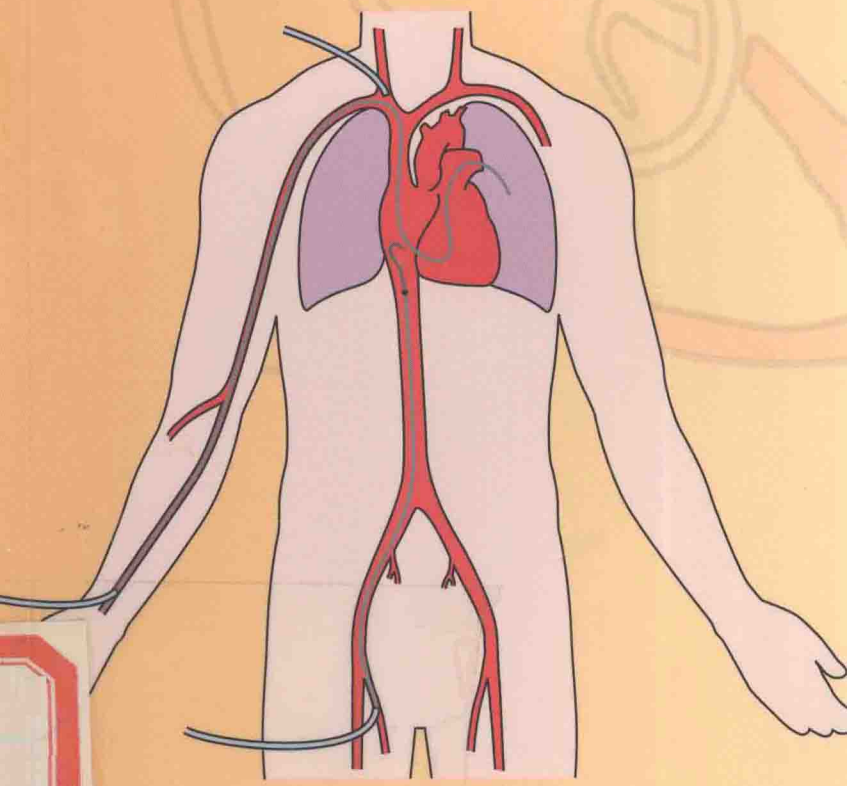
5TH EDITION

The Cardiac Catheterization Handbook

Morton J. Kern



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THE CARDIAC CATHETERIZATION HANDBOOK

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To Margaret and Anna Rose—inspirations beyond measure

Preface

Cardiac catheterization has been and will likely continue to be a central and key diagnostic procedure. The laboratory will serve as a major theater of therapeutic interventions for patients with heart disease, especially as new nonsurgical approaches emerge into daily use. The complex nature of the catheterization laboratory technology and techniques requires study and a clear understanding by the personnel involved to acquire diagnostic information and perform interventions in a safe and complete manner. The purpose of this handbook is to provide a basic, straightforward, and practical explanation of the cardiac catheterization laboratory and its procedures.

In this fifth edition of *The Cardiac Catheterization Handbook*, new material has been added to replace historical but now obsolete discussions and methods. As in the previous editions, the initial chapters are designed to assist the novice and newcomer, including nurses, technicians, students, residents, fellows-in-training, and new industry representatives to the catheterization laboratory. Descriptions on how the procedure should flow, what steps should be learned first, how to approach patients undergoing this often frightening test, being part of the catheterization laboratory team, and similar work matters are presented. New sections address recent requirements concerning conscious sedation, time-outs, informed consent, and workplace safety.

The most updated material is the vascular access technique in Chapter 2. Radial artery access is strongly emphasized. The newest femoral vascular closure devices are briefly presented. Matters of anticoagulation, coronary artery cannulation, and procedure-related complications have been edited to reflect modern practice. In subsequent sections, the hemodynamic and angiographic data chapters remain steadfast with minor modifications, adding new pressure tracings for review. The transition from traditional image intensifiers to modern flat-panel image detectors has occurred over the last several years, making the material on film, cameras, and operations of the older imaging systems of lesser importance. A new section added to this edition is Chapter 5, Dr. Patel's discussion of peripheral vascular disease and angiography. This aspect of cardiology and its exploration in the catheterization laboratory has become an everyday experience.

