GOLDEN'S DIAGNOSTIC RADIOLOGY

Laurence L. Robbins, Editor

Section 18:
SELECTIVE ANGIOGRAPHY

William N. Hanafee *(Section Editor)*, E. W. L. Fletcher, John P. Gartland, Julius H. Grollman, James W. Lecky, Josef Rösch, Richard J. Steckel, Gabriel H. Wilson



GOLDEN'S DIAGNOSTIC RADIOLOGY

Laurence L. Robbins, Editor

Clinical Professor of Radiology, Harvard Medical School; Radiologist-in-Chief, Massachusetts General Hospital, Boston

Section 18: SELECTIVE ANGIOGRAPHY

William N. Hanafee *(Section Editor)*, **E. W. L. Fletcher, John P. Gartland, Julius H. Grollman, James W. Lecky, Josef Rösch, Richard J. Steckel, Gabriel H. Wilson**

The Williams & Wilkins Company Baltimore

Made in the United States of America

Library of Congress Catalog Card Number 73-175644 SBN 683-03865-6

Issued as Section 18 of Golden's Diagnostic Roentgenology in both loose-leaf and book form.

Composed and printed at
Waverly Press, Inc.
Mt. Royal and Guilford Avenues
Baltimore, Maryland 21202 U.S.A.

GOLDEN'S DIAGNOSTIC RADIOLOGY

Section 18: SELECTIVE ANGIOGRAPHY

VOLUMES OF
GOLDEN'S DIAGNOSTIC RADIOLOGY SERIES

Section 1: **Diagnostic Neuroradiology** (*Taveras & Wood*)
Section 2: **Roentgen-Ray Examination of the Paransal Sinuses and Mastoids** (*Grier*)
Section 3: **Radiology of the Chest** (*Rabin*)
Section 4: **Radiology of the Heart and Great Vessels** (*Cooley & Schreiber*)
Section 5: **The Digestive Tract** (*Golden et al.*)
Section 6: **Roentgenologic Diagnosis of Diseases of Bone** (*Edeiken & Hodes*)
Section 7: **Lymphography** (*Clouse*)
Section 8: **Urologic Roentgenology** (*Sussman et al.*)
Section 9: **Uterotubography** (*Robins*)
Section 10: **The Use of the Roentgen Ray in Obstetrics** (*Moloy & Swenson*)
Section 11: **The Roentgen Diagnosis of Fractures** (*Garland*)
Section 12: **Dental Roentgenology** (*Zegarelli*)
Section 13: **The Soft Tissues of the Air and Food Passages of the Neck** (*Young & Funch*)
Section 14: **The Abdomen** (*Taveras & Golden*)
Section 15: **Pediatric Roentgenology** (*Davis*)
Section 16: **Soft Tissue Roentgenology** (*Robbins*)
Section 17: **Development and Application of Body Section Radiography** (*Moore*)
Section 18: **Selective Angiography** (*Hanafee et al.*)
Section 19: **Mammography and Breast Diseases** (*Egan*)

Editor's Introduction—1972

The recent ten years of the new editor of Golden's *Diagnostic Roentgenology/ Radiology* have seen a large number of rapid advances in particular areas of Radiology. These unique developments are reflected in the revisions and new sections which have appeared and are appearing in these volumes. It is further expected that the material of the future will encompass all of Diagnostic Radiology, including technical matters as well as radionuclides.

The present editor has enjoyed the continued influence and effect of his predecessor; may he continue his activities for many more years. It is intended that the authors will continue to have their own literary license, and that there may be variation in presentation from author to author without loss of clarity of fact. Should there be certain repetitions from one particular presentation to another, it is an accepted method in publications of this type and accomplishes an intended variety of opinions available only in such a conglomerate approach to a subject as vast as Diagnostic Radiology.

The editor and authors will welcome any suggestions as to format and content for the future. In addition, the editor and authors extend appreciation to the publishers for their outstanding cooperation in the preparation and presentation of *Diagnostic Roentgenology/Radiology*.

LAURENCE L. ROBBINS, M.D.

