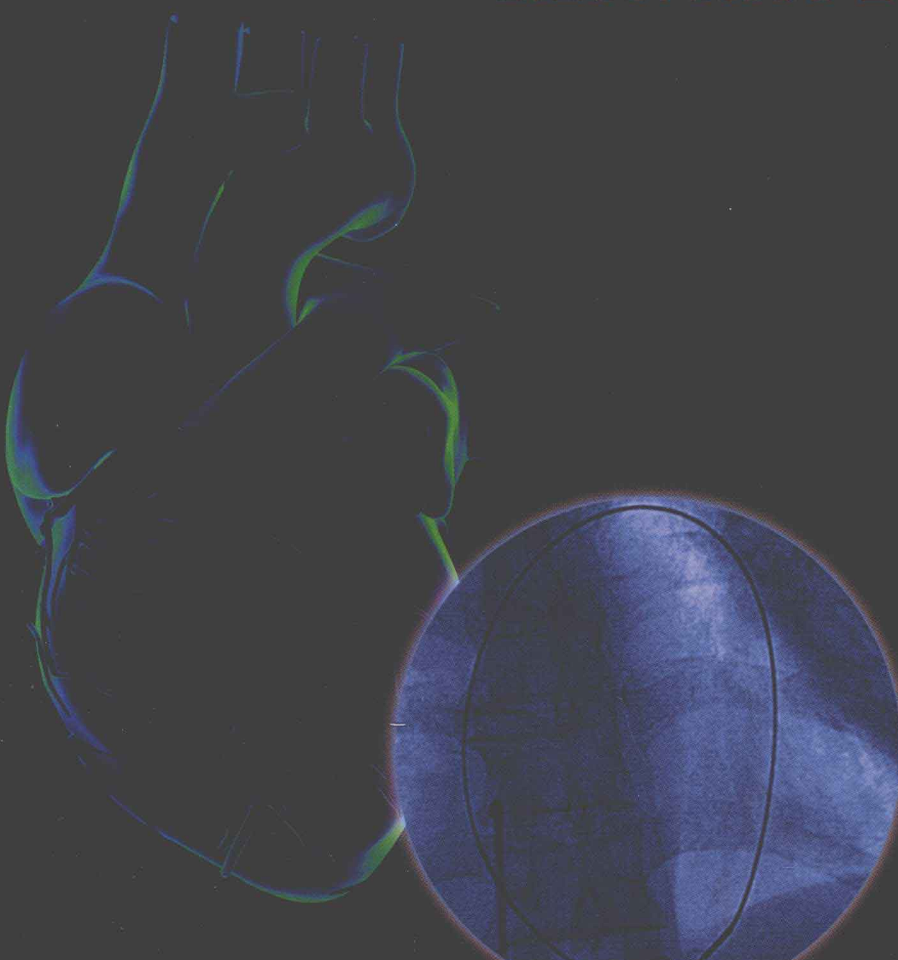
CARDIAC CATHETERIZATION

An Atlas and DVD

Michael Ragosta



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Cardiac Catheterization:
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Cardiac Catheterization: An Atlas and DVD

PREFACE

Cardiac catheterization laboratories are very exciting places. Lives are routinely saved in this fast-paced, high-tech environment, and even the most jaded clinicians find the diagnostic and therapeutic procedures fascinating. In addition to clinical service, other functions vital to a modern hospital, such as education, training, and clinical research, are centered in the cardiac catheterization laboratory.

Percutaneous interventional procedures often receive greater interest than the less glamorous, invasive diagnostic studies. However, the fundamental skills inherent to diagnostic catheterization form the foundation for more complicated procedures. It is crucial that an operator become highly proficient in the techniques used to gain arterial and venous access, enter the various chambers of the heart, measure and interpret hemodynamic waveforms, and perform and interpret angiography of the heart chambers, the coronary arteries, and the aorta and its branches.

In addition to mastering the physical manipulations required to perform cardiac catheterization, a competent clinician must also learn to carefully scrutinize the angiographic and physiologic data produced during the procedure. There is a disturbing tendency to equate procedural speed with technical proficiency. While an efficiently performed procedure is desirable, the operator has failed if the end result of this frantic effort is a collection of nondiagnostic images and indecipherable data. There is simply no excuse for poor-quality angiograms and sloppy hemodynamic studies, and it goes without saying that the capable clinician always strives to obtain the highest-quality diagnostic data.

