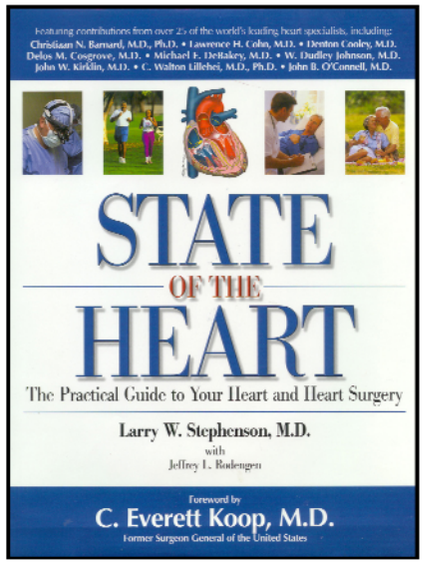

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Hospitals have designated cardiac and vascular catheterization labs where specialized procedures are performed by cardiologists and radiologists.

CHAPTER SIX

What is Cardiac Catheterization?

CATHETERS ARE FLEXIBLE, HOLlow tubes (originally rubber, but now advanced plastic) that are threaded through an artery or vein into the body. They are able to travel from the insertion site in the groin or arm into major arteries and veins, heart chambers, and even the brain. Although cardiac catheterization is primarily diagnostic and not considered heart surgery, it is an invasive procedure that in some cases has replaced open heart surgery. These devices have a wide variety of uses, including

- ♥ dilating coronary arteries and heart valves using inflatable balloons,
- ♥ placing stents, or small metal coils, in blood vessels to keep them open,
- ♥ guiding lasers through the coronary arteries, which are used to open blockages,
- ♥ introducing devices to close holes in certain types of congenital heart defects such as atrial septal defects, and
- ♥ enlarging a hole in the atrial septum (the wall between the right and the left atrium).

Today, there are more than one million cardiac catheterization procedures performed in the United States each year.

Experimenting on Himself

The first human heart catheterization is credited to a medical intern from Berlin, Germany, named Dr. Werner Forssmann. Forssmann began his catheter studies on cadavers, passing his rudimentary devices into the right ventricle. He next wanted to conduct an experiment on a living subject but couldn't get approval from his superiors. He decided to use himself. He later wrote about the experience:

"In a preliminary experiment, I asked a colleague to puncture a vein in my right arm with a large-bore needle. Then I advanced a well-lubricated urethral catheter (used to drain the urinary bladder) ... into the vein. The catheter was easily passed to fourteen inches, but we aborted the experiment, which my colleague considered too risky. I felt perfectly well during the experiment.

"One week later, I tried it again without assistance. I proceeded with a venous puncture in my left arm vein and introduced the catheter to its full length of twenty-six inches. I only perceived some sensation of warmth similar to the sensation during intravenous injection of calcium chloride. There was no pain.

When I pushed on the catheter, I felt a warm sensation behind the collar bone and near the jawbone."

Forssmann's 1929 report, which included a photograph of an x-ray showing the catheter in his heart, was received coolly by a medical establishment that was critical of something so outlandish. When he requested permission from his superiors to pursue further studies, he was told his methods were good for a circus but not for a respected hospital.

Nevertheless, Forssmann continued his cardiac catheterization studies on himself and in laboratory animals. He later called himself an outsider with "ideas too crazy to give him a clinical position."

Forssmann was eventually vindicated. In 1956, he shared the Nobel Prize in Physiology or Medicine with two faculty members of Columbia University in New York, Drs. Andre F. Cournand and Dickenson W. Richards, Jr., for work in cardiac catheterization.

Right: In 1929, a young German doctor named Werner Forssmann conducted the first heart catheterization on a living human. Forbidden by his superiors to experiment on a patient, he conducted the historic catheterization on himself.

Angiography: The process of making a blood vessel visible by injecting a substance that can be seen under x-ray.