Contributors

MELVIN E. CLOUSE, M.D., Boston, Massachusetts; Assistant in Radiology, Harvard Medical School and Assistant in Radiology, Massachusetts General Hospital.

CHRISTIAN V. CIMMINO, M.D., F.F.R., F.A.C.P., Fredericksburg, Virginia; Roentgenologist, Mary Washington Hospital; Clinical Professor, Radiology, Medical College of Virginia; Visiting Lecturer, Radiology, University of Virginia.

LOIS C. COLLINS, M.D., Houston, Texas; Professor of Radiology, Baylor University College of Medicine; Consultant in Radiology, Veterans Administration Hospital and Texas Children's Hospital.

ROBERT N. COOLEY, M.D., Galveston, Texas; Professor and Chairman, Department of Radiology, University of Texas Medical Branch, Galveston.

LAWRENCE A. DAVIS, M.D., Louisville, Kentucky; Professor of Radiology, University of Louisville Medical School; Radiologist, The Children's Hospital.

JACK EDEIKEN, M.D., Philadelphia Pennsylvania; Associate Professor of Radiology, Jefferson Medical College and Medical Center.

ROBERT L. EGAN, M.D., Atlanta, Georgia; Professor of Radiology and Chief, Mammography Section, Emory University School of Medicine.

E. W. L. FLETCHER, M.D., Los Angeles, California; Visiting Assistant Professor of Radiology, U.C.L.A. Center for the Health Sciences.

ROBERT B. FUNCH, M.D., Philadelphia, Pennsylvania; Chief of Radiology, Germantown Dispensary and Hospital, Philadelphia; Clinical Professor of Radiology, Temple University School of Medicine; Visiting Lecturer, Graduate School of Medicine, University of Pennsylvania.

L. HENRY GARLAND, M.B., B.Ch., M.D.* (hon.), F.F.R.I.

JOHN P. GARTLAND, M.D., Los Angeles, California; Instructor in Radiology, U.C.L.A. Center for the Health Sciences.

ROSS GOLDEN, M.D., Los Angeles, California; Visiting Professor of Radiology, University of California at Los Angeles; Emeritus Professor of Radiology, College of Physicians and Surgeons, Columbia University; formerly Director of the Radiological Service, Columbia Presbyterian Medical Center, New York.

GEORGE W. GRIER, M.D.*

JULIUS H. GROLLMAN, M.D., Los Angeles, California; Assistant Professor of Radiology and Chief, Cardiovascular Radiology Section, U.C.L.A. Center for the Health Sciences.

WILLIAM N. HANAFEE, M.D., Los Angeles, California, Professor and Chairman, Department of Radiology, U.C.L.A. Center for the Health Sciences.

JOSEPH HANELIN, M.D., Boston Massachusetts; Clinical Instructor in Radiology, Tufts Medical School; Chief Radiologist, Newton-Wellesley Hospital, Newton; Clinical Associate, Department of Radiology, Massachusetts General Hospital.

PHILIP J. HODES, M.D., Philadelphia, Pennsylvania; Professor of Radiology and Head of the Department; Jefferson Medical College and Medical Center.

GEORGE JACOBSON, M.D., F.A.C.R., F.A.C.P., Los Angeles, California; Consultant Radiologist, Long Beach Veterans Administration Hospital; Professor of Radiology and Chairman of the Department, University of Southern California School of Medicine.

MURRAY L. JANOWER, M.D., Boston Massachusetts; Assistant Professor of Radiology, Harvard Medical School; Associate Radiologist, Massachusetts General Hospital.

E. HOWARD JAYNE, M.D., Los Angeles, California; Assistant Professor of Radiology, University of Southern California School of Medicine.

JAMES W. LECKY, M.D., Los Angeles, California; Assistant Professor of Radiology and Chief, Urological Radiology Section, U.C.L.A. Center for the Health Sciences.

HOWARD C. MOLOY, M.D.*

SHERWOOD MOORE, M.D., St. Louis, Missouri; Professor of Radiology Emeritus, Washington University School of Medicine.