Finally, in addition to technical proficiency and production of high-quality data, competency entails a solid understanding of the array of normal and pathologic findings and the ability to recognize and manage all potential complications.

It is the goal of this book to help the operator master these fundamental skills. All routinely performed diagnostic catheterization procedures are described in detail, emphasizing the practical and technical aspects of the techniques. Importantly, this book is designed to serve as an image atlas. Still frames in the text are augmented by almost 200 movies contained on the enclosed DVD representative of both common and rare conditions encountered during diagnostic catheterization. This book attempts to distill many years of experience into a single volume with the inclusion of images collected over 15 years of practice in a busy, cardiac catheterization laboratory.

This book and supplemental DVD are designed primarily for cardiologists in training, practicing cardiologists, and cardiac catheterization laboratory nurses and technicians. Both novice and advanced individuals will find interest in the text and in the wide breadth of images available for review. The book and supplemental DVD may also be of interest to anyone involved in the care of cardiac patients, including coronary care unit nurses, nurse practitioners, physician assistants, and internal medicine and critical care physicians.

"To study the phenomenon of disease without books is to sail an uncharted sea, while to study books without patients is not to go to sea at all."

Sir William Osler

ACKNOWLEDGMENTS

The abundant examples of normal and pathologic conditions observed in the cardiac catheterization laboratory form the core of this book and atlas. These could not have been collected single-handedly. Aware of my obsession with finding the perfect example of each of these entities, I would like to thank my colleagues, namely Drs. Ian J. Sarembock, Eric R. Powers, Scott D. Lim, and Lawrence W. Gimple, as well as many of the cardiology fellows at the University of Virginia for their ongoing vigilance for the ideal "teaching case." Their contributions augmented my teaching collection and provided many of the cases appearing in this work. I would also like to pay tribute to the many patients I had the privilege of caring for and whose images are provided here. All physicians recognize that one never wants to be inflicted with an "interesting disease"; I hope there is some consolation to the patients included in this work that their afflictions offer valuable lessons, thereby helping future patients. Finally, I want to thank my wife, Kiyoko, and my three marvelous children, Nick, Tony, and Sachi, for their support and patience while writing this text.

CONTENTS

CHAPTER 1

Patient Evaluation

Many functions vital to modern medical centers occur in the cardiac catheterization laboratory. Cardiologists perform numerous diagnostic and life-saving therapeutic procedures each day in this highly technical environment. Countless physicians, nurses, and technicians regularly undergo important medical training, and many of the recent strides in cardiovascular medicine are based on research activities focused in the cardiac catheterization laboratory.

The complex and fast-paced environment that characterizes the modern cardiac catheterization laboratory also provides an ideal breeding ground for serious problems. Catheter-based procedures entail significant patient risks, and the consequences of even minor mistakes can be devastating. Ensuring that each patient undergoes proper evaluation before catheterization and that the appropriate procedures are performed with the minimal possible risk are important principles that underlie all successful cardiac catheterization laboratory enterprises. Importantly, optimal patient outcomes depend on a "systems"-based approach with development of patient care protocols based on input and cooperation of a team of professionals including physicians, nurses, pharmacists, technicians, and administrators.

Preprocedural Evaluation. All patients require a thorough evaluation before undergoing a procedure in the catheterization laboratory consisting of a focused history and physical examination, and a review of pertinent tests such as laboratory values, the electrocardiogram, noninvasive studies, and prior catheterizations.

Table 1-1 lists the crucial elements in the patient's medical history. It is important to screen for any history of bleeding or recent surgery that may influence the use of heparin, aspirin, or platelet inhibitors. Similarly, several comorbid conditions such as renal failure, pulmonary, cerebrovascular, and peripheral vascular disease are predictive of increased risk of catheterization and impact decisions regarding surgical versus percutaneous revascularization. Details of prior peripheral vascular surgery or intervention are important to determine the route of arterial access chosen for catheterization. This must be defined before the procedure and not when the operator is finding it difficult to secure vascular access. For patients who have undergone prior coronary bypass surgery, it is imperative to know the nature and location of the bypass grafts. Similarly, it is helpful to review the angiograms of patients who have undergone a previous cardiac catheterization or coronary intervention. Other important issues to discern include the presence of a patient's advanced directives and "do not resuscitate" orders, blood product refusal, the patient's ability to follow directions, communicate, and give informed consent, and for female patients, their childbearing potential and the need for pregnancy testing before the procedure.