Catheters Today

Today, catheters are used to both diagnose and treat cardiac disorders. The procedure is usually done on an outpatient basis, and patients who undergo catheterization are often released from the clinic or hospital on the day of the procedure.

Diagnostically, the catheter is an important tool that allows doctors to observe the inside of coronary arteries and actually watch the heart at work. The most popular form of heart catheter procedure is called coronary **angiography**, in which a catheter is used to inject contrast material into the heart's own arteries. It takes anywhere from twenty minutes to an hour to obtain an angiogram.

If it is used in any other artery, such as the pulmonary artery, it is called pulmonary angiography. In the pulmonary artery, angiography is sometimes used

Center:
A cardiac catheterization laboratory. Catheters are used to both diagnose and treat heart disease.

to find blood clots, possibly related to a clot that had broken loose from a vein in the leg or elsewhere and worked its way through the heart and into the arteries in the lung.

The Coronary Angiogram

Coronary angiograms were first described in 1962 by Dr. Mason Sones at the Cleveland Clinic. Because it allowed doctors to see exactly where the coronary arteries were blocked and what condition they were in beyond the blockage, coronary angiography was a major impetus for the development of the coronary bypass graft operation.

Coronary angiography procedures are done in a special area of the hospital called the cardiac catheterization laboratory. Depending on the size of the hospital's cardiovascular unit, there may be one room or several rooms where catheterization procedures are performed using special x-ray equipment. During the angiography, the patient lies on a special table while the cardiologist performs the catheterization. Heart surgeons typically do not perform coronary angiographies. They are usually performed by an internist who has completed specialty work in cardiology and further specialized in cardiac catheterization.

During the coronary angiogram, the catheter is not in the heart itself. Instead, the dye is injected directly into the coronary arteries where they originate in the aorta. This will determine whether there is atherosclerosis or some other type of blockage in the coronary system. Important information can be gained as to whether blockages are severe enough to require some form of therapy.

Before the catheter is inserted, the skin is cleaned and anesthetized with a local anesthetic. A small needle is used to puncture the vein or the artery, and a wire is threaded through the needle. Next, a larger plastic introducer is placed. The catheter itself, which is a little larger in diameter than a piece of spaghetti, is threaded through the introducer into the blood vessel.

Once inside the body, catheters can be steered through heart valves and into the heart chambers themselves (Fig. 6.1), where catheter-based devices can measure pressure in the various chambers. This is particularly important in diagnosing some types of heart valve disease.

Blood samples also can be taken from the chambers, and the level of oxygen can be measured. This is helpful when looking for possible holes in the heart that are allowing unoxygenated blood to mix with oxygenated blood, or vice versa. It can be an important diagnostic tool in children with some types of congenital heart defects.

Besides coronary angiography, catheters are also used to image the heart itself and other arteries. Radiopaque dyes are injected into the heart's chambers and recorded with x-rays as they course through the heart. This shows how well the heart muscle is contracting and, if

