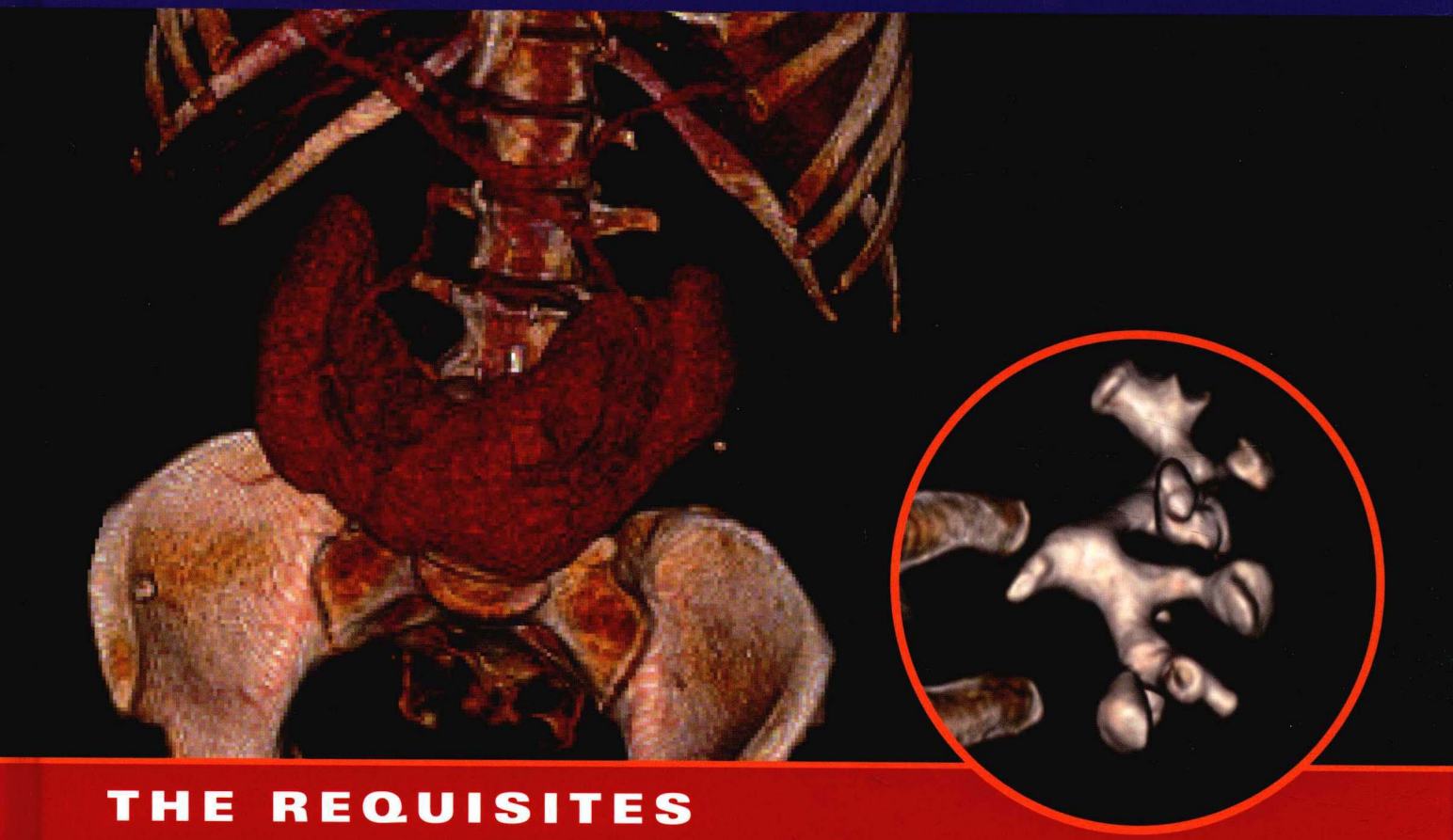

THE REQUISITES

Genitourinary Imaging

Third Edition

Ronald J. Zagoria • Raymond Dyer • Christopher Brady

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This book is dedicated to my wife, Kat Zagoria,
who exemplifies a truly giving person
and whose love and support have made me a better person.—RZ

Foreword

The series of textbooks encompassing The Requisites in Radiology series has flourished over the last 25 years due to the diligence and success of the authors in producing very high quality work. *Genitourinary Imaging: The Requisites* exemplifies this high standard and is now appearing in its third edition through leadership of Dr. Ronald Zagoria with co-authors Dr. Raymond Dyer and Dr. Christopher Brady.

With each new edition of the respective books in The Requisites in Radiology series, it is quite interesting to see and marvel at the magnitude of change in radiology practice that has occurred in the interval. This was certainly true from the first to the second editions of this book and is true again. Genitourinary radiology has continued to undergo substantial changes based on new technologies and new understanding of diseases and conditions of the genitourinary system. Ultrasound is even more established and is being used in new ways such as diagnosis of urinary tract stones. Dual energy computed tomography and multispectral computed tomography offer the ability to characterize calculi, aiding in diagnosis and also selection of appropriate therapy. MRI diffusion imaging and related methods are establishing roles in prostate cancer. The excretory urogram or intravenous pyelogram is a historical curiosity.

One of the features of The Requisites series most appreciated in reader feedback is the use of tables and boxes to restate and summarize essential information in concise form. This reinforces the narrative discussion, and the liberal use of this approach again is an important feature of this book. In particular, important differential diagnoses and summaries of key findings in important diseases and conditions are included in summary form in each chapter.

Because radiology is fundamentally a visual specialty, the quality of illustrative material is also extremely important and is another particular strength of *Genitourinary Imaging: The Requisites*. Each chapter is richly illustrated with up-to-date material, further highlighted by classic illustrations where appropriate.

The Requisites books have become old friends to a generation of radiologists. The intent of the series was to provide the resident or fellow with a text that might be reasonably read within several days at the beginning of each subspecialty rotation and perhaps reread several times during subsequent rotations or board preparation. The series is intended not to be exhaustive but to provide basic conceptual, factual, and interpretive material required for clinical practice. Each book is written by a nationally recognized authority in the respective subspecialty areas, and each author is challenged to present material in the context of today's practice of radiology rather than grafting information about new imaging modalities onto old, out-of-date material.

Dr. Zagoria, Dr. Dyer, and Dr. Brady have done an outstanding job in sustaining the philosophy of The Requisites in Radiology series and have produced another truly contemporary text for genitourinary imaging. I believe that *Genitourinary Imaging: The Requisites* will continue to serve residents in radiology as a concise and useful introduction to the subject and will also serve as a very manageable text for review by fellows and practicing radiologists. Congratulations to Dr. Zagoria, Dr. Dyer, and Dr. Brady on another outstanding contribution to the radiology book shelf.

James H. Thrall, *MD*
Radiologist-in-Chief Emeritus
Massachusetts General Hospital
Distinguished Juan M. Taveras Professor of Radiology
Harvard Medical School
Boston, Massachusetts

Preface to the Second Edition

Books are for use, not for show; you should own no book that you are afraid to mark up, or afraid to place on the table, wide open ...