A precatheterization physical examination focuses on the cardiovascular system. Auscultation of the heart assesses for the presence of murmurs. Examination of the brachial, radial, femoral, and distal lower extremity pulses is critical to determine the location of arterial access. In addition to palpation, the examiner should auscultate over the femoral, abdominal, and subclavian areas in search of bruits that might suggest the presence of occlusive disease. Blood

Table 1-1. Precatheterization Evaluation: Key Elements of Medical History

1. Indication for cardiac catheterization
2. Nature of the presenting syndrome
3. Allergies or intolerances
   a. Intravenous contrast or iodine
   b. Benzodiazepines, opiates, other sedatives
   c. Aspirin, heparin, protamine, platelet glycoprotein IIb/IIIa inhibitors
   d. Beta-blockers or nitrates
4. Bleeding disorder or tendency
5. Relevant comorbid illnesses
   a. Renal insufficiency
   b. Diabetes mellitus
   c. Significant pulmonary disease
   d. Cerebrovascular disease
   e. Peripheral arterial disease
6. Prior coronary diagnostic or revascularization procedures

pressure measured in both arms serves as a screen for subclavian stenosis; a systolic pressure difference of more than 10 mm Hg suggests significant subclavian disease. If subclavian artery stenosis is suspected and it is determined that the patient needs coronary bypass surgery, angiography is necessary to assess the suitability of using the left internal mammary artery as a bypass graft. Patients under consideration for a radial access approach should undergo an Allen's test (see Chapter 2). A focused physical examination also includes an assessment of the airway and documentation of the American Society of Anesthesiologists (ASA) Classification to determine the suitability for conscious sedation (Tables 1-2 and 1-3).

Several laboratory parameters routinely evaluated before cardiac catheterization include a complete blood count with platelets and levels of serum glucose, electrolytes, blood urea nitrogen, and creatinine. Patients who take warfarin and patients with liver disease, severe right-sided heart failure, or history of bleeding disorder require measurement of a prothrombin time usually expressed as an international normalized ratio (INR). All women of childbearing potential should have a serum pregnancy test checked before exposing them to radiation and potentially teratogenic medications. Laboratory values considered acceptable for catheterization are listed in Table 1-4; patients with laboratory values outside these parameters should not undergo elective catheterization until these abnormalities are addressed. In addition, the risk-benefit ratio of the procedure should be carefully considered for patients with other forms of laboratory derangement (e.g., marked hyperglycemia,

Table 1-2. Airway Examination before Conscious Sedation

1. Examine head and neck for abnormalities that lead to difficult intubation
   a. Neck range of motion (flexion and extension at least 35 degrees)
   b. Cervical spine instability or fusion
   c. Ability to open mouth
   d. Temporomandibular joint movement
   e. Mandible-hyoid bone distance (space between chin and notch of the thyroid cartilage with neck extended)
      • Adequate space is about 7 cm
      • Distance <7 cm is associated with more difficult intubation
2. Craniofacial abnormalities
   a. Congenital abnormalities
   b. Previous head or neck surgeries
   c. Previous head or neck radiation
3. Dentition and oral cavity
   a. Note missing, chipped, or loose teeth
   b. May need to remove partials for procedure
   c. Is uvula easily visualized when patient protrudes tongue?

Table 1-3. American Society of Anesthesiologists Classification

Class I

Class I includes patients with no organic, physiologic, biochemical, or psychiatric disturbances. The pathologic process to be treated is localized and does not entail a systemic disease.

Class II

Class II includes patients with mild systemic disease caused by either the condition to be treated or by other pathophysiologic processes (i.e., irritable airway caused by tobacco abuse). No functional limitations.

Class III

Class III includes patients with severe systemic disease from any cause, even though it may not be possible to de fine the degree of disability with finality. Examples are limiting organic heart disease, diabetes with vascular complications, moderate-to-severe degrees of pulmonary insufficiency, and obesity that may limit airway and respiratory management.

Class IV

Class IV includes patients with severe systemic disease not a constant threat to life. Examples include hospitalized patient with heart failure or persistent anginal syndrome and advanced degrees of pulmonary, hepatic, renal, or endocrine insufficiency.

Class V

Class V includes moribund patients not expected to survive without the operation/procedure. Conditions include profound shock, massive pulmonary embolism, ruptured blood vessels, and cerebral trauma with increasing intracranial pressure.

hyponatremia, acidosis). In general, for stable patients without a clinical suspicion of changing laboratory parameters (i.e., bleeding, renal failure, diuretic therapy), laboratory values no older than 30 days are acceptable.

Informed Consent. Informed consent is an extremely important part of the procedure and must be obtained for all patients before administration of conscious sedation. The physician begins by describing the planned procedure in layman's terms with the patient and the family. Then, the physician discusses the risks of conscious sedation, catheterization, and coronary intervention in appropriate detail. Providing informed consent takes great communication and interpersonal skills, and it is an important part of the procedure. Every patient deserves to hear the common potential complications of diagnostic cardiac catheterization (Table 1-5); these complications are discussed in greater detail in Chapter 3. The risks should not be glossed over or minimized. Patient dissatisfaction and potential lawsuits often arise from unexpected and improperly addressed minor complications. Depending on the patient's associated comorbidity, the likelihood of development of a serious complication might be higher than usual; the consent process should reflect this. For example, a patient with diabetes with a serum creatinine level of 3.0 mg/dL with multiple unmarked saphenous vein grafts should clearly understand the potential risk for development of further renal failure possibly

Table 1-4. Common Laboratory Values Acceptable for Elective Cardiac Catheterization

LABORATORY TEST	VALUE
Prothrombin time (international normalized ratio)	<1.6 for routine catheterization procedures <1.2 if associated thrombocytopenia <1.1 if transseptal catheterization or myocardial biopsy
Potassium level	3.2–5.8 mmol/L
Serum creatinine level	<1.5 mg/dL
Hematocrit	>28%
Platelet count	>100,000/mm^3

Table 1-5. Risks of Cardiac Catheterization

COMPLICATION	FREQUENCY RANGE
Serious complications Death, myocardial infarction, stroke	0.1–0.4%
Vascular access site complication Bleeding Vessel Injury Hematoma Pseudoaneurysm Arterial thrombosis	1–6%
Renal failure	1–5%
Contrast allergy	0.1–0.5%
Risk of conscious sedation Respiratory failure	0.1–0.5%
Miscellaneous Infection Cardiac perforation Catheter entrapment Nerve injury Pulmonary embolism	Rare (<0.1%)

requiring dialysis after the procedure. Under no circumstance should a physician "talk a patient into" cardiac catheterization. Finally, a realistic and frank description of the risks involved is important, but it must be tailored to the patient. Some patients require a detailed and careful explanation of each potential risk; others need more in the way of reassurance when each risk is explained, sparing them graphic details.

Planning the Appropriate Procedure. Based on the precatheterization evaluation, the physician should determine the site of vascular access and plan the exact procedure to be performed. It should be determined whether a right heart catheterization is indicated. In general, any patient with a heart failure syndrome, unexplained dyspnea or edema, congenital heart disease, pericardial disease, or valvular heart disease, and any patient under evaluation for a heart, lung, or liver transplantation may require a right heart catheterization. Similarly, patients with unusual chest pain syndromes may need a right heart catheterization to exclude pulmonary hypertension. Patients undergoing catheterization primarily for the evaluation of recent acute myocardial infarction, stable or unstable angina, or chest pain syndromes without heart failure, hypotension, edema, or suspicion of a mechanical complication generally do not require right heart catheterization.

The location of vascular access should be decided. Most operators in the United States use the right or left femoral artery for arterial access. The presence of an arterial bruit in a patient with peripheral vascular disease does not exclude that artery as a site as long as a femoral pulse is present. In general, the presence of previous arterial bypass surgery (femoral-popliteal bypass or aortobifemoral bypass) does not exclude those locations as a possible access site but should be avoided if possible, particularly if surgery has been recent. Gaining central aortic access from the femoral region in the presence of a femoral-femoral or axillary-femoral bypass may prove difficult or impossible in some patients and should be avoided. Brachial artery access is reserved for patients with extensive vascular disease and no arterial pulses in the femoral region, and possibly patients who have had bilateral femoral vascular surgery. Radial artery access is becoming increasingly popular and can be considered in patients with peripheral vascular disease but may also be used routinely as an alternative to femoral access. Radial or brachial artery punctures are also performed for patients with morbid obesity or inability to lie flat for the procedure (e.g., in patients with severe lung disease or lower back conditions).

The type of contrast agent should be determined. A more detailed discussion regarding the different iodinated contrast agents is presented in Chapter 10. Most diagnostic catheterization laboratories use nonionic agents. The more expensive, nonionic, isosmolar contrast agents are used in patients with renal insufficiency or who undergo peripheral angiography because of less irritation. In patients with renal failure, use of a biplane laboratory, if available, may help reduce contrast use and decrease the likelihood of contrast-induced nephropathy.