COLEMAN B. RABIN, M.D., New York, New York; Consultant Physician for Chest Diseases, The Mount Sinai Hospital, New York City, Brookdale Medical Center, Brooklyn, Veterans Administration, Brooklyn Regional Office and East Orange Hospital; Associate Radiologist, The Mount Sinai Hospital; Lecturer in Radiology and Clinical Professor of Environmental Medicine, The Mount Sinai School of Medicine, New York City; Vice President, American College of Chest Physicians.

LAURENCE L. ROBBINS, Boston, Massachusetts; Radiologist-inChief, Massachusetts General Hospital, Boston; Clinical Professor of Radiology, Harvard Medical School.

SAMUEL A. ROBINS, M.D., Boston, Massachusetts; Emeritus Professor of Radiology, Tufts University Medical School; Emeritus Radiologist-in-Chief, Beth Israel Hospital.

JOSEF RÖSCH, M.D., Prague, Czechoslovakia; Docent, Charles University; Visiting Professor of Radiology, U.C.L.A. Center for the Health Sciences, Los Angeles.

MELVYN H. SCHREIBER, M.D., Galveston, Texas; Professor of Radiology, John and Mary R. Markle Foundation Scholar in Academic Medicine, University of Texas Medical Branch, Galveston.

RICHARD J. STECKEL, M.D., Los Angeles, California; Assistant Professor of Radiology and Chief, General Inpatient Radiology, U.C.L.A. Center for the Health Sciences.

MARCY L. SUSSMAN, M.D., F.A.C.R., F.A.C.P., F.A.C.C., Scottsdale, Arizona; Consultant Radiologist to the Veterans Administration Hospital and the Arizona State Hospital, Phoenix; Clinical Professor of Radiology, University of Southern California.

PAUL C. SWENSON, M.D.*

JUAN M. TAVERAS, M.D., St. Louis, Missouri; Professor and Chairman, Department of Radiology; and Director of Mallinckrodt Institute of Radiology, Washington University School of Medicine.

GABRIEL H. WILSON, M.D., Los Angeles, California; Associate Professor of Radiology and Chief, Neuroradiology Section, U.C.L.A. Center for the Health Sciences.

ERNEST H. WOOD, M.D., New York, New York; Professor of Radiology, College of Physicians and Surgeons, Columbia University, and Director of Radiology, Neurological Institute, Columbia-Presbyterian Medical Center.

BARTON R. YOUNG, M.D., Philadelphia, Pennsylvania; Professor of Radiology, Temple University; Director, Department of Radiology, Germantown Hospital.

EDWARD V. ZEGARELLI, D.D.S., M.S., New York, New York; Edwin S. Robinson Professor of Dentistry, Director, Division of Stomatology, School of Dental and Oral Surgery, Columbia University; Attending Dental Surgeon, Columbia-Presbyterian Medical Center and Francis Delafield Institute for Cancer Research; Central Office Consultant, Veterans Administration, Washington, D. C.

* Deceased

Author's Introduction

Difficulties are immediately apparent when multiple authors try to cover a subject so heavily dependent upon technique as selective arteriography. Many so-called "tricks" of technique must, of necessity, be left out since they are somewhat dependent upon the skill of the individual operator and his available equipment. By having multiple authors, we hope to reach a compromise of varied opinions as to approach and yet remain parochial in the sense that the consolidated ideas of one institution remain dominant.

The authors tend to direct their remarks to the level of a second-year radiology resident. Hopefully, in this fashion the presentations will be clear enough as an introduction to selective angiography, and only moderately boring to the more advanced angiographer. At UCLA, angiography is the most rapidly growing segment of our department in terms of professional time and expenditures. The reader must maintain a spirit of tolerance if new technical advances supersede the submission of this manuscript. Perhaps this is one reason why we all enjoy the enthusiasm and stimulation of this new modality.

Our thanks to the contributing authors, to our photographers, Mr. Paul Stout and Miss Yolanda Fuentes, and to Mrs. Lois Haas and the secretarial staff at UCLA for their energetic pursuit of this chapter.

Dedication

We humbly dedicate this book to three giants of radiology who continue to shape the medical thinking of UCLA—to Dr. Ross Golden, who exemplifies the gentleman in radiology; to Dr. Andrew Dowdy, with his wisdom for stimulating freedom of ideas and expression; and to Dr. Leo Rigler, the master diagnostician who serves as a model for all students of radiology.

