UROLOGIC RADIOLOGY

SECOND EDITION

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Editor's Introduction—1976

The authors of *Urologic Roentgenology* have arranged the presentations in an extremely orderly fashion from the plain film, intravenous urogram, infusion studies with nephrotomography and associated special procedures, including angiographic examinations, through nuclear radiologic approaches in a very careful manner. More advanced diagnostic procedures are also well described.

The embryology, anatomy, and pathology are included in significant detail. It is also noted that physiologic and physical chemical backgrounds are provided.

This revision is very worthwhile in that it has brought a large amount of material up to date with a reorganization of the text.

The editor is indebted to the authors for a fine presentation as well as to Mrs. Ruby Richardson and her staff at Williams & Wilkins for their cooperation.

L. L. R.

Preface to Second Edition

In common with so many other branches of medicine, there has been a striking expansion in the scope of uroradiology during the 4 decades since the first publication of this text. This is now the era of dynamic flow studies permitting the radiologist to quantitate physiologic data and to correlate with the structural data of urography. Of greatest significance is the realization that the patient in chronic renal failure may be subjected to in vivo radiologic study without significantly increased morbidity. The advent of noninvasive techniques such as ultrasound and renal imaging has radically increased the availability of tissue for histologic diagnosis and, combined with brush biopsy, provides data concerning the entire anatomic extent of the kidney. The study of function has elevated nephrology to a highly significant subspecialty which is now further expanded by the data accumulated in conjunction with renal transplantation and dialysis. Modern instrumentation has added a new dimension to the study of function. The radiologist must now be conversant with regional renal blood flow and kidney function, with the circulation times and vascular resistance, as well as providing access to body fluids, as for example, the renal vein blood for renin activity. A new and promising field concerns pharmacology in relationship to the vascular systems. Radioimmunoassay is a new and very productive field. The introduction of the measurement of tumor-associated antigens may double its use although its role in endocrinology and nephrology is already well established.

The present volume is the result of an effort to update the first edition of *Urologic Roentgenology* in as complete but concise a form as possible. There have been many significant changes in the field in recent years both in respect to procedure and interpretation. A review of the most of the literature prior to June 1974 has been made. No claim of originality or priority is made and the urologic literature has been used freely. Wherever possible, our own data is added.

There remains our apology for subjects too briefly discussed and publications inadequately mentioned and inadvertently overlooked.

Acknowledgements

It is impossible to give thanks to all who have helped in the production of this volume, both directly and indirectly. However, special mention is made of Dr. J. Mangalat, Mr. Richard Blanton, and Dr. William Crowe, all of the Maricopa County General Hospital. Illustrations of certain specific types of cases have been possible only through the generous cooperation of Dr. M. D. Cosgrove, Los Angeles, California; Dr. M. Halpern, Los Angeles, California; Dr. G. Hernandez, Kingsport, Tennessee; Dr. G. Leopold, San Diego, California; Dr. R. A. Older, Durham, North Carolina; Dr. J. R. Patterson, Bakersfield, California; Dr. J. G. Rabinowitz, Memphis, Tennessee; and Dr. I. Hyde, Southhampton, England. However, errors are to be ascribed to the authors of the present text and not to these contributors.

Mr. W. Proctor of the Maricopa County Health Services, Phoenix, has applied his photographic skill and patience to the production of excellent reproductions. Celia J. Newman is responsible for many of the splendid drawings and diagrams. Dr. Harold Hicks of the Department of Radiology (Nuclear Medicine), Maricopa

County General Hospital is the author of the brief section on Radioimmunoassay, which activity we feel is properly carried on in this department.

Mrs. Sue Dodge has been an invaluable secretary and critic. Deep appreciation is due Mrs. Ruby Richardson and her colleagues at The Williams and Wilkins Company for their generous assistance and constructive criticism.

M. L. S.
A. N.

Preface to First Edition

In 1936, when this text first appeared, it seemed likely that the addition and/or replacement of a relatively small number of looseleaf pages every five years or so, would keep the text up-to-date. However, the generally rapid tempo of modern scientific achievement has been paralleled in the fields of radiology and urology. Furthermore, there has been a spill-over into internal medicine particularly in relation to hypertension, kidney function and infection and metabolic diseases. Consequently, it has been necessary virtually to re-write the text and to replace most of the illustrations.

It is hoped that the present text reflects another change that has taken place and is continuing in the practice of Radiology. The Radiologist now is performing or is intimately concerned with many more of the technical procedures that precede making the x-ray exposures. In many Institutions, for example, he performs the vascular catheterizations himself. Not only does he thus become more aware and more critical in the particular field of investigation but also, being exposed to modern instrumentation in one area, he can appreciate and seek its application in other fields. This, along with cineradiography or multiple film techniques, has resulted in the addition of the study of dynamics to that of structure. Furthermore, the rapidly developing field of radioisotopic diagnosis requires an understanding of renal function that was not essential to the Radiologist of years past. All of these fields are expanding so rapidly that it has been necessary to limit arbitrarily the review of the literature to that prior to May 1965.

Illustrations and emphasis in a subject as wide as Urologic Roentgenology often have a geographic limitation. An attempt has been made to "smooth out" the emphasis in the text but it was not always possible to do this in the matter of illustrations.

It is impossible to list and thank individually our many colleagues who have contributed directly or indirectly to the information which we have tried to collect and review. Particular thanks however are due to Dr. Pierre Haig for reviewing the material on radioisotopic diagnosis. Thanks are due to the Publisher who was willing to scrap and replace so many illustrations in order to achieve photographic uniformity of presentation. Thanks are also due to Dolores Wilson, R.T. who suffered through so many rewrites. Credit for most of the photography is due to Lloyd Matlovsky, photographer at the Los Angeles General Hospital. Our wives are particularly to be congradulated for suffering through the many conferences of collaborators who live 400 miles apart.

Marcy L. Sussman, M.D.
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Diagnostic Armamentarium of the Urinary Tract

HISTORY

Historically, urologic roentgenology falls into four periods of development: (1) the search for calculi, (2) urography, (3) angiography, and (4) radioisotopic diagnosis. It is no exaggeration to assert that, today, the practice of urology is inconceivable without adequate radiologic facilities and interpretation.

In July 1896, about 6 months after Roentgen's first publication, James Adams, a Glasgow surgeon, had already detected a renal calculus roentgenologically and removed it. In 1904 Klose injected an emulsion of bismuth into the kidney pelvis and ureter. Retrograde urography was thus initiated. Progress was made through the development of more satisfactory contrast media and in the method of their injection, first under pressure by a hand syringe, then by gravity, and later under direct vision cystoscopic control. Voelcker and von Lichtenberg in 1906 used colloidal silver successfully to outline the pelvis and ureter. In 1918 Cameron, as well as Graves and Davidoff, introduced a 12% solution of sodium iodide for retrograde pyelography and a 6% solution for retrograde cystography. Since 1929 sodium iodide has been replaced by organic halogens. In 1907 Burkhardt and Polano injected oxygen into the renal pelvis; others have used air. Neither is miscible with urine, and there is difficulty in differentiating urinary structures from intestines. In addition, air embolism is said to be a potential danger. Lipiodol, introduced by Sicard and Forestier, is rarely used today.

Excretion urography was introduced in 1929 by Swick, first with Uroselectan, then with Hippuran, and has become the most important radiologic examination of the urinary tract other than the plain film. The list of contrast media now available is long, and the subjects will be discussed in detail later (p. 5).

The nephrotomogram and renal angiogram are later developments of prime importance. Renal angiography was first described in 1929 when Dos Santos et al. introduced direct percutaneous needle puncture of the aorta. Renal angiography became a clinical procedure in the early 1950s when Peirce (1951) suggested a percutaneous method of arterial catheterization by introducing a polyethylene catheter through a puncture needle into the arterial lumen. Seldinger in 1953 improved the technique, and his system is in wide use today. A further refinement of renal angiographic procedure was described practically simultaneously by Ödman, Edholm and Seldinger, and Tillander in separate articles in 1956 when they reported techniques for the selective catheterization of the renal artery. Ödman made other valuable contributions when he incorporated lead oxide into the catheter wall to make it radiopaque (1959).

The latest and still developing field is the application of radioisotopes in dynamic function studies and in scanning as well as ultrasound. Taplin and Winter performed the first renograms in 1954. Their work was made feasible through the production of radioisotopes as a by-product of the Manhattan Atomic Bomb Project and the development of the scintillation counter in 1947 by Köllman of Germany. Scanners designed in 1951 to outline the thyroid gland were applied to the kidney, liver, etc. Since 1956 there has been progressive improvement in instrumentation, particularly in the development of the scintillation camera, data processing, and in the availability of more efficient radiopharmaceuticals.

METHODS OF INVESTIGATION

Patient Preparation

A major problem in urologic roentgenology is the removal of obscuring intestinal content. Many methods have been suggested, but there seems to be little advantage to any one method in a difficult case. The ambulatory, nonhospitalized patient often may be examined successfully without any preparation, except that some insist on dehydration in the adult. At the other extreme are patients with poor colonic tone and chronic air-swallowers, for whom there is practically no effective method of cleansing the colon. When the examination is not urgent, a low residue diet for 3 days, with vegetable cathartics and repeated colonic irrigations, may be employed. In many clinics, castor oil or such vegetable cathartics as compound licorice powder are administered the night before, with or without an enema in the morning. Colonic mucosal stimulants have not proved efficient in our hands, but others are enthusiastic advocates. Pitressin (0.5 ml) and Prostigmin (1.0 ml) have been recommended when intestinal gas is still present, but they should be used with great caution since they have been known to precipitate or exaggerate coronary insufficiency.

It has been our practice to recommend that the adult take 2 oz of castor oil at about 4 P.M. of the day preceding the examination and to limit himself to a light supper. He is asked to take an enema before retiring, and one on arising, and to come for examination without food or drink. When excretory urography is to be done, he is also asked to limit or exclude fluids during the night, but this is not essential for high dosage urography. It is unfortunate that the routine enema often introduces more air than it removes.

Alternate Preparation. At lunch and supper the day before the excretion urogram, food is limited to bouillon soup, plain Jell-O, plain chicken or turkey sandwich, and apple or grape juice.

Water must be encouraged during the day and evening.

Magnesium citrate (11 oz) (in adults) is taken at 8 P.M., and, at 10 P.M., three Dulcolax (bisacodyl N.F.) tablets are taken with at least one full glass or more of water. Nothing is taken by mouth after midnight.

At 7 A.M. on the day of examination, a Dulcolax suppository is inserted and retained for 20 to 60 min.

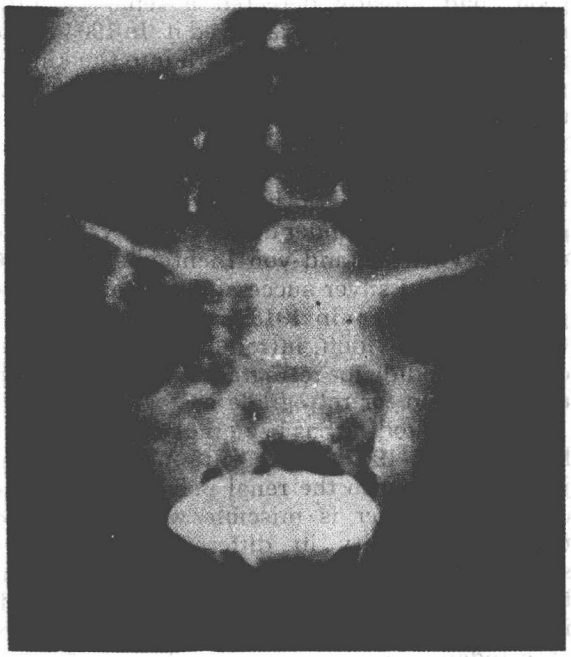
(Scout Film)

The x-ray exposure factors are defined by the available x-ray apparatus. Exposures of not more than ½ sec are desirable, and the Potter-Bucky diaphragm is mandatory. In general, 90 kv should not be exceeded. In infants, however, exposures of the order of $\frac{1}{30}$ sec or less are necessary and may require the use of a fixed Bucky grid. It is sometimes useful in infants to distend the stomach with an orally administered carbonated beverage which, if successful, shows the kidney outlines by contrast (Fig. 1.1). Abdominal compression is valuable particularly in the study of special areas. It is helpful to "cone down" for extra detail and to limit the radiated area.

Radiation Dosage

The radiation dosage to gonads and skin as the result of urographic examination requires consideration and is given in Table 1.1.

The addition of a 2-mm aluminum filter in the primary beam reduces the skin dose by 35% for the same quantity of radiation reaching the film.



1.1. IMPROVEMENT OF URINARY TRACT VISUALIZATION
Advantage is taken of a large gastric air bubble in an infant or young child contrasting the renal collecting system.

TABLE 1.1

DOSE FROM ROENTGENOGRAPHY AND FLUOROSCOPY, DEPARTMENT OF RADIOLOGY, ATOMIC BOMB CASUALTY COMMISSION

Site of Examination	Projection	Average Thickness	Film Size	kvp	ma	Added Filtration	FFD	Bone Marrow Integral Dose	Gonadal Dose		Surface Dose
									Male	Female	
		cm	*inch*			*(mm Al)*	*inch*	*gm-rad*	*mrad*		*mrad*
Chest	PA	21	14×17	100	5	2.5	72	1.73	0.02	0.04	9.21
	Lateral	32	14×17	110	15	2.5	72	3.29	0.03	0.08	37
	Lordotic	23	11×14	100	10	2.5	72	1.6	0.02	0.02	18
	Bucky PA	20	14×17	100	40	2.5	72	14	0.16	0.32	74
	Bucky lateral	30	14×17	110	80	2.5	72	18	0.16	0.43	200
Abdomen	AP	17	14×17	100	20	2.5	40	17.7	11.6 (6.59)	51.1	159
	Lateral	27	14×17	120	60	2.5	40	57.2	9.77	61.5	820
Upper gastrointestinal series	Fluoroscopy (image)	17		90+	PHT	3.0		7.21/min	0.348/min	12.8/min	328/min
	Spot	17	8×10	90		3.0		1.35	0.07	2.68	101
	AP (survey film)	17	14×17	100	20	2.5	40	17.7	11.6 (6.59)	31.1	159
	PA	17	14×17	120	20	2.5	40	39.0	7.54	33.1	265
	RAO 45°	22	11×14	120	30	2.5	40	46.5	3.20	29.6	400
	RAO 60°	26	11×14	120	40	2.5	40	34.7	3.65	24.7	413
Barium enema examination	AP (survey film)	17	14×17	120	20	2.5	40	75.5	60.2	132	675
	Fluoroscopy (image)	17		90+	PHT	3.0		30/min	11/min	140/min	480/min
	Spot	17	8×10	90		3.0		5.90			110
Intravenous pyelogram	AP (Abdomen, KUB)	17	14×17	120	30	2.5	40	75.5	60.2 (17.9)	132	675
	AP (bladder)	20	14×17	120	30	2.5	40	102	181	105	659
	Tomogram	17	11×14	120	20	2.5	40	33	12	80	450

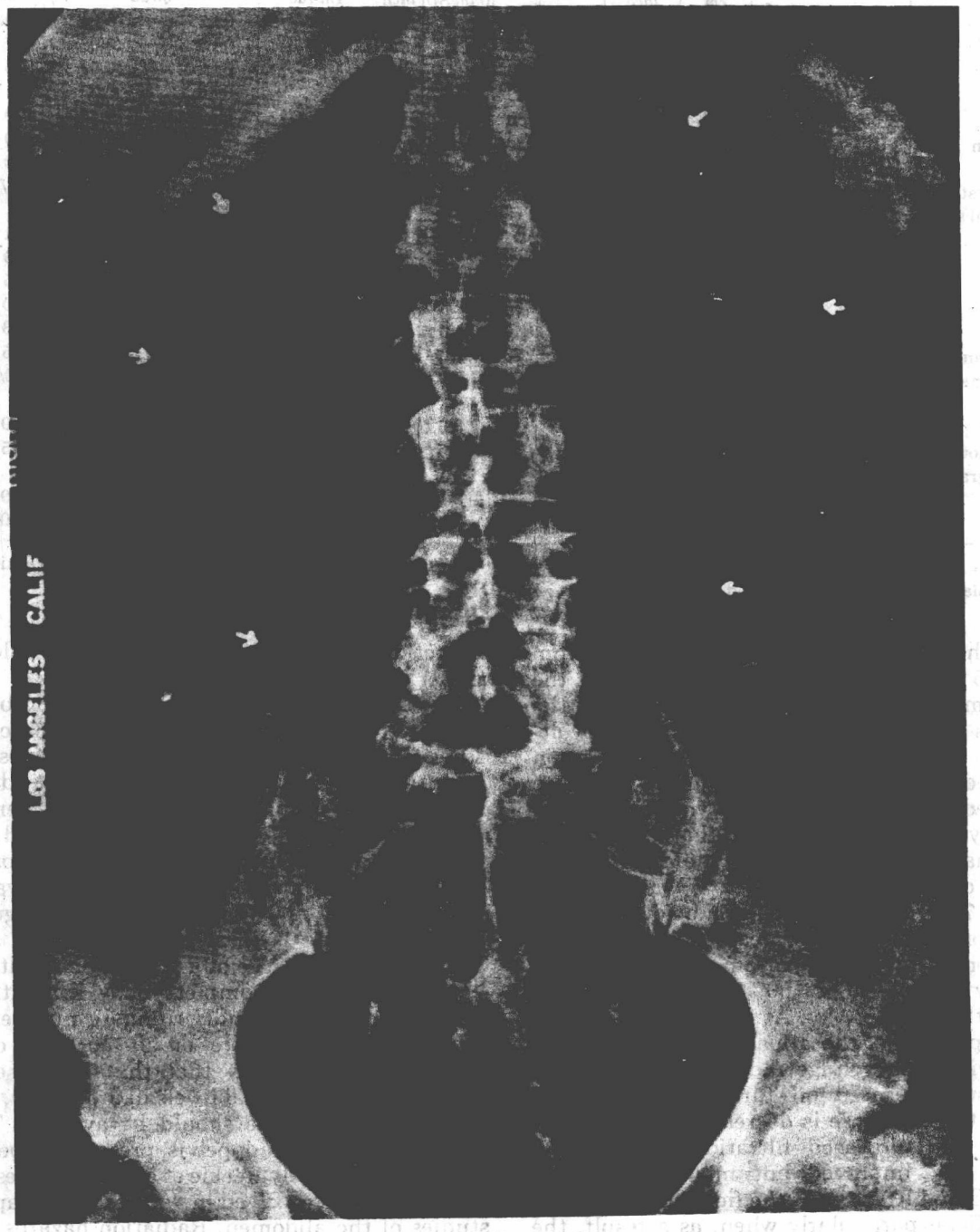
FFD = focus film distance; PA = posteroanterior; AP = anteroposterior; RAO = right anterior oblique; KUB = kidney, ureter, bladder; PHT = photo-timed exposure.

When the diameter of the beam is reduced from 12 to 5 inches, the scatter radiation in the phantom 9 inches from the central axis of the beam is reduced 10-fold. The effect of kilovoltage also is considerable. When 120 kv radiation was used, only about one-third of the skin dose delivered at 70 kv is necessary for the same quantity of radiation to reach the film. On the other hand, 9 inches below the surface, the "depth dose" at 120 kv is 4 to 5 times greater than at 70 kv, and, at any depth below 5 inches, it is more than 3 times greater. The scattered radiation inside the phantom but outside the primary beam is about 50% more intense with 120 kv than with 70 kv. As Stanford and Vance (1955) point out, the apparent great improvement with high voltage radiography is not entirely substantiated on further analysis. Although the skin dose is decreased both by high voltage and increased filtration, the gonadal dose is not improved but might be slightly larger. Careful control of the field area, however, is beneficial particularly when, as a result, the reproductive organs are not included in the primary beam. A precaution taken by many is protection of the scrotum with lead or lead rubber. This is mandatory in children.

Whether the radiation levels discussed above in regard to urography are genetically significant is not a problem within the scope of the present essayists. However, in children and in the adult, particularly those under 35 years of age, there is no doubt that the gonadal dose should be reduced to an absolute minimum. Limitation of the primary beam seems to be of greatest value in this respect, and the use of a rectangular collimating cone is important. In infants and young children the use of a large cone results in what is essentially complete body irradiation. Large cones and an indiscriminate number of exposures must therefore, on all scores, be condemned. It is unlikely that the skin dose in adults will reach critical levels in urography, but unnecessary exposure should be avoided. The female abdomen and pelvis present a special case. An analysis by Reekie et al. (1967) assessed the actual dose involved in various radiographic studies of the abdomen. Radiation hazards fall into two classes—the somatic hazard and the genetic hazard. The somatic hazard may lead

either to the death of the embryo or to the induction of cancer, especially leukemia. With a dose of 1 rad the risk of leukemia in an adult is 1 to 50,000, whereas in a fetus the risk might be 1 in 5,000, which doubles the natural risk of an early cancer death. The risk of developmental abnormalities in offspring already conceived, in the doses commonly employed, is negligible. The genetic hazard concerns the ovaries, but the risk of producing mutation is even less than that of the somatic hazards.

Gonad and fetal doses were obtained by calcu-



1.2. Normal Urinary Tract

This satisfactory film includes: *above*, the lower two ribs, and *below*, the entire pelvis. The kidney outlines (*upper arrows*) and the margins of the psoas muscles (*lower arrows*) should be delineated.

lating the dose delivered to the most probable position of the ovaries before and during pregnancy and to the fetus at term. The results showed that in early pregnancy the embryo may receive 1 rad in lateral films of the lumbosacral spine, renal arteriography, and in all screening examinations of the pelvis and lower abdomen. It was felt unlikely that these or other abdominal examinations would be carried out on pregnant women without clear-cut clinical indications. It was also suggested that these examinations should be limited to the 10-day interval following the onset of menses in nonpregnant women to save inadvertent exposure of a newly conceived embryo. The important principle is that no x-ray exposure is justified unless there is an adequate medical indication. When this principle is properly observed, the information obtained is far more important than the potential danger.

The satisfactory examination of the urinary tract should extend slightly below the symphysis pubis, and above the diaphragm (Fig. 1.2). Stereoscopic views may be useful but oblique and/or lateral views are more informative to most observers. It may not be entirely needless to point out that the film should be free of respiratory motion. The "good" film is the one that shows the pathology that is present. It is customary to make the x-ray exposures in expiration. Comparison with a film made in deep inspiration, however, or in the erect position, gives a measure of renal mobility.

CONTRAST MEDIA

Physical Data

The contrast media are numerous and the subject complicated. Hoey et al. (1971) state that, in a given contrast agent, it is the iodine in the molecule which provides opacification to the x-rays. The remaining carbon, hydrogen, nitrogen and other atoms merely provide a framework or 'carrier' for the iodine atoms". However, the structural arrangement of these additional atoms is important in providing stability, nontoxicity, solubility, and concentration in various organs. Stability of the iodine atoms in the molecule is achieved in most compounds by attaching them to an aromatic nucleus. Water solubility is obtained by incorporating an acid function (---CO_2H, ---SO_3H), from which soluble salts may be prepared.

The fulfillment of these two requirements has most frequently been accomplished by the use of aromatic acids, principally the iodobenzoic acids, as the basic structure for water-soluble agents. The various iodobenzoic acids, while chemically stable, are not by themselves sufficiently water-soluble and/or nontoxic to serve as useful intravascular contrast agents. A greater degree of solubility, as well as decreased toxicity, is conferred on such a molecule by the addition of suitable solubilizing and detoxifying groups.

The general structural requirements for contrast agents are summarized in formula shown in Diagram 1.

The urographic agent given intravenously depends on active physiologic processes to take up the iodinated material and pass it through the kidney. The substance must be physiologically

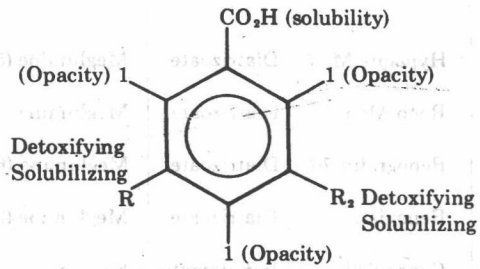


DIAGRAM 1

inert. The structural classes are given in Table 1.2.

Many investigators record a definite preference for meglumine over the sodium salts while others feel strongly oriented to sodium or mixed salts. Some aqueous solutions are more viscous than others, and this influences the choice of the radiocontrast agent and the technique of the injection. Dacie and Fry (1971) report that the sodium salts result in fewer unsatisfactory examinations than in those using the methylglucamine salt, and they exphasize the importance of variations in the state of hydration of the patient. It is also important to note that data from one substance cannot be transferred to other substances. They comment further that there is no advantage to be gained from strict hydration when using compounds containing predominantly the methylglucamine salt. The density of the nephrogram was unrelated to the state of hydration. Pearson et al (1971), however, conclude from a similar study that sodium iothalamate is preferable for routine studies. The addition of small amounts of calcium and magnesium ions decreases the effects of both sodium and

TABLE 1.2
CONTRAST MEDIA PHYSICAL DATA (APPROXIMATE)

Group	Product	Anion	Cation(s)	Concentration	Iodine	Viscosity at 37°C	Total Iodine
				%	*mg/ml*	*cps*	*gm/unit*
I	Hypaque 25%	Diatrizoate	Sodium	25	150	1.19	45
	Reno-M-dip	Diatrizoate	Meglumine	30	141	2.2	42.3
	Conray-30	Iothalamate	Meglumine	30	141	2.2	42.3
II	Hypaque 50%	Diatrizoate	Sodium	50	300	2.5	6
							9
							15
	Hypaque 60%	Diatrizoate	Meglumine	60	282	4.2	5.6
							8.5
							14.1
	Conray-60	Iothalamate	Meglumine	60	282	4.1	5.6
							8.5
							14.1
	Renografin-60	Diatrizoate	Meglumine (52%) sodium (8%)	60	288	3.9	8.6
							14.4
	Reno-M-60	Diatrizoate	Meglumine	60	282	4.0	8.5
							14.1
III	Hypaque-M-75	Diatrizoate	Meglumine (50%) sodium (25%)	75	385	8.3	7.7
							19.3
	Reno-M-76	Diatrizoate	Meglumine	76	358	9.2	7.2
							17.9
	Renografin-76	Diatrizoate	Meglumine (66%) sodium (10%)	76	370	9.1	7.4
							18.5
	Renovist	Diatrizoate	Meglumine (34.3%) sodium (35%)	70	372	6.0	9.3
							18.6
	Conray-400	Iothalamate	Sodium	66.8	400	4.5	10
							20
	Vascoray	Iothalamate	Meglumine (52%) sodium (26%)	78	400	8.7–9.3	10
							20
IV	Hypaque M-90	Diatrizoate	Meglumine (60%) sodium (30%)	90	462	18.7	9.2
							23.1
	Angio-Conray	Iothalamate	Sodium	80	480	8.4	9.6
							24
	Cardiografin	Diatrizoate	Meglumine	85	400	15.1	20

meglumine salts. Physical data regarding the common contrast media are given in Table 1.2. It is advisable to prescribe dosage in terms of iodine content so that there is a common frame of reference. For example, an average dose of 50 ml Renografin-60 contains 14.5 gm iodine; Renografin-76 contains 18.5 gm iodine; Hypaque-50 contains 15.0 gm iodine; Hypaque-75 contains 19.1 gm iodine. Conray contains 14.1 gm iodine; Conray-400 contains 20 gm iodine.

Toxicity

None of the substances in current use is completely innocuous (Table 1.3). From the clinical point of view, reactions to the contrast media may be described as either allergic or a manifestation of shock (Table 1.4). It has not been possible to study the allergic manifestations experimentally. There has been no demonstrated antigenicity, and attempts at passive transfer have been unsuccessful. However, Borra et al. (1971) report a patient who received 157 ml meglumine diatrizoate (Renografin) during cardiac catherization. The patient developed proliferative glomerulonephritis. One month later, all parameters had returned to normal with relief of the nephrotic syndrome. This was thought to suggest true hypersensitivity to the contrast medium.

There have been many studies of the nature of the "shock reaction." For example, one of the

TABLE 1.3
COMPARISON OF SODIUM AND METHYLGLUCAMINE MEDIA IN REACTIONS TO INTRAVENOUS PYELOGRAM (1967–1968)

	Sodium Media (80,255 Intravenous Pyelograms)	Methylglucamine Media (36,600 Intravenous Pyelograms)
Hypotension	16 (1 in 5,000)	9 (1 in 4,000)
Bronchospasm	5 (1 in 16,000)	8 (1 in 4,600)

Sodium media: Hypaque-45, Conray-420, Conray-480.
Methylglucamine media: Urografin-60, Urografin-76, Conray-280.

TABLE 1.4
CLASSIFICATION OF REACTIONS

Minor	Intermediate	Severe
	Faintness	
Nausea, retching	Severe vomiting	Severe collapse
Slight vomiting	Extensive urticaria	Loss of consciousness
Feeling of heat	Edema of face or glottis	Pulmonary edema
Limited urticaria	Bronchospasm	"Cardiac arrest"
Mild pallor or sweating	Dyspnea	Myocardial infarction syndrome
Itchy skin rashes	Rigors	Cardiac arrhythmias
Arm pain	Chest pain	
	Abdominal pain	
	Headache	

present authors (Gordon et al., 1950) found that the rapid intravenous injection of 35 to 70% Diodrast in dogs produced an early rise in the blood pressure followed by a precipitous fall. There was an increase in the pulse pressure associated with marked changes in the contour of the femoral pulse, a rise in the venous pressure, a decreased pulse rate, and electrocardiographic changes suggesting a myocardial disturbance. It was thought that the most significant reaction was vasodilatation followed by depression of the heart muscle. This is reminiscent of a histamine reaction.

An anatomic basis for these findings was suggested by the report of Killen and Lance (1960) who found varying degrees of microscopic injury to the tubular epithelium. The glomeruli were not damaged. Wiedeman (1964) found, in the experimental animal, during and after intravenous injection, an impaired blood flow for which a complicity of events was responsible. The change was not uniform: to varying degrees, red blood cell aggregates, platelet clumps, and vasoconstriction were seen to block effectively arterial distribution and sometimes venous return from one or more areas. There was a marked decrease in the erythrocyte sedimentation rate. Intraarterial injection sometimes resulted in crenated red blood cells and platelets and damaged endothelial lining of vessels as evidenced by the adherence of leukocytes to vessel walls. These caused an initial vasodilatation that was followed in 10 to 15 min by intense vasoconstriction of some of the vessels whose walls had been in direct contact with the bolus. Arterial inflow was reduced more often at local sites of vasoconstriction. Blockage of vessels for example was most likely to occur in a constricted vessel or at vessel junctions.

Sobin et al. (1959) reported on a study of the corneal-scleral vessels of patients who were subjected to intravenous urography. Vascular changes were seen 1 to 2 min after the end of the injection. There was a marked slowing of the microcirculation, and the fine granular appearance of the erythrocyte column was quickly replaced by a much coarser granularity with red blood cell masses. Variable degrees of vasoconstriction were noted in both minute arterial and venous vessels with marked irregularity in blood vessel margins resulting in a scalloped edge. At times there was almost complete pinching off of the red blood cell column and formation of sausage-like masses which moved slowly down the vascular trunk. Despite the numerous red blood cell aggregates, actual stasis did not occur. Pinched off masses moved slowly and erratically to the confluence with larger vessels and then disappeared into the more rapidly moving larger stream. There was an overall decreased vascularity in the microscopic field. The intensity of these vascular alterations was maximal at 4 to 6 min after the injection, and although no attempt was made to follow the return of the vascular bed to normal in all persons, in most instances it has returned to its previous state 20 min after the administration of the radiopaque material.

Reactions, Treatment, Sensitivity Testing

Severe reactions are quite unusual and are becoming even more infrequent (Table 1.5). Feldman et al. (1962) reported 7 fatalities in over 1,500,000 injections of diatrizoate. Hamm et al. (1960) reported 21,525 intravenous urograms performed with no fatalities but one near fatal. There were four serious reactions. Three were severe immediate reactions of the "allergic" type. One occurred after a test dose of 1 ml diatrizoate and part of the major injection. One patient suffered delayed shock 30 min after

TABLE 1.5
INCIDENCE OF REACTIONS TO UROGRAPHY

	Intermediate reactions	Severe reactions	Death
Total reports received	164	35	13
Reports 1966–69*	142	24	8
Incidence 1966–69	1 in 2,000 (0.044%)	1 in 14,000 (0.0075%)	1 in 40,000 (0.0025%)

* Urographic examinations, 1966–69: 318,500.

injection. In a more recent report, acute renal failure and nephrotic syndrome followed angiocardiography with meglumine diatrizoate. Four cases of renal failure following injection of the contrast media were reported by McEvoy et al. (1970); one of these azotemic patients died 2 days following renal arteriography, and two fatalities followed intravenous cholangiography in patients with jaundice.

A local reaction at the site of intravenous injection is the result of venospasm. It is thought by some to be limited to those cases in which there is extravasation, but we have observed venospasm when there appeared to have been a perfect intravascular injection (however, it is always difficult to be sure there has been no leakage). The pain can be very severe and prolonged and may extend proximal to the site of injection as well as distally. The treatment consists of local cold applications (some use heat) and the use of analgesics.

Systemic reactions may be immediate or delayed. The delayed reaction, also rare, is said to occur in the patient with severe renal and/or liver insufficiency. The precise nature of the reaction to the urographic media in the individual case is not always clear. The "allergic" reaction consists of flushing, urticaria, and angioneurotic edema. Treatment with antihistamines, adrenalin, and/or corticosteroids may be effective, but the continued presence of these symptoms for several days in spite of intense antiallergic therapy is not rare. Many radiologists premedicate with antihistamine particularly in individuals giving an "allergic" history. The evidence that this is of value is inconclusive. In any case, mixing antihistamines and contrast in the same syringe is condemned (Marshall et al., 1965). There is no convincing proof that the "allergic" individual is indeed more susceptible. However, it is advisable that where a history of severe and unquestioned allergy is present, the need for the urographic examination be reviewed and the examination performed as a calculated risk only after consultation as to the proper precautionary measures. It would be wise to consider whether a renogram and renal scan might not suffice since these procedures are not subject to reactions. If urography is performed, it is also wise in these cases to inject through an established perfusion drip so that treatment can be applied rapidly if a reaction develops.

The neuroallergic reaction is the result of an acute encephalopathy which may be severe. These allergic reactions are distressing but are rarely serious.

Clinical evidence suggests that most severe reactions, and possibly those more likely to result in fatality, are the result of peripheral vascular collapse along with a toxic effect on the heart. In these patients, syncope, marked hypotension, respiratory collapse, cyanosis, and cardiac arrest are characteristic (Table 1.6). Other generalized reactions include acute pulmonary edema, convulsions, carpopedal spasm, headache, and chills.

A patient with known myocardial irritability should be examined with particular care. Ventricular tachycardia during excretory urography has been reported by Stadalnik et al (1974). Since this condition is often reversible by the intraveneous administration of lidocaine

TABLE 1.6
DEATHS

Cause	Aggravating factors
Cardiac arrest (5)	Hypertension, cardiac failure, digoxin (1)
	Hypertension (1)
	Intravenous epinephrine, age 73 (1)
	Secondary deposits in adrenals (1)
	No appreciable disease (1)
Cardiac arrest edema glottis (1)	Chronic bronchitis
Tracheobronchial edema (1)	History of angioneurotic edema
Sneezing, cardiac arrest (1)	Rapid injection, age 83
Inhalation vomit (1)	Age 88
Delayed reaction, pyrexia, rash, coma, hypotension (1) myocardial infarction	Hypertension, nephrocalcinosis, renal impairment
Aggravation of renal failure (1)	Ureteric transplants, pelvic malignancy
Overdose in neonates (2)	Congenital heart disease (1)
	Renal failure (1)
Total (13)	

Doses of contrast media: 10 ml (2); 14 ml (1); 20 ml (1); 25 ml (2); 40 ml (2); 50 ml (1); infusion pyelogram (3); unknown (1).

(Xylocaine) 100 mg, these authors advise continuous monitoring of the electrocardiogram. However Walsh (1974) points out the contrast medium used was Conray-400 (150 ml) containing 157.5 meq of sodium, a dose that might cause problems for an irritable myocardium. Increase in the circulating blood volume may also be a factor in the failing heart. Therefore there may be justification for electrocardiographic monitoring in elderly patients where there is clinical suspicion of heart disease.

Reactions are thought by some to be lessened but are not excluded by slow injection. It is questionable whether the morbidity is reduced. The main advantage of slow injection is that it can be stopped if there is an early reaction. However, there are disadvantages which may be paramount, and at present most examinations are performed by the rapid technique. The most important therapeutic procedure is the inhalation of 100% oxygen with, if necessary, artificial respiration. For severe hypotension, 0.2 or 0.5 mg neo-synephrine may be used intraveneously followed, if necessary, by 4 mg *l*-norepinephrine in 500 ml fluid administered by drip. Cardiac massage through the unopened chest may be lifesaving. Respiratory stimulants are contraindicated. Severe restlessness or convulsions may be treated by 25 to 50 mg Seconal or thiopental sodium intravenously.

Preliminary testing for contrast medium hypersensitivity has no practical value. Correlation between reactions and skin and ocular hypersensitivity is unsatisfactory, and the latter test is not without danger to the eye. It is, however, a wise precaution to inject at least the first 1.0 ml of the contrast substance very slowly—some radiologists wait for 5 min after this test injection—but the absence of a reaction to this small amount does not exclude trouble with a full injection. A further precaution is to make the injection through a previously prepared intravenous infusion of 250 ml of normal saline. This is recommended when a patient has suffered a previous reaction. The contrast material can be injected through the connecting tubing. Should a severe reaction occur, the vein is thus readily available for appropriate medication. There are other practical uses for this method. (See "Enhancement Techniques," p. 11 and "Function Tests," p. 26.)

Contraindications

There is no absolute contraindication to excretion urography. In the past, uremia, acute renal disease, known iodine sensitivity, serious liver or cardiac disease, debility, hypertension, psychoneurosis, active tuberculosis, and hyperthyroidism, in addition to the history of "allergy" described above, have been considered contraindications by various authors. These are no longer considered significant. Indeed, high dosage excretion urography may be of great value, for example, in the study of the uremic patient. A summary of acceptable recommendations follows:

1. The radiologist should have enough information to concur that the examination is needed.

2. A history concerning allergy should be obtained and more strict indications for the examination be considered when the benefits definitely outweigh the apparent increased chances of a reaction.

3. The patient should be informed of the risks in such a way that there is understanding without induced fear which might increase the reaction potential.

4. Except for a very questionable value of the intravenous test, pretesting is of no use. In our opinion, no error is committed if pretesting is omitted.

5. Pretreatment with antihistamines and/or corticosteroids may be considered in the high risk patients with a positive history of allergy to many things; there is no good evidence that this is significantly effective.

6. Plan ahead to treat a reaction quickly and effectively, keeping cardiovascular collapse, asthma, and laryngeal edema in mind—mental preparedness (Fig. 1.3, *A* and *B*). The legal implications of not being physically prepared to take care of a reaction is obvious (Thomas and Weigen, 1973).

Vicarious Excretion

In infusion studies reported by Becker et al. (1968) *vicarious excretion* was not demonstrated in normal subjects. Thirty-one patients with renal disease were studied: in 11 there was eventual vicarious excretion. All of these patients had a low urine specific gravity despite moderate to severe degrees of proteinuria. In the other patients the radiographic density of the contrast material may have been too low for resolution. Some patients with severe urinary tract disease excreted urographic material into the gallbladder and bowel by means of both liver detoxification and selective mucosal excretion by the small bowel. The relationship between the degree of renal impairment and this vicarious