Dr. Mason Sones

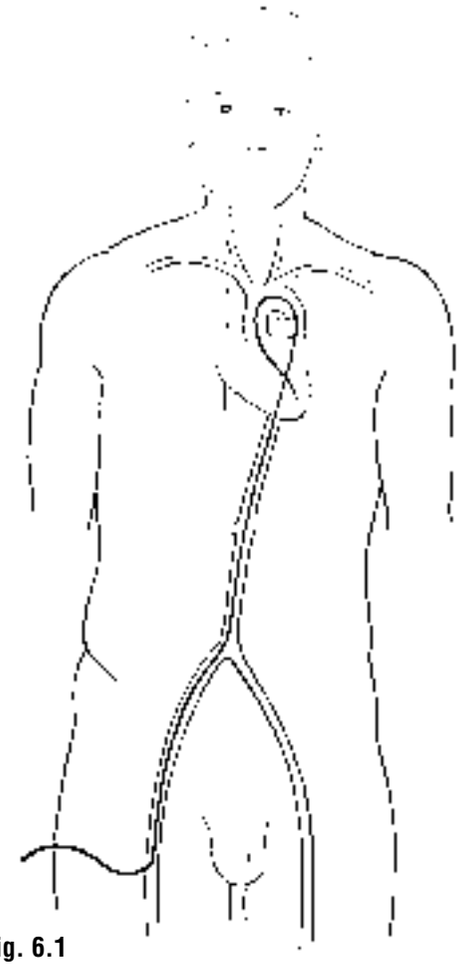


Fig. 6.1

Fig. 6.1: Catheters can be introduced into the heart through a major artery in the groin.

some of the dye flows backwards, it may indicate a leaking heart valve.

After the cardiac catheterization is complete, the devices are removed. If the catheter is inserted through an artery in the arm, the puncture site may have to be stitched closed. If the catheter is introduced through an artery in the leg, pressure held on this artery for a couple of hours will normally allow the puncture to seal over on its own. In this case, the patient will need to lie flat in bed for several hours, and there may be some bleeding after the pressure is relieved.

If the area around the artery becomes swollen because of blood gathering, this is called a hematoma. Occasionally, if the hematoma gets large, a surgeon will have to make an incision and place a few stitches directly into the artery. Currently, however, there are techniques available to seal the hole as the catheter is removed from the artery, which makes these complications less likely.

Like any invasive procedure, catheterization carries with it other risks. Although it happens rarely, the heart itself can be lacerated by the catheter. This may require emergency heart surgery. Other times, the heart will go into an irregular rhythm. Fortunately, these rhythms usually correct themselves, but they may require some medication. Some patients may become allergic to the dyes that are injected into the arteries. Very rarely, a heart attack or stroke may occur as a result of cardiac catheterization.

Therapeutic Cardiac Catheterization

Percutaneous Transluminal Coronary Angioplasty (PTCA)

Catheters are also used to treat blocked coronary arteries in a procedure called percutaneous transluminal coronary angioplasty (PTCA). Several hundred thousand of these procedures are performed in the United States each year. The catheter used for PTCA is tipped with a