William Lyon Phelps
Professor at Yale University, 1901-1933

The first edition of the textbook *Genitourinary Radiology: The Requisites* was published in 1997. When Glenn Tung and I wrote the first edition, we had no idea that it would be published at the beginning of a period of rapid change in the field of genitourinary radiology. In the first edition there is only a brief mention of using computed tomography (CT) for the detection of urinary tract stone disease, and little information on magnetic resonance (MR) of the urinary tract. Since that time, genitourinary radiology has ridden the wave of rapid advances in computer-based imaging technology. Helical CT has given way to multislice CT, with more rows of detectors being added continually. This has led to the development of new paradigms for genitourinary disease evaluation and improved diagnosis of pathology. Also, MR technology has rapidly progressed. The biggest advance has been development of rapid 3-D acquisitions, allowing radiologists to detect and characterize smaller renal lesions than with older techniques.

The second edition of *Genitourinary Radiology: The Requisites* includes much new information. While the diseases are the same, and there has been little change in treatment techniques, the imaging evaluation of the genitourinary system has changed substantially. The second edition of this textbook has greatly increased coverage of CT stone studies, now a commonly used technique. Also, CT urography is rapidly replacing other techniques—intravenous urography, sonography, and abdominal radiography—in the evaluation of patients with hematuria. While still evolving, this technique is described in detail in this second edition. Other applications of CT, specifically 3-D reconstructions for treatment planning and diagnosis and advanced adrenal CT techniques, have been added to the textbook. The descriptions of CT angiography and MR angiography have been updated and expanded, as have their roles in vascular imaging of the genitourinary system. Also, in the second edition of this textbook I have maintained and expanded sections on interventional genitourinary radiology, the female genital tract, and the male genital tract. This gives the reader the opportunity to review the entire spectrum of genitourinary radiology with this one textbook. In fact, the revised section on genitourinary interventional radiology includes a description of percutaneous image-guided ablation of malignant renal tumors. This area was completely nonexistent when the first textbook was written. This field could rapidly expand as early results with this technique appear to be very promising. With the proven accuracy of radiologists for identifying small renal cell carcinomas, image-guided treatment seems to be a natural evolutionary step. I hope that this information will spur others to advance this exciting new field. The second edition of this textbook has been substantially updated and now better reflects imaging of the genitourinary tract in the 21st century.

In authoring the second edition I have maintained the trademark style of The Requisites series. I have likened this style as analogous to the *USA Today* of textbooks; easily readable text that is factually concentrated. This includes numerous figures, tables, and highlighted lists of key concepts in each chapter. I wanted this textbook to be used rather than left on a bookshelf unread.

I am hopeful that the second edition of *Genitourinary Radiology: The Requisites* will be widely read by radiologists and others interested in genitourinary radiology. The intent of this textbook is to allow the reader to review and become educated in the key principles of genitourinary tract radiology, both diagnostic and interventional. The second edition of this textbook reflects current state-of-the-art techniques in this field.

Open this textbook regularly, mark it up, and feel free to leave it wide open on a table!

Ronald J. Zagoria, *MD*

Acknowledgments

Since we cannot change reality, let us change the eyes which see reality.

Nikos Kazantzakis

So many things in genitourinary (GU) radiology have dramatically changed in the 10 years since the last edition of this book. Intravenous urography has almost completely disappeared, computed tomography (CT) radiation has decreased, prostate magnetic resonance imaging (MRI) has increased in importance as has kidney tumor ablation, and CT and MRI have become the main imaging procedures in GU radiology. It's been an exciting decade for those practicing GU radiology. The third edition of *Genitourinary Radiology: The Requisites* has been extensively updated to reflect the many changes in our knowledge and practice. This new book is greatly enhanced by the contributions from Raymond Dyer, a recognized authority in GU radiology and master teacher, and Christopher Brady, a rising star in the field. I appreciate their willingness to help author this book, and their work is superb. Readers will benefit greatly from these new contributors. I also want to thank my colleagues at the University of California at San Francisco whose support and expertise helped mold this revised work. Special thanks go to my assistant Cheree Fernandez for help completing and organizing the revisions and to several outstanding UCSF residents and fellows for help with editing my contributions. They are Lauren Hollowell, Nancy Benedetti, and Dare Olorunsola.

Support and encouragement from my wonderful wife Kat have been instrumental in completing this book, as has been the case throughout my career. The accomplishments of our children, David and Michael, and my role-model parents, Sam and Sylvia Zagoria, have helped inspire me to teach and to improve the care of as many patients as possible through work such as this textbook.

Please read, learn, and enjoy *Genitourinary Imaging: The Requisites,* third edition!

Ronald J. Zagoria, *MD*

After completing my military service in San Antonio, Texas, I accepted a faculty position at Wake Forest University School of Medicine. Shortly thereafter, Ronald Zagoria approached me about helping with the third edition of *Genitourinary Imaging: The Requisites*. It did not take me long to realize that you do not pass up an opportunity like this. Having the chance to work with Ronald Zagoria and Raymond Dyer, both of whom are truly gentlemen and scholars, has been a privilege and I have learned much from their expertise in genitourinary radiology.

I am also deeply thankful to my wife, Emily, and my children, Nathan, Lauren, Savannah, Matthew, and Eric, for their love and support in my various pursuits. Without the support of family, a task such as this would be impossible. They give me purpose in life and keep me focused on the things that matter most.

Finally I would like to thank the residents and abdominal imaging fellows at Wake Forest for helping me to continually learn and grow as a professional through their insightful and challenging questions during our daily interactions as we do our best to help the patients we serve.

It is my hope that this third edition of *Genitourinary Radiology: The Requisites* will serve as a strong foundation for those looking to expand their knowledge of this growing field and serve as a catalyst for further inquiry. Ultimately, I hope that patients will benefit from the information contained within these pages. If that is the case, I will consider it a success!

Christopher Brady, *MD*

If I don't learn something every day in our reading room, it's only because I wasn't paying enough attention!

It is a unique privilege to have been asked to contribute to this wonderful work that belongs to my former "student," Dr. Ronald J. Zagoria. There is perhaps no greater joy for a teacher than to participate in the success of someone they have taught and I thank him for this opportunity.

I also thank our co-author, Dr. Christopher Brady; I smile each day in our reading room as he patiently instructs me (and perhaps the residents, too). I would also like to thank Dr. R. Wayne Gandee, whose enthusiasm for radiology changed my mind and whose many decades of friendship I count among my greatest blessings.

And speaking of those blessings, I would like to thank my family: my wife, Susanna, my son Chris and his wife Rachel, my son Richard, and the newest Dyer, Davis Townsend, for reminding me of the most important things in life.

Raymond Dyer, *MD*

Contents

Chapter 1

An Introduction to Radiologic Methods

CHAPTER OUTLINE

Optimal radiologic investigation of the genitourinary system requires a combination of diverse but complementary examinations that evaluate form and function. This chapter presents an overview of diagnostic tests that are commonly used to evaluate genitourinary disease. First, the pharmacology of iodinated contrast media is reviewed. Adverse effects and an approach to the management of common adverse reactions are also discussed. The chapter then turns to the individual radiologic methodologies and examines the

general indications for the tests and guidelines for interpretation. The following sections review the cross-sectional imaging methods—ultrasonography, computed tomography (CT), and magnetic resonance imaging (MRI)—as well as angiography and nuclear medicine. Recommended methods for performing these examinations are presented in a series of appendices.