Section 18:
SELECTIVE ANGIOGRAPHY

Contents

1

Fundamentals of Selective Angiography

J. H. GROLLMAN, Jr., M.D.,
J. RÖSCH, M.D.,
R. J. STECKEL, M.D.

INTRODUCTION

After the pioneer work of Brooks (1924) in the area of femoral arteriography, Moniz *et al.* (1928) in carotid arteriography, and dos Santos *et al.* (1929) in translumbar aortography, arteriography rapidly gained acceptance. Injection of contrast through a needle only, however, limited the examination to the abdominal aorta and peripheral vessels. With the introduction of the catheter into arteriographic techniques, it became possible to visualize more remote parts of the vascular system including pathologic changes in smaller vessels and individual organs. The surgical exposure of the artery actually first restrained broad acceptance of catheter arteriography, as it was used only in a few institutions despite stimulative work of Farinas (1941), Radner (1948), and others.

Arteriography as a routine examination first became feasible with Seldinger's (1953) description of the catheter replacement technique. With the continuous refinement of techniques and development of improved catheter materials, visualization of arteries nearly anywhere in the body became possible, especially with selective arteriography.

The developments in contrast agents, x-ray equipment, and rapid film changers have greatly aided this progress, with arteriography, once primarily a surgical procedure, passing into the field of radiology. Radiologists have assumed responsibility for the performance as well as the interpretation of the angiographic studies, and angiography has become a subspecialty of radiology in which there are individuals spending a major portion of their time. Under the guidance of angiographers, the risks of angiography have decreased immensely, while techniques have progressed even to the point of application to therapeutic intervention.

The purpose of this monograph is to review the field of selective angiography. It will be based upon published reports, of course deeply influenced by our own experience. Exclusion of any approach or experience should not be taken as an indication of their lack of merit. Any technique used safely by an angiographer that reliably obtains good results should be continued. However, an open mind should be kept with a willingness to try new methods as they become available. Arteriography is still under development with much remaining to be accomplished both in technique and interpretation.

MATERIALS

X-ray Equipment

At least a 500 MA generator is required, but newer 1,000 MA three-phase equipment is preferable because it allows techniques using a low peak kilovoltage to enhance contrast. In addition, a far too frequently forgotten point is the focal spot size of the x-ray tube. For routine angiography, a focal spot of approximately 1 mm. should be employed. We have found a 2-mm. focal spot to allow too much penumbra for good definition of small vessels and atheromatous plaques. Clinical serial magnification angiography is now possible with newer tubes having a 0.3-mm. focal spot.

Either a floating table top or a standard fluoroscopic tilt table may be utilized. The former is preferable because of the ease and the greater speed in which the examination may be accomplished. However, the more conventional type of tilt table is satisfactory and allows use of the examination room for other purposes.

A film changer is imperative, preferably one which will allow three or more films per second. Film rates of 2 per sec. are permissible, but will occasionally miss important information. A cut-film changer without individual cassettes or a roll-film changer are the most popular because of their ease of loading. Individual cassettes, although potentially giving the greatest detail, are somewhat inconvenient and time-consuming in their loading. Roll-film changers are the most reliable, but film storage is a problem unless individual film frames are cut.

An image intensifier of high quality is necessary. Marginal intensifier tubes do not allow the detail that is so important during manipulation of catheters. Television monitoring is very helpful as it permits the angiographer greater flexibility of movement. Tape recording and cine capabilities are useful, but not imperative, except in selctive coronary angiography.

Pressure injectors of the flow rate type are most valuable in selective angiography, as they allow within certain limits predetermination of a desired flow rate. Their reliability has been shown to be best at the lower flow rates which of course are more often used with selective techniques (Komar *et al.,* 1966). Angiographers are still reluctant to give up any knowledge of the "pressure" used during an injection. It must be remembered, however, that the pressure dialed on an injector is generally that at the tip of the injection syringe and not at the tip of the catheter. The actual pressure drops considerably along the catheter, dependent upon its length and internal diameter; therefore, it is our feeling that notation of the pressure used for an injection is of no real relevance, but the flow rate is.