Fig. 6.2

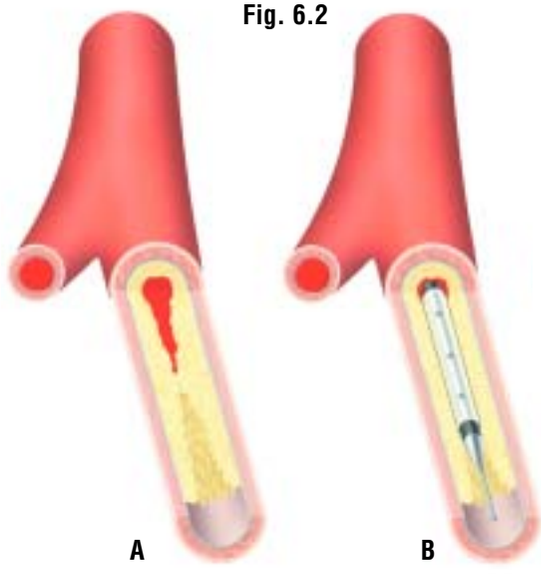


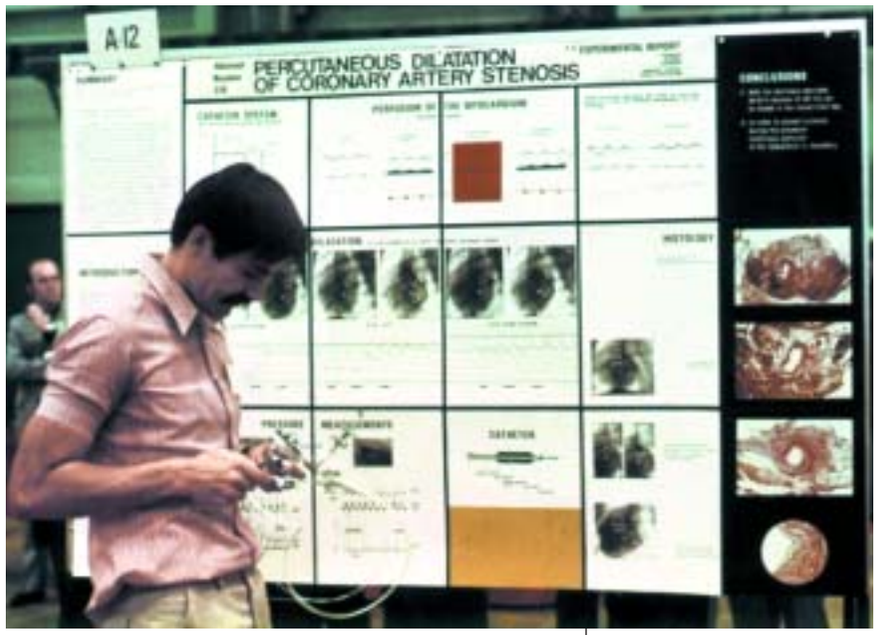
Fig. 6.2: Catheters can be used to open blocked arteries (A) in a procedure called PTCA. During PTCA, the balloon-tipped catheter is first guided to the artery segment that is narrowed (B). Next the balloon is inflated and dilates the artery by crushing the plaque against the arterial wall (C and D). When the procedure has been completed, the artery has been reopened (E).

very small, sausage-shaped balloon that is threaded into the coronary artery and into the obstructed part of the vessel. Once it's in place, the balloon is inflated, crushing the plaque and atherosclerotic material against the arterial wall (Fig. 6.2). The balloon may have to be inflated several times.

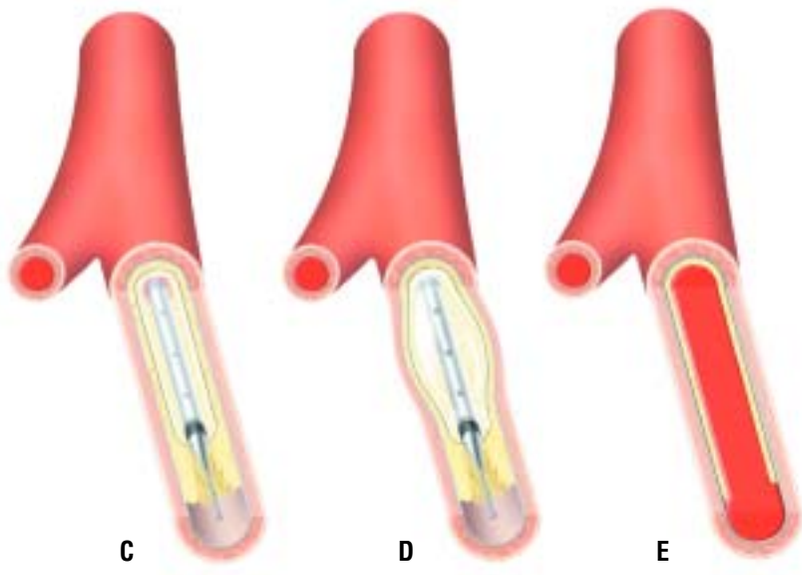
The PTCA procedure was developed by Dr. Andreas R. Gruentzig at the University of Zurich in Switzerland, although balloon-tipped catheters were already in use to dilate arteries in the leg that were blocked by atherosclerosis. Gruentzig made the existing catheters much smaller so they could be used in the coronary arteries. His first human PTCA was successfully performed in September 1977. Since then, this procedure has rapidly evolved.