RADIOGRAPHIC CONTRAST MEDIA

Radiographic contrast media (RCM) were developed to increase differences in the attenuation (absorption) of radiation by soft tissues. As a result, all commercially available radiographic contrast agents are triiodinated derivatives of benzoic acid. The other chemical constituents of the contrast molecule carry the iodine so that it can be delivered in large volumes, in high concentrations, and with as little toxicity as possible. Some older contrast materials are ionic, which means that these agents dissociate into cations and anions in water. The *osmolality* of a solution is a measure of the number of dissolved particles in each liter of solution. Some of the adverse effects of RCM are related to hyperosmolality, which may be up to six times that of plasma. The density of RCM is related to the number of iodine atoms per milliliter of solution and directly correlates with x-ray attenuation. RCM can be subdivided into three classes, which are based on a ratio between the number of iodine atoms in the molecule and the number of osmotically active particles produced by that molecule in a solution (Table 1-1 and Fig. 1-1). At present, ratio 1.5 (high-osmolar contrast media, HOCM), ratio 3 (low-osmolar contrast media, LOCM), and ratio 6 (iso-isomolar, nonionic dimer, IOCM) agents are in active use.

All ionic contrast media are salts of iodinated, organic molecules that dissociate completely in blood. Thus these molecules consist of a positively charged cation and a negatively charged anion. The diagnostically useful contrast molecule itself is the organic anion, which consists of an iodine-substituted benzene ring, with sodium or meglumine serving as the cation. The cation provides no radiographically significant information but contributes half of the osmotic effect of the medium. Diatrizoate and its derivatives are ionic monomeric salts of triiodinated, fully substituted benzoic acids. As ratio 1.5 agents, ionic monomeric salts are also referred to as *HOCM* because, for every three

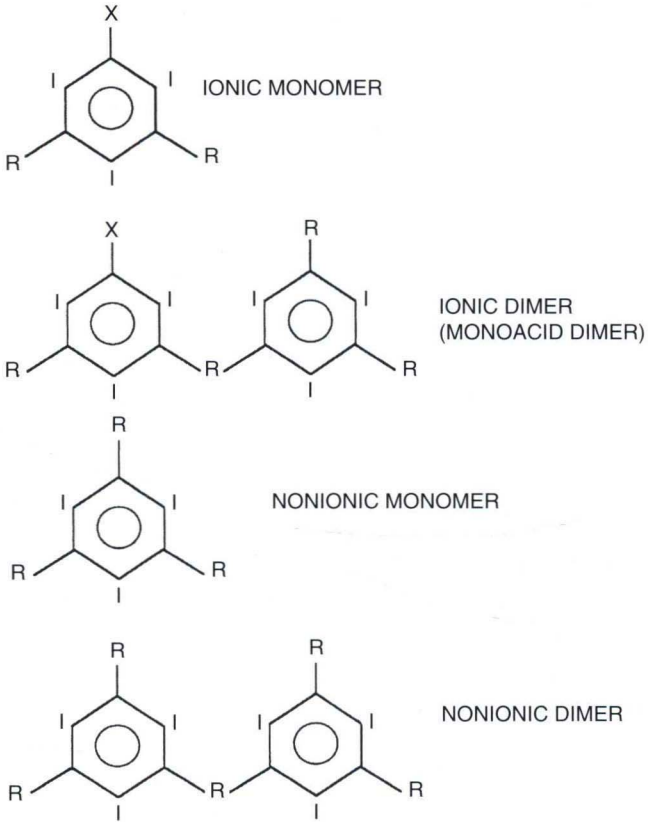

FIGURE 1-1 Radiographic contrast media (RCM). All RCMs are based on a 2-, 4-, 6-substituted triiodobenzoic acid molecule. High-osmolar contrast media (ratio 1.5) are ionic monomers. Low-osmolar contrast media are either ionic dimers (ratio 3), nonionic monomers (ratio 3), or nonionic dimers (ratio 6). (R, hydrophilic, nonionizing side-chains; X, ionic moiety: $-COO^-$ and either a sodium or methylglucamine cation).

TABLE 1-1 Classification of Radiographic Contrast Media

Ionicity	Monomer or Dimer	Ratio*	Relative Osmolality†,‡	Examples
Ionic	Monomer	1.5	~5	Diatrizoate Iodamide Ioglicate Iothalamate Ioxithalamate Metrizoate
Ionic	Dimer	3	~2	Ioxaglate
	Nonionic	3	1.5-1.8	Iohexol Iopamidol Iopentol Iopromide Ioversol Ioxilan
Nonionic	Dimer	6	1	Iodixonal Iotrol

*Ratio between the number of iodine atoms per molecule and the number of osmotically active particles produced by that molecule in solution.
†Relative osmolality expressed as a multiple of serum osmolality, 278-305 mOsm/kg serum water.
‡Data from product package inserts, product brochures, or technical information services.

iodine atoms in solution, there are two osmotically active particles in the solution. The ionic dimeric salts are ratio 3 contrast agents, consisting of an anionic moiety with two triiodinated benzene rings. Ioxaglate is an example of a monoacidic dimeric salt that is intended for intravascular use but not for myelography.

The nonionic compounds were developed to reduce the osmolality of contrast agents while preserving excellent image contrast. The addition of a nonionizing glucose moiety to the carboxyl group transforms the iodinated benzoic acid derivative into a nonionic compound. The nonionic monomer class of RCM consists of ratio 3 agents because, for every three iodine atoms, there is only one particle in solution. Iopamidol and iohexol are two examples of second-generation nonionic monomers. These agents, along with the ionic dimer class of contrast medium, are referred to as *LOCM* because the osmolality of these compounds is about two times that of serum osmolality. The third class of RCM is made up of nonionic dimers that do not dissociate in solution. Iotrol and iodixanol provide six iodine atoms for every osmotically active molecule. These ratio 6 agents have the lowest osmolalities but also the greatest viscosity of all RCM because of the large molecular size.

Pharmacokinetics

All RCM are hydrophilic and have low lipid solubility. Having little affinity for proteins and membrane-bound receptors, RCM also are nearly inert having minimal pharmacologic action. After intravenous administration, the decline in the plasma concentration of contrast material results from diffusion into the extravascular space, vascular mixing, and renal excretion. The kidneys normally excrete more than 99% of the intravenous dose of contrast media. Less than 1% is excreted through nonrenal routes, including the hepatobiliary system, sweat, tears, and saliva. All of the currently available contrast media are excreted through the kidney by glomerular filtration with no significant tubular excretion or resorption. HOCM causes significant osmotic diuresis, which secondarily decreases the tubular concentration of contrast medium. By comparison, LOCM and IOCM cause less osmotic diuresis, and as a result, the concentration of ratio 3 and 6 contrast media in the urine is significantly higher.

Contrast Nephropathy

Contrast-associated nephropathy (CN) is defined as an acute impairment of renal function after exposure to a RCM. Although there are various specific definitions, a common definition of renal impairment is a rise in the serum creatinine level of at least 1.0 mg/dL within 2 to 5 days of exposure to RCM. Creatinine levels usually return to normal by 7 to 12 days. Contrast nephropathy is typically reversible, but rare cases of permanent nephrotoxicity, which is more common when renal failure is oliguric, have necessitated dialysis or transplantation. A delayed, persistent nephrogram at 24 hours has been observed in the majority of patients with CN, but this finding is not specific for CN. Various mechanisms have been suggested to explain the adverse effect of contrast media on renal function. Some putative mechanisms include prerenal effects from dehydration or hypotension; direct effects on intrarenal hemodynamics; direct nephrotoxic effect on tubular cells; intratubular obstruction from proteinuria and uricosuria; and indirect nephrotoxic effects from an altered immunologic response.