Discussion of electrophysiologic testing and device use in the catheterization laboratory have been dramatically updated and include descriptions of new modalities of remote guidance of electrophysiology catheters and electrophysiologic arrhythmia ablations. Because of the increasing complexity of procedures, the author, Dr. Krishnan, recommends a dedicated electrophysiology suite, outfitted with state-of-the-art imaging and electrophysiology mapping systems. For individuals working in electrophysiology laboratories and fellows entering this area while in training, this section also provides an excellent basic framework for understanding when and how these very specialized procedures should be used.

Chapters 7, 8, 9, and 10 are dedicated to special techniques, high-risk catheterizations, research techniques in the catheterization laboratory, and percutaneous coronary interventions. These chapters have been updated to provide both the fundamentals and the latest applications in everyday practice. The documentation section in the last chapter is worth reviewing for nurses and physicians alike. The understanding of recordkeeping in both patient care and medical legal matters should be part of a well-run catheterization laboratory.

Since both my profession and my avocation involve teaching in the laboratory and bringing this information to users, I am truly fortunate to be able to speak to such a large audience. I am grateful to the many people who have helped me over the years, encouraging me in my work with the catheterization laboratory. I thank my mentors, teachers, colleagues, and fellows. I thank the nurses and technicians in the many laboratories in which I have worked and visited. In my latest positions at the University of California, Irvine and the Long Beach Veterans Administration Medical Center, and despite my years on the job, I continue to learn a great deal from these diligent, delightful, and devoted catheterization laboratory teams.

I thank my wife, Margaret, and daughter, Anna Rose, who as I mentioned in *Hemodynamic Rounds*, now in its third edition, remain the systole of my life. I would also like to remind all new catheterization laboratory students not to be overwhelmed. As I once told my daughter and as she reminded me later, "It's not 'rocket surgery,' Dad. It's just the cath lab."

I hope *The Cardiac Catheterization Handbook* will continue to serve as a helpful and often-used reference. By improving our knowledge, we can take better care of families, friends, and all those who ultimately become our patients in the cardiac catheterization laboratory.

Morton J. Kern, MD

Contents

1

Introduction to the Catheterization Laboratory

MORTON J. KERN

Cardiac catheterization is the insertion and passage of small plastic tubes (catheters) into arteries and veins to the heart to obtain x-ray pictures (angiography) of coronary arteries and cardiac chambers and to measure pressures in the heart (hemodynamics). The cardiac catheterization laboratory performs angiography to obtain images not only to diagnose coronary artery disease but also to look for diseases of the aorta and pulmonary and peripheral vessels. In addition to providing diagnostic information, the cardiac catheterization laboratory performs catheter-based interventions (e.g., angioplasty and stents, now called percutaneous coronary intervention [PCI]) or catheter-based treatments of structural heart disease for both acute and chronic cardiovascular illness. Table 1-1 lists procedures that can be performed with coronary angiography. Figure 1-1 shows common access routes for cardiac catheterization.

Indications for Cardiac Catheterization

Cardiac catheterization is used to identify structural cardiac diseases such as atherosclerotic artery disease, abnormalities of heart muscle (infarction or cardiomyopathy), and valvular or congenital heart abnormalities. In adults the procedure is used most commonly to diagnose coronary artery disease. Other indications depend on the history, physical examination, electrocardiogram (ECG), cardiac stress test, echocardiographic results, and chest radiograph. Indications for cardiac catheterization are summarized in Table 1-2.

Elective Procedures

For most patients, cardiac catheterization is performed as an elective diagnostic procedure. It should be deferred if the patient is not prepared either psychologically or physically.

Urgent Procedures

If the patient's condition is unstable because of a suspected cardiac disorder, such as acute myocardial infarction, catheterization must proceed. In the event of decompensated congestive heart failure, rapid medical management is often needed. Although a patient must be able to lie flat for easy catheter passage, patients with acute cardiac decompensation may benefit more from aggressive management in the catheterization laboratory than from management in