Although most PTCA procedures are successful, not all blockages can be relieved with the balloon. Doctors do not usually attempt to use a balloon catheter in the left main coronary artery. There is a risk that the procedure will dislodge atherosclerotic debris that will travel into one or both of the main coronary branches and cause a massive acute heart attack that would likely be fatal. In addition, when any coronary artery is totally blocked, a catheter might not be able to get through the blockage. In that case, balloon procedures would not be attempted.

About five percent of the arteries dilated with the balloon catheter will close off before the patient even leaves the hospital. Such an event is usually treated with another PTCA. In a few cases, the patient will have to be taken to the operating room, where a heart surgeon will have to perform a bypass operation.



Dr. Andreas Gruentzig, a physician from Switzerland, performed the first percutaneous transluminal coronary angioplasty (PTCA). During this procedure, a tiny balloon is used to widen a coronary artery that has been partially blocked by plaque. Gruentzig is pictured in the 1970s at a trade show booth sponsored by Boston Scientific, a catheter and medical device company. *(Photo courtesy of Boston Scientific Corporation.)*



Even after leaving the hospital, about 30 to 50 percent of the four hundred thousand cases of PTCA performed every year restenose, or narrow again to the original level or worse. This often happens within three to twelve months of the procedure, and it is a significant problem.

Stent Procedures

Stent: A device usually made from metal or other material that is placed in a blood vessel to help keep it open.

Stenosis: An abnormal narrowing of a blood vessel, heart valve or any other orifice or tube-like structure in the body.

In 1993, a new technology called **stenting** came into widespread use as a partial treatment for **restenosis**. Stents were first tested in the coronary artery of a human by Dr. Ulrich Sigwart from Lusanne, Switzerland, in 1987. Stents are small metal coils that are "wrapped" around the PTCA balloon before it is inserted into the coronary artery. Once the balloon catheter is in place, it is inflated, pushing the stent open and lodging it against the arterial wall. The balloon is removed, but the stent stays in place and keeps that area of the coronary artery dilated.

So far, stents seem to perform better than PTCA itself and have improved the safety and efficacy of PTCA. However, a risk of stent stenosis remains when either material forms inside the stent or the blockage occurs just beyond either end of the stent. This is reported in between 10 and 20 percent of cases within six months of stent placement. Nonetheless, the results are promising, and the stenting procedure has become widespread since its introduction.

Atherectomy

Catheters are also used to treat coronary artery blockage in a technique known as atherectomy. This procedure uses a small device that rotates, much like a miniature drill, to shave off the atherosclerotic blockage. The resulting debris is collected and removed from the artery. The atherectomy procedure is useful in cases with significant blockage, but it is not as widely used as the balloons and the balloons with stents. In a similar procedure, nicknamed the "Roto Rooter," a tiny burr grinds off the hardened blockage material.

Lasers

Lasers are also used to clear coronary arteries of atherosclerotic plaque. However, the restenosis rate with lasers, including balloon lasers, has not been as good as originally hoped. Nonetheless, research with these procedures continues.

Transmyocardial Laser Revascularization

Transmyocardial laser revascularization is reserved for patients whose arteries are so diseased both upstream and down that bypasses, balloon angioplasties, or stents are no longer an option. In this case, a laser is used to bore tiny holes in the heart muscle itself, in the hope that new blood channels will develop.

The lasers can be introduced into the left ventricular cavity through the catheter or directly with surgery (See Chapter Eight).

Catheter Heart Valve Procedures

Besides the coronary arteries, narrowed heart valves can be dilated with balloon catheters (Fig. 6.3). They tend to be quite successful in treating infants and children born with narrowed pulmonary heart valves, and they are also sometimes used to dilate narrowed aortic valves in newborns.

In adults, balloon catheters are used to treat mitral valves abnormally narrowed as a result of rheumatic fever. Although the balloon catheter can be very successful in treating mitral valve stenosis and can spare the patient a heart operation, this procedure is not applicable to every patient.