The most important risk factor for the development of CN is pre-existing renal insufficiency, practically defined as a serum creatinine level greater than 1.5 mg/dL or estimated glomerular filtration rate (GFR) less than 45. Unsuspected azotemia caused by hypertensive nephropathy or vascular disease is especially prevalent in the elderly patient group. Pre-exposure dehydration, whether inadvertent or intentional, may exacerbate nephrotoxicity, particularly in patients with azotemia. Patients with insulin-dependent diabetes mellitus and secondary renal disease are at a particularly high risk for development of CN; the frequency of CN is 50% to 100% when serum creatinine is more than 3.5 mg/dL in these patients. However, patients with diabetes mellitus or multiple myeloma and normal renal function do not appear to be at an increased risk. Repeated administration of contrast material over a short period (within 24 hours) increases the risk of developing CN. In general, a total iodine dose of 80 g in a 24-hour period is safe. With a total iodine dose of more than 100 g in a 24-hour period, the patient is at increased risk of renal failure.

Compared with ionic counterparts, nonionic monomers cause fewer changes in the GFR and less tubular damage. However, some studies of patients with normal or slightly decreased renal function report no statistical difference in the prevalence of contrast-induced nephrotoxicity between patients receiving ionic compounds and those receiving nonionic compounds. Other studies suggest that patients who have pre-existing renal insufficiency, defined as serum creatinine levels between 1.4 and 2.4 mg/dL, may be at higher risk for nephrotoxicity with HOCM than with LOCM. In 1993, Barrett and Carlisle concluded from a meta-analysis of 24 trials that the use of LOCM may be beneficial in patients with pre-existing renal failure because the mean postexposure change in the serum creatinine level was 0.2 to 6.2 μmol/L less with LOCM than with HOCM.

The prevention of CN first involves determining whether the requested examination is appropriate for the given clinical question. Directing the work up away from an examination requiring contrast material administration is appropriate when the potential risks of adverse reaction might be serious or life threatening. Careful screening of patients for well-defined high-risk factors, known renal disease, advanced age, treatment with nephrotoxic drugs, renal insufficiency, and diabetes mellitus is mandatory. If any of these high-risk factors is present, an assessment of renal function is prudent. In patients with none of these risk factors, the likelihood of suffering permanent renal damage from CN is so remote that routine measurement of renal function is unnecessary. Preparation protocols that involve intentional dehydration or catharsis should be avoided. If multiple examinations requiring contrast

material are indicated, they should be performed over an extended period—for example, longer than 72 hours.

Adverse Reactions

As with other drugs, RCMs are associated with untoward reactions attributable to their physicochemical structure, direct toxic effects on sensitive organs, and allergylike reactions (anaphylactoid, idiosyncratic, or pseudoallergic). These adverse side effects occur after administration of 5% to 8% of all intravenous injections with ionic HOCM and in 1% to 3% of injections with nonionic or LOCM. Fortunately, most of these adverse reactions are minor in severity; they include sensations of body warmth, pruritus, urticaria, nausea, and vomiting.

A practical way to classify untoward reactions to RCM is to group them by nature and clinical severity.

- *Mild* contrast reactions include pruritus, hives, nausea, warmth, altered gustatory sensations, swelling of the face, conjunctival injection, and vomiting. In the majority of patients, no treatment beyond reassurance is necessary. However, like all untoward effects, these mild reactions require close observation because they rarely do progress or are prodromal to more serious reactions.
- About 1% to 2% of patients receiving conventional HOCM have a non-life-threatening, *moderate* reaction. Examples of these types of reactions include bradycardia or tachycardia (especially when associated with acute changes in blood pressure), dyspnea, laryngospasm, and bronchospasm. Patients with moderate reactions require close monitoring and often require treatment.
- Any reaction may be classified as *severe* when it is potentially life threatening. Often, the patient loses consciousness or has clinically significant dysrhythmia. Patients with severe reactions not only must be treated promptly, but almost always require hospitalization for optimal treatment. Severe, life-threatening reactions occur after 0.05% to 0.10% of injections with HOCM. Reported fatalities attributable to reactions caused by contrast media are estimated to occur in one of every 75,000 administrations.

Most adverse effects are evident immediately after injection, and all life-threatening reactions occur within 15 minutes after injection. Rarely, delayed reactions can occur 24 to 48 hours after exposure. However, these delayed reactions are almost exclusively mild in character and include rash or pruritus and pain near the injection site. There is an increased risk of a delayed reaction to RCM injection in patients who have received interleukin-2 therapy. *Iodine mumps* refers to delayed parotid swelling caused by trace levels of free iodide in contrast media. Specific management of the more commonly encountered mild and moderate adverse reactions is outlined in Tables 1-2 and 1-3.

TABLE 1-2 Management of Common Adverse Reactions to Radiographic Contrast Media

Adverse Reaction	First Line	Second Line	Third Line
Urticaria (hives)	Reassurance	Diphenhydramine	Epinephrine intramuscularly or subcutaneously
Vagal reaction	Elevate legs; consider volume expansion*	Atropine sulfate	—
Laryngeal edema	Oxygen	Epinephrine intramuscularly or subcutaneously	Intubation
Bronchospasm	Oxygen	Inhaled beta$_2$-agonist†	Epinephrine intramuscularly or subcutaneously‡
Hypotension and tachycardia	Elevate legs; consider volume expansion*	Epinephrine intravenously	—

*Volume expansion with 0.9% saline or lactated Ringer solution.
†Inhaled beta$_2$-agonists, such as metaproterenol, albuterol, or nebulized terbutaline.
‡Alternatives to subcutaneous epinephrine in the management of bronchospasm include aminophylline drip or terbutaline (subcutaneous or intramuscular).

TABLE 1-3 Drugs Used in the Management of Common Adverse Reactions

Drug	Trade Name	Dose	Route of Administration
Albuterol	Proventil, Ventolin	—	Inhaled
Aminophylline drip	—	6 mg/kg loading dose; 0.5-1.0 mg/kg/h intravenous drip	Intravenous
Atropine sulfate	—	1-mg doses to a total of 2 mg	Intravenous
Diphenhydramine	Benadryl	25-50 mg	Oral/intramuscular/intravenous
Epinephrine	—	1:10,000 dilution; 3-mL doses to a total of 10 mL	Intravenous
Epinephrine	—	1:1000 dilution; 0.3-mL dose to a total of 1 mL	Intramuscular or subcutaneous
Metaproterenol	Alupent, Metaprel	—	Inhaled
Terbutaline	—	0.25-0.5 mg	Subcutaneous/intramuscular

The frequency and severity of reactions to contrast material may be influenced by the type, dose, route, and rate of delivery. Experimental and clinical data suggest that LOCM produces fewer chemotoxic adverse side effects compared with HOCM. The prevalence of anaphylactoid reactions may also be lower. Multicenter surveillance studies have estimated that the relative risk of any adverse reaction is reduced by a factor of 3 to 8, and the risk of severe reaction is reduced by a factor of 4 to 12 when LOCM are used. The prevalence of most reactions is greater with the intravenous route than with the intra-arterial route. Exposure of mast cell–rich pulmonary capillary beds to relatively higher concentrations of contrast may explain this observation. However, the prevalence of severe reactions is greater after intra-arterial injections. Bolus intravenous injection produces fewer reactions compared with drip infusion.

If the use of nonionic or other LOCM is selective, the prevention of adverse reactions to HOCM depends on identifying those patients at higher risk for these reactions. In these patients, the selective use of LOCM or medical pretreatment, or both is logical and advised. For patients with a history of allergy or asthma, the relative increased risk of any adverse reaction is about two times that for the general population. In any patient who is debilitated or has a history of severe cardiopulmonary disease, the effects of even a moderate reaction may be poorly tolerated. For patients who have a history that includes an adverse reaction after RCM exposure, the re-reaction prevalence is 17% to 35%, or three to eight times the risk for the general population.

Several studies have concluded that medical pretreatment can reduce the prevalence of adverse side effects in high-risk patients to that observed in the general population. Most of these premedication regimens include a corticosteroid administered alone or together with either an H1- or an H2-antihistamine. Steroids exert a salutary effect through stabilization of membranes and therefore may impede release of critical mediators of anaphylactoid reactions. In a group of patients with a history of adverse reaction to RCM, Lasser and associates concluded that pretreatment with an oral regimen of methyl-prednisolone 32 mg, taken 12 and 2 hours before the intravenous administration of HOCM, decreased the occurrence of all classes of reactions. Other studies delivering a three-dose oral regimen of prednisone 50 mg, taken every 6 hours beginning at least 13 hours before exposure to HOCM, and diphenhydramine 50 mg, administered orally or intramuscularly 1 hour before exposure to HOCM, have also demonstrated reduced reaction prevalence (Box 1-1).

BOX 1-1 Pretreatment Protocol for Intravascular Administration of Iodinated Contrast in Patients Who Have Had a Previous Major Reaction

1. *Prednisone* 50 mg per os or intravenously; 13 hours, 7 hours, and 1 hour before contrast material injection.
2. *Diphenhydramine* 50 mg per os or intravenously; 30-60 minutes before contrast material injection.

RADIOLOGIC EXAMINATIONS

Computed Tomography Urography

CT urography (CTU) is the most accurate and comprehensive urinary tract imaging evaluation. It allows detailed images to be obtained of the vasculature, renal parenchyma, and the urothelium along the entire length of the urinary tract. The advent of multidetector CT made CTU possible. There is no significant motion artifact, studies can be completed during a single breath hold, and low dose multiphase imaging can be obtained to cover the entire urinary tract. Indications for CTU are broad, but the main indication is usually hematuria. Other common indications include screening for urinary tract neoplasms in patients with a history of cancer, or for surveillance following cancer treatment, evaluation of congenital urinary tract anomalies, evaluation of ureteral obstruction, evaluation before or after urinary tract surgery, and for patients with suspected urinary tract injuries. CTU allows optimal stone detection, excellent renal mass detection and characterization, diagnosis and staging examination for renal tumors, vascular anatomy assessment, and evaluation of the urothelium with a single examination.

Computed Tomography Urography Technique

There are three essential phases in a CT urogram. These three phases are a noncontrast CT, a nephrogram phase CT, and an excretory phase CT (Fig. 1-2). Each of these phases is important for a comprehensive study of the urinary tract. Noncontrast CT is used to detect stones, calcifications in renal masses, to get baseline measurements to determine mass enhancement, and for detection of small amounts of fat in a renal mass. The CT nephrogram phase is essential for the detection of renal and urothelial masses (Fig. 1-3), mass characterization including enhancement measurement, and determination of the Bosniak classification for cystic renal masses. The excretory phase study is important to detect abnormalities of papillary necrosis (Fig. 1-4), and for filling defects (Fig. 1-5) and wall thickening in the urothelium. In order to obtain these three essential elements of a CTU, there are various approaches, but two main approaches have evolved and are used for most CTUs. A three scan CTU encompasses three separate scans through the entire urinary tract (Appendix A): one scan during the noncontrast phase, one scan during the nephrogram phase, and the final scan during the excretory phase. The two scan technique, also known as a split bolus CTU, includes a precontrast CT of the urinary tract followed by a second scan which combines both the nephrogram phase and the excretory phase. For both protocols all scans should be obtained using 2.5 mm (or thinner) collimation. Multiplanar reconstructions should be obtained using the thinnest reconstructions available for high-resolution reformations.

For the three scan CTU, a precontrast CT of the abdomen and pelvis from just above the kidneys to just below the bladder base is performed. This is followed by nephrogram phase scans. The nephrogram phase scan is obtained following power injection of at least

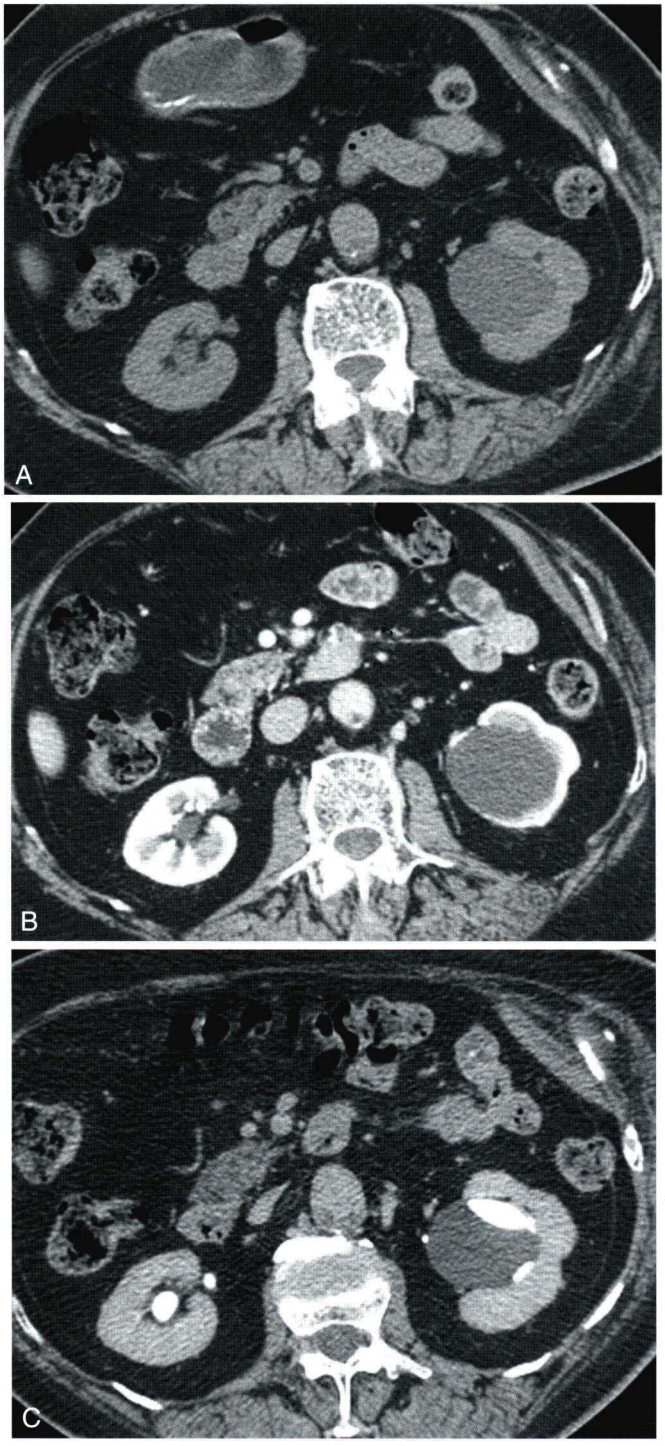

FIGURE 1-2 Computed tomography urogram (CTU) images show the three phases of a CTU. **A,** Noncontrast shows a cystic mass in the left renal sinus. **B,** Nephrogram phase is shown and is best for diagnosing renal tumors and urothelial tumors. **C,** Image shows the excretory phase and demonstrares that the cystic mass is a renal sinus cyst. Excretory phase is best for diagnosis of papillary necrosis and other abnormalities of the pyeloureteral lumen.

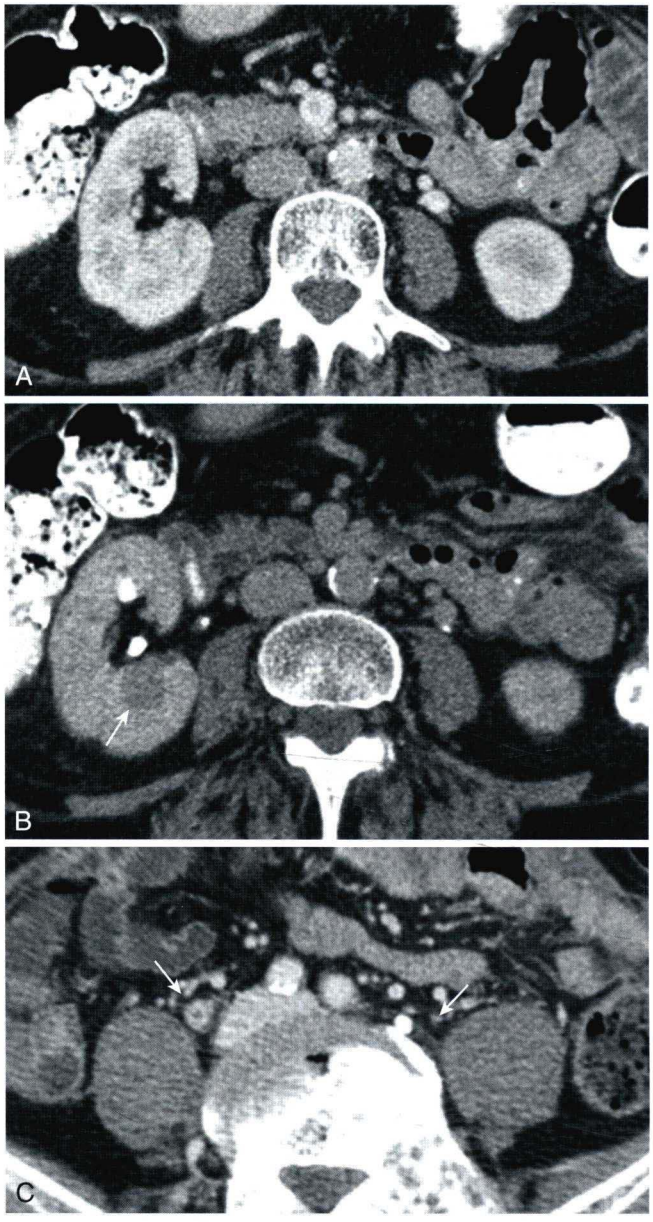

FIGURE 1-3 Computed tomography urogram (CTU) images show advantage of the nephrogram phase. **A,** Scan through the kidneys during the cortico-medullary phase and no renal mass is detectable. **B,** During the nephrogram phase a 1.5 cm mass *(arrow)* is readily visible in the right kidney. This was biopsied before ablation and proven to be a renal cell carcinoma. **C,** In another patient, scan through the mid ureters *(arrows)* shows a thickened and avidly enhancing area in the right ureter that was biopsied and proven to be a urothelial carcinoma. The nephrogram phase is optimal for renal parenchymal mass and malignant urothelial mass detection.

125 mL of contrast material at a rate of 4 mL/second. The scan delay is optimally between 85 and 120 seconds after the beginning of contrast injection. Excretory phase CT scans should be obtained 10 to 15 minutes following the initiation of intravenous contrast material injection. Furosemide (Lasix) has been shown to substantially improve urinary tract distention during this phase and therefore 10 mg of furosemide may be injected intravenously 3 to 5 minutes before the excretory phase scans. Low-dose CT can be utilized during the noncontrast phase and excretory phase scans to reduce radiation dose for this CTU protocol. Abnormalities detected during these phases tend to be high contrast abnormalities that can be readily detected even with low-dose CT technique.

The technique for split bolus CTU is significantly different. Initially a noncontrast CT of the entire urinary

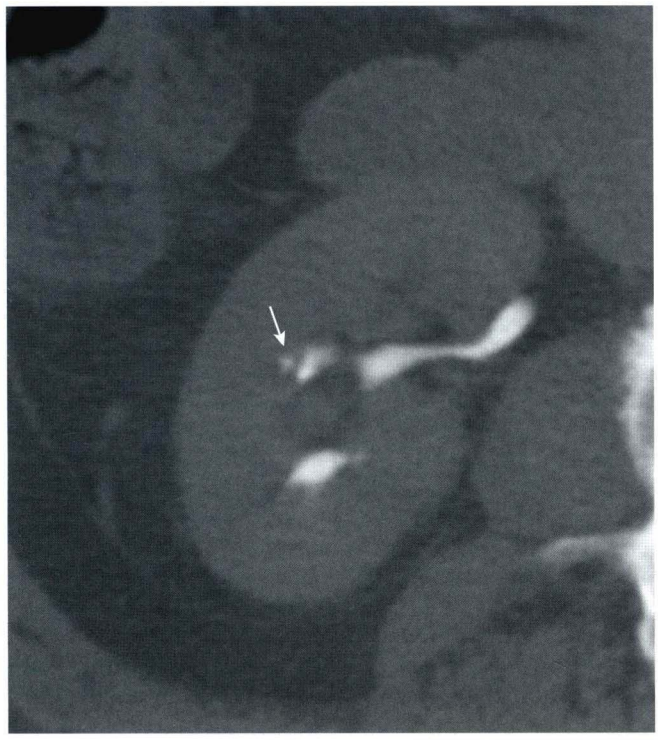

FIGURE 1-4 Excretory phase shows a *ball-on-tee* outpouching filled with excreted contrast material; a finding diagnostic of papillary necrosis. This finding is only detectable with computed tomography urogram (CTU) during the excretory phase.

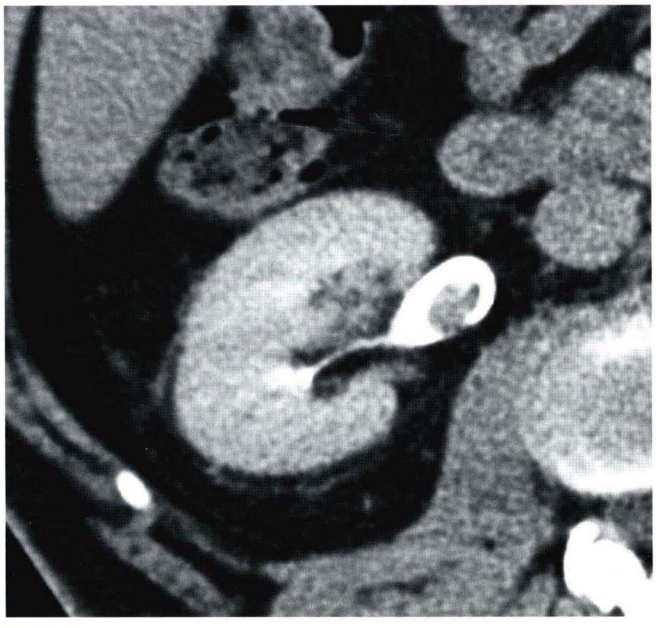

FIGURE 1-5 Excretory phase image from a computed tomography urogram (CTU) shows a conspicuous polypoid filling defect in the right renal pelvis. This was proven to be urothelial carcinoma.

tract is obtained using thin collimation as described above. After the scan 10 mg of furosemide is injected intravenously. Immediately following this injection 50 mL of intravenous contrast material is injected. Following a 6-minute delay, a second bolus of 100 mL of contrast material is injected at a rate of 4 mL/second. The entire urinary tract is scanned using a 100 second

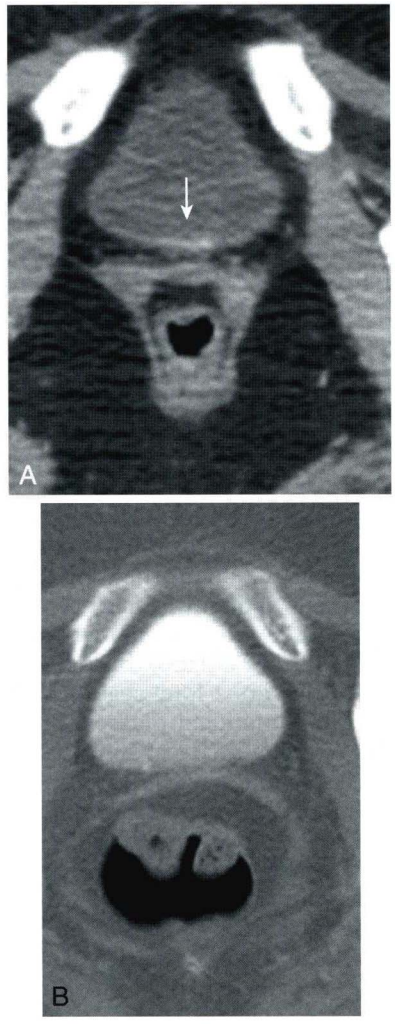

FIGURE 1-6 Flat bladder tumor best seen during the nephrogram phase. **A,** During the nephrogram phase a flat area of increased enhancement is seen in the posterior bladder wall. This was biopsy proven to be urothelial carcinoma. **B,** During the nephrogram phase this mass is not detectable.

delay. The second scan in this protocol will yield combined nephrogram and excretory phase images.

There are significant benefits of utilizing the three scan CTU protocol. It is very important to detect lesions that show urothelial enhancement. These may be impossible to detect using the split bolus technique. The detection of urothelial tumors is greatly improved when enhancement within the lesions can be visualized. This may be obscured on the combined excretory and nephrogram phase split bolus scans. For the detection of urothelial carcinomas, a challenge for radiologists, it has been shown that there is a higher sensitivity using the nephrogram phase than the excretory phase. A radiologist is more likely to miss flat bladder (Fig. 1-6), and pelvocalyceal cancers utilizing the split bolus technique than with the three scan CTU protocol. The authors of this chapter recommend utilizing the three scan protocol for most patients, and limiting use of the split bolus technique to those patients who have very low risk of urothelial carcinoma, predominately for very young patients, such as kidney transplant donor candidates.

Computed Tomography Urography Interpretation

The precontrast CT images should be evaluated for the presence of urinary tract calculi, fat containing renal masses, and to determine baseline measurements of any masses detected on later scans. Nephrogram phase scans should be evaluated in great detail to detect renal parenchymal tumors and enhancing urothelial lesions. A substantial number of renal masses will go undetected during earlier corticomedullary phase scans. The nephrogram phase, 85 to 120 seconds following the initiation of contrast material injection, is the optimal phase for detecting renal tumors. It is also crucial to carefully evaluate the entire length of the urothelium, including the ureters and bladder, during the nephrogram phase. Urothelial carcinomas are best, and sometimes only, detected during this phase of the CTU. Urothelial carcinomas almost always enhance very avidly and therefore are usually readily detectable during this phase. Most urothelial carcinomas will appear as focal areas of enhancement during this phase. Other causes of increased enhancement include inflammation and infection. In most of these benign situations the enhancement covers a long segment of the urothelium without enhancing focal masses. Excretory phase images should be evaluated carefully for intraluminal filling defects and for changes of papillary necrosis. Images in this phase of scanning should be evaluated with various window and level settings. Standard soft tissue setting should be used to evaluate for wall thickening, and bone window and level settings can be utilized to detect intraluminal filling defects that may be obscured by the excreted contrast material.

CTU is a very sensitive test for the detection of urothelial carcinomas, but it is not highly specific for smaller masses. Approximately 80% of urothelial masses larger than 5 mm in diameter are malignant. This percentage is increased to 92% if urine cytology is suspicious or positive for urothelial carcinoma. Approximately 50% of cases of urothelial thickening represent carcinoma. This percentage is increased to 90% if there is positive or suspicious urine cytology in the patient. Alternatively, masses smaller than 5 mm are not usually malignant. These abnormalities typically represent inflammatory lesions or imaging artifacts. When only small masses are detected, imaging follow up or ureteroscopy is advisable before initiation of treatment. As urothelial carcinomas are often multifocal, once a mass is detected, careful scrutiny of the remainder of the urothelium is advised. While cystoscopy is often performed in patients with hematuria, careful evaluation of the bladder during the nephrogram phase is recommended. The detection of bladder carcinomas with CTU is nearly as accurate as cystoscopy.

In summary, CTU is the best imaging test for hematuria evaluation and as a comprehensive evaluation of the urinary tract. Key components of performance and interpretation for CTUs have been described. The three scan CTU is preferable in most instances since there is improved sensitivity for detection of urothelial carcinomas. A nephrogram phase scan at approximately 100 seconds following the injection of contrast material should be utilized to optimize detection of renal parenchymal tumors and urothelial masses. Thoroughly evaluate the entirety of the urinary track during the nephrogram phase to detect small enhancing masses. Cancers will be best, or perhaps only, detected during the nephrogram phase. Furosemide should be used whenever possible to improve ureteral distention during the excretory phase scans. Excretory phase scans should be viewed with various window and level settings to detect wall thickening, changes of papillary necrosis, and inflammatory filling defects.

Intravenous Urography

Intravenous urography (IVU), once the test of choice as a screening examination of the upper and lower urinary tracts, is rarely used today, having been superseded by CTU, MRI, and ultrasound examinations. This test is primarily used to investigate a suspected or known congenital anomaly of the urinary tract, or a limited IVU for suspected ureteral obstruction during pregnancy when other tests are unavailable or inconclusive.

Because the appearance of contrast medium in the renal tubules depends on glomerular filtration, renal visualization may be suboptimal in patients with moderate and severe renal failure. In general, urography is unlikely to be useful in patients with serum creatinine levels above 3.5 to 4.0 mg/dL. In addition, the risk of contrast nephropathy is increased with serum creatinine levels above 1.5 mg/dL.

Normal Intravenous Urogram

A careful evaluation of the preliminary or scout film is mandatory. This preliminary film is not only important for the subsequent interpretation of the IVU, but it may provide important ancillary information about the axial skeleton, abnormal calcifications, visceral enlargement, soft tissue masses, and bowel gas pattern (i.e., "bones, stones, mass, gas"). Renal shadows and the pubic symphysis must be included on the preliminary film.

At 60 to 90 seconds after the bolus administration of contrast medium, a cortical nephrogram can be seen. The nephrogram represents contrast material within the tubules and depends on the plasma concentration of contrast and the GFR. The peak nephrogram density after bolus administration of contrast occurs earlier and is somewhat greater, but it decreases more rapidly than when contrast medium is given by intravenous drip infusion. The lower limit of normal renal length can be approximated by the distance between the superior endplate of L1 and the inferior endplate of L3. Renal length should not exceed the span of the first four lumbar vertebrae. Peak opacification of the intrarenal collecting system and renal pelvis occurs approximately 5 minutes after contrast material administration (Fig. 1-7). Ureteral filling with contrast begins at about this time, and peak opacification occurs 5 to 10 minutes after intravenous contrast material is given. As contrast medium slowly appears in the bladder, it preferentially collects against the dependent posterior wall in the patient positioned supine. In the patient positioned prone, contrast is seen along the anterior bladder wall, which is in a relatively more cephalad position than the posterior wall. The mucosal pattern of the bladder is

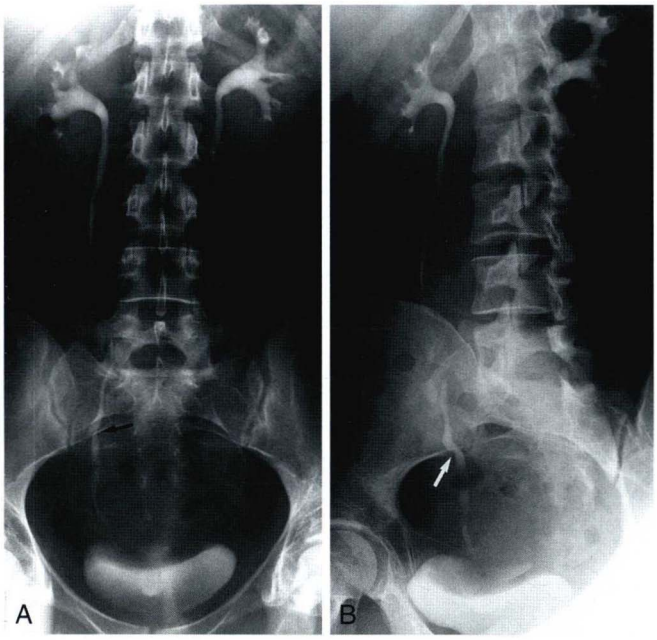

FIGURE 1-7 The normal ureter on intravenous urogram. Anteroposterior **(A)** and oblique **(B)** 15-minute urograms demonstrate the normal morphology of the collecting system. The abdominal part of the ureter begins at the renal pelvis. In general, a ureter that is medial to the ipsilateral lumbar pedicle is abnormally deviated medially, and a ureter that lies more than 1 cm lateral to the tip of the ipsilateral lumbar transverse process is deviated laterally. The abdominal ureters should be separated by 5 cm or more. The pelvic part of the ureter begins where it crosses the iliac vessels at the pelvic brim *(arrow)*. The level of the ureterovesical junction is approximated by the ipsilateral ischial spine. Normal areas of ureteral narrowing are expected at the ureteropelvic junction, at the pelvic brim, and at the ureterovesical junction.

best assessed on the film after voiding because dense contrast in the filled bladder may obscure a lesion (Fig. 1-8). Furthermore, a radiograph obtained after voiding that shows complete emptying suggests normal bladder function. The converse is not true, however, because a moderate amount of residual urine may be explained by causes other than dysfunctional micturition.

Cystography and Urethrography

Retrograde cystography is the radiologic evaluation of the bladder after instillation of contrast material by catheter, either transurethral or suprapubic, or by needle puncture. Voiding cystourethrography (VCUG) is contrast radiography of the urinary bladder and urethra during spontaneous micturition (Appendix B). Dynamic retrograde urethrography is radiography of the urethra while it is being distended by instillation of contrast through a catheter (Appendix C).

The main indications for cystography are the evaluation of acquired disorders of micturition, vesicoureteral reflux, and traumatic injury of the bladder. Injury to the bladder should be suspected in a patient with difficulty voiding, pelvic fracture, gross hematuria after trauma, or iatrogenic injury during surgery or instrumentation. Radiologic evaluation of the bladder frequently is performed before renal transplantation and in patients with spinal cord injury. Cystography has been used to distinguish a mechanical obstructive cause of micturition dysfunction from a neurogenic cause. VCUG in children is used to determine whether vesicoureteral reflux or a congenital anomaly of the urinary tract is responsible for urinary tract infection or collecting-system dilatation. In adults, reflux should be suspected in the patient with an upper urinary tract infection when no other cause is plausible or when reflux nephropathy is noted on urograms. In women, cystourethrography frequently is used to evaluate stress incontinence or suspected urethral diverticulum. In men, benign prostatic hyperplasia and urethral stricture are common reasons why cystourethrography is performed.

In boys or men, the main indication for dynamic retrograde urethrography is suspected injury or stricture of the anterior urethra. If no trauma to the urethra is documented by urethrography, the catheter can be advanced safely into the bladder. As necessary, cystography may follow. Urethrography with a double-balloon catheter is performed in women primarily when a urethral diverticulum is suspected but cannot be confirmed by VCUG or MRI.

Normal Cystogram and Urethrogram

The wall of the distended bladder is smooth and thin. In men, the height (vertical dimension) of the bladder may be greater than the width (horizontal dimension); the opposite is often true in women. The base of the bladder is normally at or just below the level of the superior pubic ramus. The base is slightly convex in the supine position, but it is funnel-shaped when the patient voids in an upright position.

The male urethra consists of the anterior and posterior segments (Fig. 1-9). The posterior urethra is divided into the prostatic and membranous parts and extends from the internal sphincter (at the bladder neck) to the external sphincter (at the urogenital diaphragm). The prostatic part is normally wide and passes through the transitional zone of the prostate gland. The verumontanum (urethral crest) is an elongated, oval filling defect on the posterior wall of the prostatic urethra; the prostatic urethra ends at the distal end of the verumontanum. The external sphincter is distal to the verumontanum and creates a narrowing on the retrograde urethrogram; this is the membranous part of the posterior urethra. The anterior urethra is divided into the bulbar and penile parts. The bulbous part of the anterior urethra extends from the external sphincter to the penoscrotal junction, where the penile urethra is angled by the suspensory ligament of the penis. Cowper glands are embedded in the muscle of the urogenital diaphragm, and its ducts enter the floor of the bulbar urethra. The penile or pendulous urethra is the most distal part of the anterior urethra and ends at the external meatus. Just proximal to the external meatus, there may be a slight widening of the penile urethra, the fossa navicularis.

The female urethra is approximately 4 cm in length and extends from the internal urethral orifice (at the bladder neck) to the external orifice (anterior in the vagina). The urethra is widest at the bladder neck