Table 1-1

Procedures That May Accompany Coronary Angiography*

Procedure	Comment
1. Central venous access	Used as IV access for emergency medications (femoral, internal jugular, subclavian) or fluids, temporary pacemaker (pacemaker not mandatory for coronary angiography)
2. Hemodynamic assessment	
a. Left heart pressures	Routine for all studies (aorta, left ventricle)
b. Right and left heart	Not routine for coronary artery disease; combined pressures; mandatory for valvular heart disease; routine for CHF, right ventricular dysfunction, pericardial diseases, cardiomyopathy, intracardiac shunts, congenital abnormalities
3. Left ventricular angiography	Routine for all studies; may be excluded with high-risk patients, left main coronary or aortic stenosis, severe CHF, renal failure
4. Internal mammary artery selective angiography	Not routine unless used as coronary bypass conduit
5. Pharmacologic studies	
a. Intracoronary/intravenous/sublingual NTG	Routine for all coronary angiography
6. Aortography	Routine for aortic insufficiency, aortic dissection, aortic aneurysm, with or without aortic stenosis, routine to locate bypass grafts not visualized by selective angiography
7. Cardiac pacing and electrophysiologic studies	Arrhythmia evaluation
8. Interventional and special techniques	Coronary angioplasty (e.g., PTCA, stenting) Intracoronary flow-pressure for lesion assessment Balloon catheter valvuloplasty Myocardial biopsy Transseptal or direct left ventricular puncture Conduction tract catheter ablation
9. Arterial closure devices	Available for patients prone to access site bleeding

CHF, congestive heart failure; IV, intravenous; NTG, nitroglycerin; PTCA, percutaneous transluminal coronary angioplasty.

*See Table 1-2 for indications.

an intensive care unit. In the catheterization laboratory, intubation, intraaortic balloon pumping, and vasopressors can be instituted rapidly before angiography and a decision for revascularization.

Contraindications

Contraindications to cardiac catheterization include fever, anemia, electrolyte imbalance (especially hypokalemia predisposing to arrhythmias), and other systemic illnesses needing stabilization (Table 1-3).

Complications and Risks

For diagnostic catheterization, analysis of the complications in more than 200,000 patients indicated the incidence of risks as death, less than 0.2%; myocardial infarction, less than 0.05%; stroke, less than 0.07%; serious ventricular arrhythmia, less than 0.5%; and major vascular complications (thrombosis, bleeding requiring transfusion, or pseudoaneurysm),

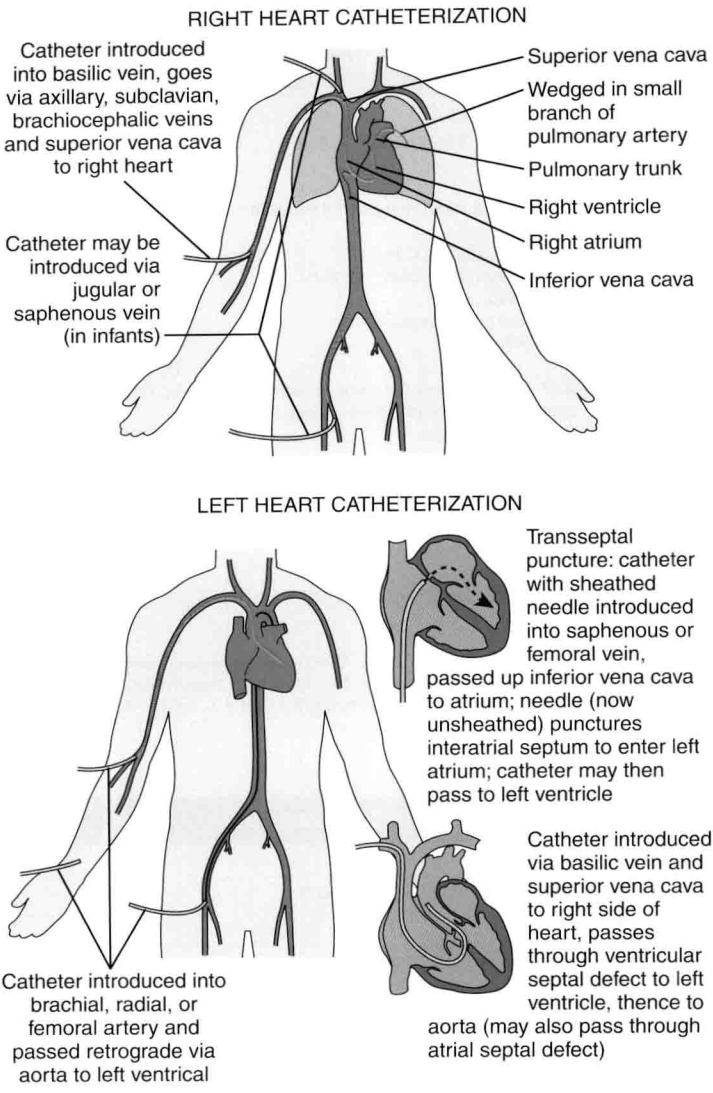

Figure 1-1 Vascular access routes for cardiac catheterization (also see Chapter 2). Radial and femoral arteries are the most common approaches.

less than 1% (Table 1-4, Table 1-5). Vascular complications occurred more often when the brachial approach was used and least when the radial approach was used. Risks are increased in well-described subgroups (Table 1-6).

Catheterization Laboratory Data

Information gathered during the cardiac catheterization can be divided into two categories: hemodynamic (see Chapter 3) and angiographic (see Chapter 4). The term *cineangiography* describes the x-ray photography of cardiac structures. Use of this term persists even though the images are now stored electronically on digital computer imaging media (e.g., CD-ROM) rather than on cine film. The digital cineangiogram provides anatomic information about the chambers of the heart and the coronary arteries. Hemodynamic information is recorded from catheters inside the heart and consists of pressure measurements, cardiac outputs, and blood oxygen saturation measurements.

Table 1-2

Indications for Cardiac Catheterization

Indications	Procedures
1. Suspected or known coronary artery disease	
a. New-onset angina	LV, COR
b. Unstable angina	LV, COR
c. Evaluation before a major surgical procedure	LV, COR
d. Silent ischemia	LV, COR, ±ERGO
e. Positive exercise tolerance test	LV, COR, ±ERGO
f. Atypical chest pain or coronary spasm	LV, COR, ±ERGO
2. Myocardial infarction	
a. Unstable angina postinfarction	LV, COR
b. Failed thrombolysis	LV, COR, ±RH
c. Shock	LV, COR, RH
d. Mechanical complications (ventricular septal defect, rupture of wall or papillary muscle)	LV, COR, L+R
3. Sudden cardiovascular death	LV, COR, R + L
4. Valvular heart disease	LV, COR, R + L, ±AO
5. Congenital heart disease (before anticipated corrective surgery or ASD/PFO closure)	LV, COR, R + L, ±AO
6. Aortic dissection	AO, COR
7. Pericardial constriction or tamponade	LV, COR, R + L
8. Cardiomyopathy	LV, COR, R + L, ±BX
9. Initial and follow-up assessment for heart transplant	LV, COR, R + L, BX

AO, aortography; BX, endomyocardial biopsy; COR, coronary angiography; ERGO, ergonovine malate,; LV, left ventriculography; RH, right heart oxygen saturations and hemodynamics (e.g., placement of Swan-Ganz catheter); R + L, right and left heart hemodynamics; ±, optional.

Table 1-3

Contraindications to Cardiac Catheterization

Absolute Contraindications
Inadequate equipment or catheterization facility
Relative Contraindications
Acute gastrointestinal bleeding or anemia
Anticoagulation (or known, uncontrolled bleeding diathesis)
Electrolyte imbalance
Infection and fever
Medication intoxication (e.g., digitalis, phenothiazine)
Pregnancy
Recent cerebrovascular accident (<1 month)
Renal failure
Uncontrolled congestive heart failure, high blood pressure, arrhythmias
Uncooperative patient

Preparation of the Patient

Consent for the Procedure

Consent is obtained by the operator or his or her assistant, usually a physician:

1. Explain in simple terms what procedure will take place and for what reason each step of the procedure will occur.
2. Explain the risks for routine cardiac catheterization. Major risks include stroke, myocardial infarction, and death. Minor risks include vascular injury, allergic reaction, bleeding, hematoma, and infection.
3. Explain any portions of the study used for research and the associated risks (e.g., electrophysiologic study—perforation, arrhythmia [<1:500]; pharmacologic study—varies depending on drug and study duration; intracoronary imaging or sensor-pressure wire study—spasm, myocardial infarction, embolus, dissection [<1:500]).

Table 1-4

Complications of Cardiac Catheterization

Major
Cerebrovascular accident
Death
Myocardial infarction
Ventricular tachycardia, fibrillation, or serious arrhythmia
Other
Aortic dissection
Cardiac perforation, tamponade
Congestive heart failure
Contrast reaction (anaphylaxis, nephrotoxicity)
Heart block, asystole
Hemorrhage (local, retroperitoneal, pelvic)
Infection
Protamine reaction
Supraventricular tachyarrhythmia, atrial fibrillation
Thrombosis, embolus, air embolus
Vascular injury, pseudoaneurysm
Vasovagal reaction

Table 1-5

Incidence of Major Complications of Diagnostic Catheterizations

	Number	Percent
Death	65	0.11
Myocardial infarction	30	0.05
Neurologic	41	0.07
Arrhythmia	229	0.38
Vascular	256	0.43
Contrast	223	0.37
Hemodynamic	158	0.26
Perforation	16	0.03
Other	166	0.28
Total (patients)	1184	1.98

Modified from Noto TJ, Johnson LW, Krone R, et al: Cardiac catheterization 1990: a report of the Registry of the Society for Cardiac Angiography and Interventions (SCA&I), *Cath Cardiovasc Diagn* 24:75-83, 1991; in Uretzky BF, Weinert HH: *Cardiac catheterization: concepts, techniques, and applications*, Walden, Mass, 1997, Blackwell Science.