It is not very effective in treating adult patients with aortic valve stenosis

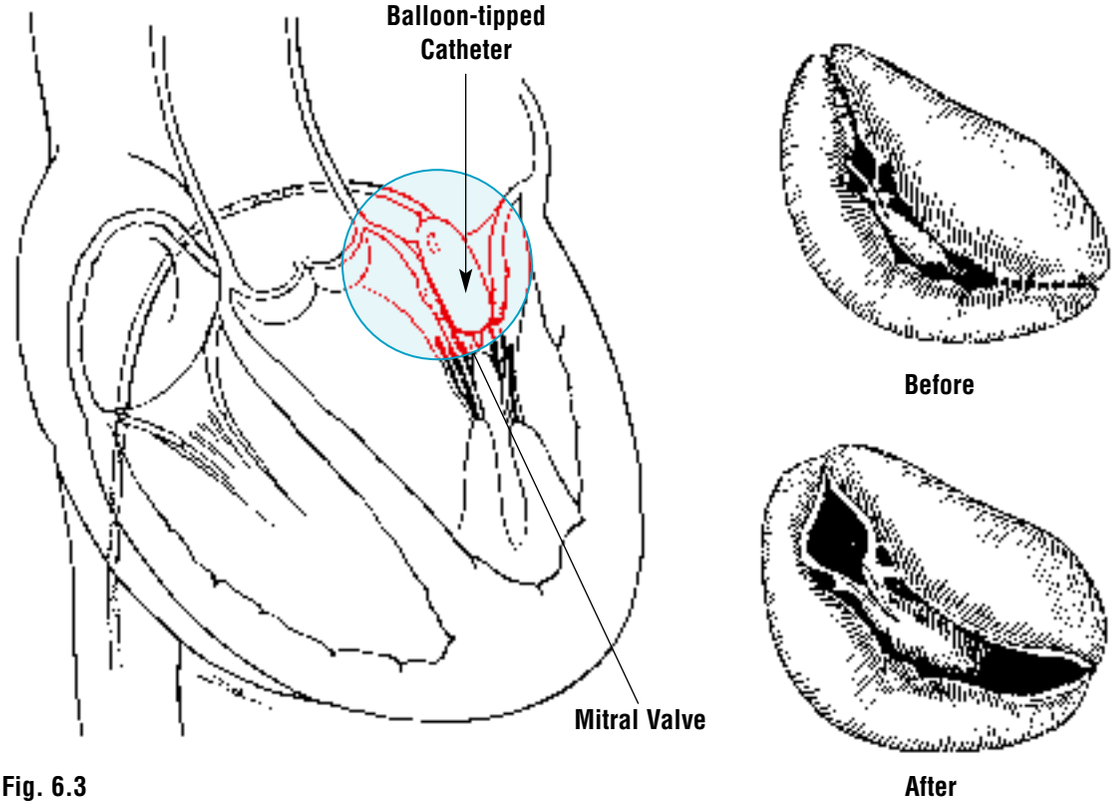


Fig. 6.3

but is sometimes used in desperate cases, such as when patients have other major medical problems and may not survive a heart operation, or to get critically ill patients in better physical condition for aortic valve surgery.

Other Heart Catheter Procedures

Catheters are also used to introduce devices that plug some holes between the two atria, or upper chambers of the heart, called atrial septal defects. This procedure is still undergoing trials under the auspices of the U.S. Food and Drug Administration (FDA).

In some cases, they can plug a patent ductus arteriosus, which is an abnormal vessel connecting the aorta and the pulmonary artery that is present in some children after birth. **Coarctation of the aorta** is another congenital condition and happens when a segment of the descending thoracic aorta is narrowed. This problem is treated surgically, but the narrowing can recur. If that happens, a balloon catheter can sometimes be used to dilate the narrow segment of the blood vessel.

Catheters are often used to make or enlarge a hole in the atrial septum in infants born with a heart defect called **transposition of the great arteries**. Called the Rashkind procedure and Rashkind Balloon Septostomy, it is named after Dr. William Rashkind, a pediatric cardiologist who developed the procedure at the Children's Hospital of Philadelphia. The procedure allows oxygenated and unoxygenated blood from the two sides of the heart to mix, which buys time until surgical correction is done.

Catheters are also used to retrieve foreign bodies such as intravenous lines or other materials that are sometimes mistakenly left in the heart or blood vessels.

Fig. 6.3: Balloon-tipped catheters are also used to open blocked heart valves. They can be used in both infants and adults to treat a variety of valvular blockages.

Coarctation of the Aorta: A birth defect in which there is a segment of the aorta that is abnormally narrowed. Typically, this coarcted area is in the descending aorta just after the aortic arch.

Transposition of the Great Arteries: A severe congenital heart defect in which the aorta, which normally comes off the left ventricle, instead originates from the right ventricle, and the pulmonary artery, which normally originates from the right ventricle, originates from the left ventricle.

How to Choose a Cardiac Surgeon

By
Julie A. Swain, M.D.
Cardiothoracic Surgeon
Professor of Surgery
Gill Heart Institute at the University of Kentucky College of Medicine
Lexington, Kentucky

THE PROSPECT OF UNDERgoing heart surgery terrifies most patients and their family members. Moreover, many cardiac surgery operations, especially coronary bypass procedures, must be done urgently. If it is possible to schedule the operation for a future date, patients will have a greater opportunity to ask questions to guide them in the choice of a surgeon and a hospital. However, if an immediate operation is needed, it should not be delayed.

When Surgery Is Recommended

Almost always, a cardiologist will diagnose a condition and, if warranted, will recommend surgery. The cardiologist may then recommend a surgeon or ask the family physician to recommend a surgeon. A personal recommendation by a cardiologist or primary care physician is the most common way a surgeon is chosen. This remains one of the best methods of choosing a surgeon. It is appropriate,

however, to ask questions about the surgeon.

A cardiologist has an obligation to know the "track records" of the surgeons to whom he or she refers. The majority of the referring doctors send patients to the surgeon whom they think will deliver the best care. However, in this era of managed care and other economic factors, referrals might be influenced by other considerations.

How to Judge Surgical Quality

The track records of cardiac surgeons have been subjected to closer scrutiny than those of any other physicians. This is because cardiac surgery is high profile and high cost, and the results are relatively easy to measure and compare. The most common indicator used to judge the quality of a surgeon is the death rate after cardiac surgery.

The average death rate after coronary bypass surgery is three out of every one hundred patients operated upon (3 percent). A patient who is older or has other diseases has a higher risk, whereas younger patients without serious medical conditions are at a lower risk of dying after surgery. To judge the quality of a surgeon or surgery program, one has to know how "sick" their patient population is. Much effort has been made to develop a "risk-adjustment" scale to level the playing field.

What You Should Know about Cardiac Surgery Databases

The Society of Thoracic Surgeons, the main professional

organization for cardiac surgeons, has spent years developing a database for risk adjustment. Although individual surgeon data and hospital data are not available, the national average data can be accessed by the public on the Internet at **www.sts.org**. Most of the cardiac surgeons in the country use this database to track their results and to compare themselves with other surgeons.

Other databases exist for regions (such as Northern New England and Cleveland) and for the Veterans Affairs hospitals. New York and Pennsylvania have databases that are available to the public and rate both individual surgeons and hospitals. Surgeons themselves should be enrolled in a database to be able to assess their results. Although many of these databases only rate the quality of results for coronary bypass operations, other operations usually parallel these results.

Still another database at **www.healthgrades.com** contains Medicare data for all heart surgery programs in the United States.

A surgeon may have a very low death rate because he or she is an excellent surgeon. Alternatively, the surgeon may be average or worse and have a low death rate because he or she only operates on the lowest risk patients. Likewise, an excellent surgeon can have a high death rate because he or she operates on the sickest of patients. The databases were developed to help physicians and hospitals sort out these results. For example, a surgeon who operates on very complicated cases may have a death rate of 4 percent (four out of every one hundred patients). If the predicted death rate from the database is 8 percent, then this death rate of 4 percent shows he or she is an excellent surgeon. Conversely, if the predicted death rate is only 2 percent and the actual death rate is 4 percent, the results indicate a worse-than-average track record.

Referring physicians should know the track records of the surgeons to whom they refer and be able to explain these relatively complicated scales to their patients. Likewise, every surgeon should know their results and share them with their referring doctors and prospective patients.

Is Bigger Necessarily Better?

There is much controversy about whether the quality of surgery is better at a big hospital where a large number of operations are performed versus at a smaller hospital. Excellent results are obtained by some small programs, whereas lower-quality results may be obtained by some

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Information on cardiac surgeons can be found on the Internet. The Society of Thoracic Surgeons website, left, posts a database at **www.sts.org**. Medicare statistics can be found at **www.healthgrades.com**, below.

large programs. There seems to be a certain minimum number of operations needed to keep an open heart team trained. This number is about two hundred operations per year.

Almost every state and most large cities have at least one high-quality surgery program. It is advantageous to have medical care close to home for many reasons, including ready access to follow-up care, proximity to family and social support structures, and the ability to be cared for by your own physician.

Surgeons Perform Operations, Not Hospitals

It may seem obvious, but surgeons perform operations, not hospitals. There may be a wide range between the abilities of different surgeons at the same hospital. However, the quality of a hospital can affect the results of all surgeons.

Surgeons should appreciate the opportunity to have an informed patient and be willing to answer all questions. The rapport patients develop with their surgeon will be important in the postoperative period, and it is important that patients are comfortable talking with the surgeon.

The following questions are suggested to help evaluate the quality of care. Patients may want to give this list to the surgeon to guide the discussion. After talk-

ing with their surgeon, patients may also want to discuss the answers with their cardiologist or primary care physician.

The Top Ten Things You Need to Ask before Cardiac Surgery

1. How many of these operations has the surgeon personally performed in the past three years? (A prevailing opinion is that a surgeon should perform at least seventy-five open heart surgery operations per year, although more experienced surgeons can obtain excellent results even though they may do fewer operations per year.)
2. What percentage of the surgeon's patients over the last three years have died in the hospital after coronary bypass operations?
3. Does the surgeon use a nationally recognized database to compare his/her results to those of other surgeons? How do the results compare? If a state database exists in your area, how does this surgeon rate?
4. Is the surgeon board certified by the American Board of Thoracic Surgery? (This is the only certifying organization for United States–trained surgeons and requires a rigorous examination process and documented training in a residency approved by the Board.)
5. Is the surgeon a fellow of the American College of Surgeons? (Don't be confused by names such as the "International College of Surgeons." The American College of Surgeons requires a peer evaluation of surgical practice and is the largest professional organization of board-certified American surgeons.)
6. Why did your doctor choose this hospital over any others in which the surgeon operates?
7. How many open heart operations are done per year at this hospital? How long has the hospital had an open heart surgery program?
8. Does the operating room have staff in the hospital twenty-four hours a day for emergencies? (Open heart surgery patients sometimes have to return to the operating room quickly.)
9. Who will assist the surgeon with the operation? (Some states require a second surgeon to be present in the operating room.)
10. Will there be a physician or physician's assistant in the hospital overnight to take care of you if an emergency arises? Are these people trained in cardiac surgical care?

These questions about case volume and quality assessment can also apply to a choice of cardiologist for an angioplasty procedure.

It must be emphasized that the personal recommendation of a trusted physician who is knowledgeable about cardiac surgery is very important and should be used in combination with these guidelines.