It should be assumed that all patients who undergo left heart catheterization also undergo left ventriculography. Important exceptions include patients with renal failure in whom it is desirable to limit contrast volume, patients with decompensated heart failure and abnormal hemodynamics (i.e., left ventricular end diastolic pressure > 30 mm Hg) who may not tolerate the additional volume of contrast, and patients with severe aortic stenosis. Most patients who undergo left heart catheterization will undergo coronary angiography. Some rare circumstances include young patients without coronary risk factors referred for evaluation of congenital or valvular heart disease.

Aortography of the aortic root and thoracic aorta may be performed in patients with aortic regurgitation or a thoracic aortic aneurysm. Abdominal aortography is often performed as a screening test for suspected renal artery stenosis at the time of cardiac catheterization in patients with uncontrolled blood pressures refractory to multiple antihypertensive agents or in other situations in which renal artery stenosis is suspected. Selective renal angiography and intervention and abdominal aortography, and lower extremity runoff procedures for peripheral vascular disease are not usually combined with a diagnostic cardiac procedure except in special circumstances because of the concern about excessive contrast exposure and the risk of multiple procedures at one sitting.

Right ventricular biopsies are performed primarily in patients who have had cardiac transplantation. Endomyocardial biopsies in patients without transplantation carry a greater risk for perforation. These are occasionally performed during the diagnostic evaluation of patients with heart failure.

Patients with coronary disease who require bypass surgery found to have a subclavian bruit or a reduction in arterial blood pressure in the left arm relative to the right arm should undergo subclavian angiography to determine the presence of disease in the subclavian artery that might alter the use of the left internal mammary for bypass surgery. In addition, internal mammary angiography should be considered in patients who require repeat coronary bypass surgery or in patients who have had prior thoracotomy or chest wall irradiation to be sure there was no damage to the left internal mammary.

During diagnostic catheterization, trans-septal left heart catheterization is required in patients with a mechanical aortic prosthesis in whom it is necessary to measure left heart pressures (e.g., to assess transaortic or transmitral gradient) or to perform left ventriculography. Other diagnostic indications for trans-septal catheterization include the need to precisely determine left atrial pressure in a patient with suspected mitral stenosis or the desire to avoid crossing the aortic valve retrograde in patients with severe aortic stenosis. Trans-septal procedures are used extensively to perform many electrophysiologic procedures, mitral balloon valvuloplasty and new interventional procedures such as closure of atrial septal defect and patent foramen ovale, percutaneous mitral valve repair, insertion of a percutaneous left ventricular assist device, and delivery of left atrial appendage exclusion devices. Valve fluoroscopy is another procedure occasionally performed in the catheter laboratory to evaluate for mechanical valve thrombosis or malfunction.

Preprocedural Orders. Commonly used physician orders before routine cardiac catheterization are listed in Table 1-6. In addition to these, most physicians recommend holding all oral hypoglycemic agents and giving a half dose of long-acting (NPH) insulin on the morning of the procedure; patients with an insulin pump should be kept at the prescribed basal rate throughout the procedure and their procedure planned early in the day to avoid a prolonged fasting state. Because of the potential for dehydration, consider holding any

Table 1-6. Preprocedural Orders

1. No solid food after midnight the night before the procedure
2. May have clear liquids until 0600 the morning of procedure and then nothing by mouth except for medications
3. If patient is to undergo an afternoon procedure, then a clear liquid breakfast is acceptable with nothing by mouth after that except for medications
4. Begin an intravenous infusion of 0.9% NaCl at 100 mL/hr
5. For patients at risk for contrast-induced nephropathy, initiate renal protection protocol (1)
6. For patients with history of contrast allergy: prednisone 60 mg by mouth the night before and the morning of the procedure; diphenhydramine 50 mg by mouth or intravenously just before the procedure
7. Consider an oral sedative just before the procedure (benzodiazepine)
8. Instruct the cardiac catheterization laboratory personnel to prepare the vascular access site

regularly scheduled diuretics. Intravenous heparin infusions are usually continued until just before the procedure. Similarly, for patients with acute coronary syndromes, the intravenous platelet glycoprotein IIb/IIIa inhibitors should not be interrupted. Warfarin is routinely held at least 48 to 72 hours before procedure with INR checks as noted earlier. For renal transplant patients taking cyclosporine or FK506 (Prograf), the morning dose before catheterization is typically held to minimize vasoconstriction and resumed the following day.

Postprocedural Orders. Postprocedure orders are important to help minimize potential complications. Commonly used orders are listed in Table 1-7. Management and monitoring of the vascular access site after the procedure is the most important aspect of these orders.

Table 1-7. Postprocedural Orders

1. Intravenous fluids: 0.9 NaCl 1 L at 150 mL/hr to finish present bag, then convert to saline lock or at "keep vein open" rate until sheaths removed
2. Once sheath has been removed, encourage fluids by mouth
3. Temperature on return to unit
4. **Before arterial sheath removal:**
   a. Bed rest and nothing by mouth
   b. Check vital signs (blood pressure and heart rate) and the affected limb temperature and sensation, distal pulses, and cannulation site for hematoma or bleeding every 15 minutes for 1 hour, then every 30 minutes for 1 hour, then every 1 hour for 2 hours, then every 2 hours until sheaths removed
   c. If patient received heparin, sheath to be removed when activated clotting time <180 seconds
5. **After arterial sheath removal**
   a. For femoral approach: bed rest for 2–4 hours with affected limb straight after sheath removal and dressing applied; the head of bed may be raised 30–60 degrees and may logroll patient side to side, then increase activity as tolerated; at completion of bed rest, obtain orthostatic vital signs before ambulation
   b. For brachial/radial approach: bed rest with affected limb flexed at chest at 90 degrees until 2 hours after sheath removal and dressing applied; assess capillary refill and sensation in hand, radial pulse (in brachial access), ulnar pulse (in radial access), and cannulation site for hematoma or bleeding; head of bed may be raised 90 degrees and patient may turn side to side, then increase activity as tolerated; at completion of bed rest, obtain orthostatic vital signs before ambulation
   c. For patients with arterial closure device: bed rest for 1–2 hours after arterial sheath removal and dressing applied; head of bed may be raised 60 degrees; patient may freely move in bed immediately after procedure as long as there is no bleeding at access site; at completion of bedrest, obtain orthostatic vital signs before ambulation
   d. When sheaths removed, check vital signs, distal pulses, access site, cannulated limb temperature, and sensation every 15 minutes for 1 hour, then every 30 minutes for 1 hour, then every 1 hour for 2 hours
6. May place bladder catheter for inability to void while on bed rest; discontinue at completion of bedrest
7. At completion of bed rest, remove adhesive dressing (if any) and evaluate site for hematoma, bruit, ecchymosis, or rash
8. Call physician for any change in pulses or appearance of cannulated limb from baseline, bleeding from site, hematoma formation, hypotension, chills, fever, or chest pain suggestive of angina, change in extremity temperature, mottling, paresthesia or pain in affected extremity, or blood pressure <90 mm Hg
9. Medications: analgesics for procedural pain, antacids, medication for nausea, sleeping aids
10. Order diet

Often, trained nurses or technical personnel remove arterial sheaths. At some institutions, sheath removal by less experienced individuals in certain "high-risk" patients may not be appropriate. These include patients with severe aortic stenosis or severe aortic regurgitation, severe left main stenosis, coagulopathy or thrombocytopenia, presence of a large access site hematoma, severe hypertension, morbid obesity, or severe peripheral vascular disease.

At least one patient visit after the procedure is important to determine the presence of any periprocedural complications such as dye reactions, subtle neurologic complications, and vascular complications. This visit also provides the patient an opportunity to ask questions regarding his or her procedure. Activity is typically restricted for 2 days after cardiac catheterization.

Reference

1. Schweiger MJ, Chambers CE, Davidson CJ, et al: Prevention of contrast induced nephropathy: Recommendations for the high risk patient undergoing cardiovascular procedures. Catheter Cardiovasc Interv 2007;69:135–140.

CHAPTER 2

Vascular Access and Hemostasis

All cardiac catheterization procedures begin with obtaining vascular access and end with achieving hemostasis. These two steps are often considered trivial, yet they arguably constitute the most important parts of the procedure. Vascular complications remain the most common cause of morbidity from cardiac catheterization, with several of them potentially life-threatening. Most complications are related to improper technique for gaining access or achieving hemostasis.

General Considerations in Obtaining Vascular Access. Choosing the arterial or venous access site is the first major decision facing a physician during cardiac catheterization. In the United States, the right femoral artery and vein are the most common access sites; the right internal jugular vein is the most common site when right heart catheterization alone is performed. The operator may seek alternatives to these sites depending on several important patient characteristics. For example, significant obesity may lead to difficulties with femoral access; radial access may be easier and reduce risk in such patients. The presence of peripheral vascular disease, prior vascular surgery, or intervention may prevent access via the usual route and require use of an alternative site. The risk for bleeding is another important variable. Patients at greater risk for bleeding (e.g., lytic state; severe, uncorrectable coagulopathy; marked thrombocytopenia) require careful planning regarding the access site. Finally, patient comfort is an important consideration, and an inability for a patient to lie flat may necessitate brachial or radial approaches instead of a femoral site.

Equipment Choices. A variety of needles, guide wires, and sheaths are available for securing arterial or venous access. The classic method of obtaining arterial access uses a two-piece, hollow-core needle with an obturator (Seldinger needle or modified Potts needle) to puncture the artery. This has mostly been abandoned by most operators for a one-piece, hollow-core needle without an obturator. Once an artery or vein has been successfully punctured, a guide wire is advanced through the lumen and the needle removed. Usually, a 0.035-inch, 145-cm-long J wire is used for the artery. Note that the standard J wire has a 3-mm diameter "J" loop. This may be too large when accessing smaller diameter arteries, necessitating the use of a smaller diameter J loop (1.5 mm). In the presence of peripheral vascular disease or vessel tortuosity, hydrophilic coated wires or "glide wires" are useful. Sheaths are used to secure access. Most cardiac catheterizations and interventions use 11-cm-long, 5- to 8-French (Fr) sheaths. Longer sheaths (24, 45, or 80 cm) are useful when there is iliac disease or severe vessel tortuosity, and larger diameter sheaths are available to perform some specific procedures. The sheath size refers to the internal lumen of the sheath (Table 2-1). The outer diameter of the sheath (i.e., the size of the hole it will make in the artery or vein) is larger than the stated French size of the sheath. In general, the external diameter of the sheath is 2 French sizes

Table 2-1. Inner and Outer Diameters of Various Sheath Sizes

SHEATH SIZE (FRENCH)	INNER DIAMETER	OUTER DIAMETER
5	1.7 mm/0.066 inch	7–8 French (Fr)
6	2.0 mm/0.079 inch	8–9 Fr
7	2.3 mm/0.092 inch	9–10 Fr
8	2.7 mm/0.105 inch	10–11 Fr
9	3.0 mm/0.118 inch	11–12 Fr
10	3.3 mm/0.131 inch	12–13 Fr

larger than the internal diameter of the sheath but may be larger or smaller depending on the specifications of the manufacturer. Many different sheaths are available on the market, with different properties useful to the operator such as hydrophilic coatings to ease passage and braided metal to prevent kinking.

Femoral Arterial Access. Left heart catheterization in the United States is most commonly performed from the femoral arteries. Nearly all vascular access is achieved using some form of the Seldinger technique, described in 1953 by the Swedish radiologist Sven-Ivar Seldinger (1921–1999). The essential steps of the Seldinger technique require puncture of the artery with a needle, passage of a guide wire through the needle lumen into the vessel, removal of the needle, and finally, replacement of the needle with a sheath or catheter.

To access the right femoral artery, the operator holds the needle with the right hand with the needle positioned between the thumb and index finger with a grip similar to holding a pencil. The index and middle fingers of the left hand are used to palpate the arterial pulse and anchor the artery. The needle is advanced at a 30- to 45-degree angle until arterial blood spurts in a pulsatile fashion from the end of the needle. The original technique used a needle with a solid obturator and intentionally passed the needle through the back wall of the artery, removing the obturator and slowly withdrawing until pulsatile blood returns. Most operators now try to puncture only the front wall of the artery. Blood should be freely pulsatile; if blood return is bright red but not pulsatile or only weakly pulsatile, the needle tip may be partially subintimal, against the wall or in a small side branch. Guide wire passage should not be attempted unless flow is brisk and pulsatile.

Once the operator is satisfied that the needle tip is within the lumen of the artery, the J-tipped guide wire is advanced through the needle lumen. The wire should pass freely with absolutely no resistance. The presence of resistance indicates a subintimal location of the needle tip, access of a small side branch instead of the appropriate vessel, or the presence of a stenosis. Difficulty passing a guide wire immediately on exiting the needle tip usually indicates a subintimal or side branch location and not a stenosis; the needle should be removed and arterial puncture reattempted. The wire should never be forced because this may result in subintimal passage and arterial dissection, vessel perforation, or plaque disruption.

With the guide wire in place in the distal aorta, the needle is withdrawn while gently applying pressure on the vessel with the left hand to prevent excess bleeding. The sheath is passed over the wire and inserted fully. Once the sheath is in place, the guide wire is removed. Again, there should be minimal or no resistance when passing the sheath over the guide wire. A small skin nick (2–3 mm) facilitates passage of the sheath. In the event of scarring from prior catheterization procedures, the operator may find that first passing a dilator alone can help allow a smoother sheath passage.

The target of the arterial puncture is the common femoral artery. Many major and potentially lethal vascular complications are related to punctures either above or below the common femoral artery. Retroperitoneal bleeds are almost entirely due to high punctures, whereas low punctures into either the profunda femoris or superficial femoral arteries are associated with hematoma, pseudoaneurysm, or arteriovenous fistula. Thus, it is imperative for the operator to understand the anatomy and major landmarks of the region when gaining access from the femoral location.

The normal anatomy of the femoral vessels and their relations to several important landmarks are shown in Figure 2-1. The inguinal ligament provides the boundary between the common femoral artery and the external iliac artery. The ideal puncture site is below the inguinal ligament and above the bifurcation of the common femoral artery into the profunda and superficial femoral arteries.

Identifying this specific site is not easy. External landmarks are completely unreliable. The commonly used technique of palpating the pubic symphysis and anterior iliac spine followed by mental visualization of the location of the inguinal ligament is inaccurate. Some operators puncture relative to the inguinal crease, made up of the skin fold between the abdomen and the groin. In the idealized (and nonexistent) patient with a normal body habitus, the inguinal crease lies 1 to 2 cm below the inguinal ligament. Based on this observation, puncture at or just below the inguinal crease is a commonly performed practice for accessing the femoral artery. However, the inguinal crease is entirely unreliable and should not form the basis of the puncture location. In obese patients, the inguinal crease may be many centimeters below the ligament, with puncture at the crease resulting in puncture of the profunda femoris or superficial femoral artery. In very thin patients, the crease may be higher than expected, causing puncture of the external iliac instead of the common femoral artery.

Bony landmarks, imaged fluoroscopically, form the most reliable landmarks to guide arterial puncture (1). The common femoral artery lies over the medial aspect of the femoral head (Fig. 2-2). Directing the puncture toward the center of the femoral head successfully accesses the common femoral artery in most cases (1). Fluoroscopic guidance must be done properly, however. It is not correct to fluoroscopically determine the relation between the femoral head and the position of a needle or hemostat simply placed on the surface of the skin. Because the needle enters at an angle and penetrates several centimeters of superficial tissue before entering the artery, arterial puncture occurs at a point several centimeters higher than the skin entry site. Therefore, if the puncture site is determined fluoroscopically by placing the needle on the skin surface, the actual site of the arterial puncture may occur above the inguinal ligament. This is particularly true for obese patients. It is more correct to pass a small-gauge "finder" needle to the level of the artery and then perform fluoroscopy to confirm the position (Fig. 2-3).

With the sheath in place, femoral arteriograms are helpful to determine the precise location of the puncture and are particularly useful when deciding on the method to achieve hemostasis, particularly in an anticoagulated patient. The ipsilateral oblique projection (20–30 degrees) is used most commonly (i.e., right anterior oblique for the right femoral artery and the left anterior oblique for punctures of the left femoral artery). The opposite oblique may be used if this view does not show the entry site or if branches overlap. The location of the inferior epigastric artery should be carefully noted on femoral angiography. This is a crucial landmark because puncture above the most inferior border of the inferior epigastric artery (not the site of origin of the branch) is associated with retroperitoneal bleed (Fig. 2-4) (2). Examples of femoral arteriograms showing both optimal punctures and punctures above and below the common femoral artery are shown in Videos 2-1, 2-2, and 2-3.

Special Considerations in Femoral Arterial Access. Several commonly encountered situations add complexity to femoral arterial access. These include the presence of iliac tortuosity, peripheral vascular disease, and coagulopathy.

Iliac tortuosity is commonly observed, particularly in elderly patients or patients with long-standing hypertension, and can create great difficulty with catheter manipulation. When obtaining access in such patients, the operator may encounter resistance during guide wire passage. In addition, it may be difficult to advance or to torque catheters, and efforts to do this may kink or knot the catheter. Use of a long sheath helps straighten the iliac vessels and facilitate catheter manipulation. An example of severe iliac tortuosity requiring a long sheath is shown in Figure 2-5.