Table 1-6

Conditions of Patients at Higher Risk for Complications of Catheterization*

Acute myocardial infarction
Advanced age (>75 years)
Aortic aneurysm
Aortic stenosis
Congestive heart failure
Diabetes
Extensive three-vessel coronary artery disease
Left ventricular dysfunction (left ventricular ejection fraction <35%)
Obesity
Prior cerebrovascular accident
Renal insufficiency
Suspected or known left main coronary stenosis
Uncontrolled hypertension
Unstable angina

*See also Chapter 8.

4. Provide the necessary information and explanation but do not overwhelm the patient. It is good practice to include the family when explaining what will happen and what possible outcomes you might expect.

There is no alternative to coronary angiography. Often the patient's and family's concern about "not knowing" about coronary disease necessitates performing the test.

The decision to undergo the procedure is always the patient's. If the patient is reluctant to have the catheterization, the referring physician should be asked to speak to the patient to clarify why the procedure is necessary. A reluctant patient should never sign the consent. When possible, the family should be present when the procedure is discussed. This approach encourages a cooperative and generally sympathetic appreciation of the procedure and expected outcome.

Communication with Patients: A Nonmedical Person's Understanding

The clinician establishes rapport and builds the patient's confidence by listening and explaining. The procedure should be discussed with the patient in terms he or she can understand. The purpose of the procedure should be clear—"to look at the coronary arteries" and "to examine the heart muscle (ventricular function)." Simple terms are best so that the patient can grasp the concepts. The clinician should explain what small catheters are (plastic tubes similar in size to spaghetti) and that they will be used to put x-ray contrast dye into the arteries supplying blood to the heart. The heart muscle may be weakened (infarcted) in certain areas, and the way to identify this weakness is to take x-ray pictures. This example of a simple, forthright explanation facilitates the operator team-patient relationship so that confidence in the operator and team performing the procedure is established.

Laboratory Atmosphere: The Patient's Confidence Builder

1. In the laboratory a confident, professional attitude should be assumed by all personnel at all times. Straightforward routine communication should occur quietly and without alarming tones. Patients should be addressed directly, by name, to let them know what their instructions are as opposed to requests or communications to co-workers.
2. The circulating team members should be confident, reassuring, and professional in every respect. The patient feels helpless and is tuned in to all types of stimuli (especially verbal).
3. Extraneous conversation is distracting for the patient and the operators. In the laboratory, all "players" should be in the game; that is, the patient's needs and safety become paramount.
4. Communication with the patient (and family) before, during, and after the procedure ensures a satisfied and well-cared-for individual. Communication among the team members in a professional, courteous, and quiet tone builds patient confidences and helps the procedure go smoothly.
5. Factory worker attitudes of "another coronary" or "another transplant" should be avoided. Each procedure is potentially life threatening and should be undertaken seriously and with concern as if each patient were a family member.
6. Cardiac catheterization is stressful to the patient and the operator team. This stress should be minimized by thoughtful preparation and professional attention to detail.
7. Practical notes for the new operator include the following: Immediately before the catheterization in the laboratory, reexamination of

the ECG is essential. A brief reiteration of the history ensures that no interval change has occurred since the last interview. A brief examination of the patient—checking heart sounds, breath sounds, and carotid and peripheral pulses—is also essential immediately before and after cardiac catheterization. No patient should be studied without full understanding of the clinical conditions and results of previous catheterizations and other pertinent laboratory data.

When on the catheterization table, the patient remembers two major potentially painful points of a case: (1) the initial introduction of the local anesthetic (and sometimes radial sheath introduction) and (2) any discomfort experienced after the study has been completed. Such discomfort usually occurs while the operator or nurse is holding the femoral puncture site. If the local anesthetic injection is performed too quickly or the arterial closure-compression after the procedure is difficult or painful, the patient will remember that the physician who performed the catheterization "hurt me." The period between the two events is often forgotten (thanks to premedication). These two points should be kept in mind as the major "take-home" messages. Patients cannot discern the operator's skill or level of accomplishment during the procedure, but they judge the operator (and the team) on the manner and care at the beginning and end of the study. Skill and accomplishment during the procedure are essential, but these are developed during the operator's training period.