With the advent of rapid film processing, the performance time of angiography has been decreased significantly resulting in greater safety to the patient. The importance of rapid processing is not that it takes 90 sec. for a film to be developed, but rather that a complete series can be developed in a few minutes as opposed to 15 min. or more.

Tools

Vascular needles of many types are available, depending upon the preference of the angiographer. We prefer to use needles without an inner stylet or obturator because of their simplicity. However, no great argument may be made for any particular type other than that it probably should not be larger than 17 gauge in adults, 18 gauge in children, and 19 gauge in infants. It should be mentioned that the bevel should be short, lessening the possibility of subintimal passage of the guide wire. A helpful modification is the use of a special hollow-ground tip which decreases wear and tear on the guide wire (fig. 1).

Catheters

For most purposes of selective angiography, opaque polyethylene catheters are preferred either thin-wall or thick-wall. They should be as small as possible, yet allowing adequate delivery of the contrast bolus for a particular examination. We prefer not to use a larger size than 8F in adults of normal size, with appropriately smaller sizes for smaller patients. For most selective studies sizes between 6 and 7F will be applicable, but even smaller catheters are appropriate for certain examinations to be discussed in subsequent chapters.

Teflon catheters have been used by some for selective catheterizations (Klatte *et al.*, 1968); however, in older patients with atheromatous changes, the use of Teflon catheters is associated with a greater risk because of their marked rigidity. In addition, molding of Teflon catheters is difficult as they tend to lose their curve unless specially tempered. We prefer restricting their use to aortic injections.

Woven Dacron catheters have been employed in selected incidences for selective angiography. A prime example is coronary arteriography which is commonly performed with woven Dacron catheters designed by Sones and Shirey (1962). They are not, however, well suited to percutaneous techniques because they are relatively rough on arteries and absorb water, allowing change in size during use. With prolonged use within the blood stream, flexibility increases making manipulation more difficult.

Polyurethane is a more recently available catheter material having excellent torque control and memory for curves, yet allowing considerable flexibility. Unfortunately, they are somewhat difficult to work with because of their rubbery nature and therefore require special Teflon coated guide wires. There will be more discussion of these catheters in subsequent chapters.

Guide Wires and Systems

The standard guide size used by most angiographers is 0.35 inch in diameter. We prefer to use a slightly smaller size, 0.032 inch, because of its greater ease of use with catheters with an internal diameter of 0.040 inch or less. Other wires that should be available to the angiographer for specific purposes are the 0.025- and 0.045-inch wires, the former for its greater flexibility, which is of value in superselective angiography, and the latter to give greater strength to very thin-walled, flexible polyethylene catheters. Movable core guides, J-guides, Teflon coated wires, and their

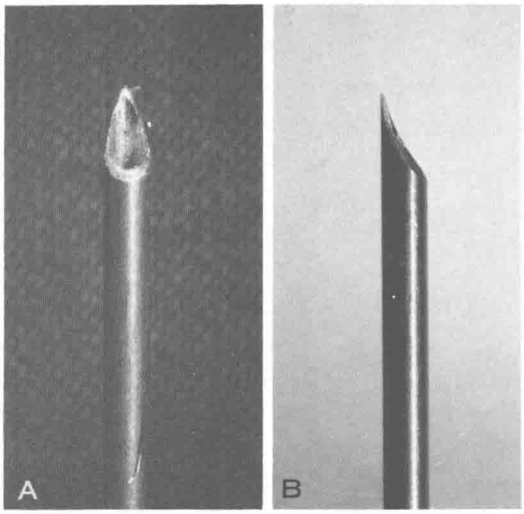

FIG. 1 (A AND B).—HOLLOW-GROUND "SCOOP" BEVEL OF UCLA VASCULAR NEEDLE

Note that in the frontal view the base of the bevel is rounded. With a conventional straight bevel the base is "V"-shaped which offers resistance to movement of the guide wire.

combinations are also other adjuncts that the angiographer should be familiar with and have available for specific purposes as will be discussed in subsequent chapters. