to recommend another specialist. If you are obtaining a second opinion from an-

other heart surgeon, you can ask the cardiologist with whom you are dealing to recommend a different heart surgeon. Patients can also check with an insurance company. These companies frequently have a list of specialists whom they will recommend. If you're dealing with a heart surgeon and you want another opinion from a cardiologist, a heart surgeon can also recommend another cardiologist because heart surgeon's deal with many different cardiologists. The local medical societies can also be contacted for advice.

Some people track down second opinions through information on the Internet. Sometimes there are specific doctors listed either in the local area or elsewhere in the country. Sometimes patients obtain their second opinion directly from information available on the Internet or from interfacing with medical people on the Internet.

There are many ways to obtain second opinions, and you should not hesitate to obtain one. Doctors are only human, and sometimes they may interpret a test or other information one way or have opinions on how a certain problem should be treated that may differ from those of another physician of the same specialty.