8. General catheterization orders: Before catheterization, preferably the preceding night, precatheterization orders should be written. All medications and procedural premedications should be tailored to the patient and timing of the catheterization. If the patient is using long-acting insulin (neutral protamine Hagedorn [NPH]), the dose should be reduced 50% and the patient should not eat breakfast. The patient should be watched carefully for hypoglycemic reactions (e.g., shaking, confusion, slurred speech).
9. Patients should wear their glasses and dentures in the laboratory to make communication easier.

In-Laboratory Preparations and the "Time-Out"

The staff of the cardiac catheterization laboratory is responsible for patient preparation before the start of the procedure. On the patient's arrival in the laboratory, a staff member should review a brief checklist to ensure that all preprocedural requirements have been met. A sample checklist follows:

- Check the patient's ID band, known allergies.
- Check laboratory results (key tests: blood urea nitrogen, creatinine, prothrombin time, partial thromboplastin time, electrolytes).
- Check blood pressure, all pulses (arms and legs), baseline ECG.
- Anticoagulant status. Check the international normalized ratio (INR) and partial thromboplastin time (PTT) and if on heparin, the activated clotting time (ACT).
- Check childbearing potential (may need β-human chorionic gonadotropin level).
- Assess the patient's understanding of the procedure and answer the patient's questions.
- Verify that the proper paperwork has been copied and filled out for the procedure. Check that the consents and oral airway forms for the procedure are signed and in the chart. If not, make arrangements for their completion before the procedure.
- Check that the intravenous (IV) line is patent.
- Check that the patient has ingested nothing by mouth before the procedure.

- Check whether premedications were given as ordered.
- Start document of the precatheterization condition, and note any physical deficits (abnormal neurologic examination, bruising or bleeding sites).

After all precatheterization requirements have been fulfilled, the patient may be taken to the angiographic suite and the technical preparations can be completed.

Catheterization Suite Preparations

Before the start of the catheterization procedure, the staff performs the following tasks:

1. Establishes ECG monitoring. The ECG should be considered first of the two major "lifelines." The heartbeat is monitored for rate and rhythm during the entire procedure. It is the responsibility of the staff to place the electrodes and lead wires in such a fashion that a quality trace is obtained. Care must be taken that the electrodes and lead wires do not interfere with the movement of the x-ray and cineangiographic unit. All leads should be secure, and a good signal should be present before the application of sterile drapes; reaching under the sterile drapes to reattach loose lead wires once the procedure has begun is difficult. Radiolucent leads permit complete 12-lead ECG monitoring but are more prone to breakage than heavier cable leads.
2. Establishes IV access for emergency medications or sedation. The second lifeline is the IV access. Without good IV access, emergency drugs to counteract vagal or allergic reactions cannot be effective. In most cases the patient is given an oral sedative as premedication before arriving at the cardiac catheterization laboratory. When the patient is in the laboratory, the nurse or physician may identify the need for additional sedation or analgesia before the start of the procedure. The IV line is also important for hydration after cardiac catheterization.

Caution must be exercised when premedicating elderly patients. If meperidine (Demerol), fentanyl, or morphine is used, a narcotic antagonist such as naloxone (Narcan) should be available. Flumazenil (a benzodiazepine antagonist) should also be available if diazepam (Valium) or midazolam (Versed) is used.

The "Time Out"

In any active catheterization laboratory, preparations can be hectic, perhaps even frantic at times. This frenetic pace can cause problems, important steps can be missed, and patient safety can be compromised. Time out is a Joint Commission requirement. It was originally designed for surgical procedures that required an accurate identification of the patient, procedure, site, and side. It is a critical safety check to eliminate the mistake of operating on the wrong patient or wrong site.

When Should the "Time Out" Occur?

The "time out," the immediate preprocedure pause, must occur in the location where the procedure is to be done (catheterization laboratory suite). The "time out" may precede anesthesia or in the operating room may occur after the patient is anesthetized (participation by the patient is not expected in surgical procedures but is recommended for catheterization laboratory procedures) but just before starting the procedure.

Who Should Participate in the "Time Out" Process?

The "time out" must involve the entire operative team. At a minimum, this includes active participation by the catheterization laboratory operator, any anesthesia provider, and circulating nurse. Participation with active (out-loud) communication by the other members of the team is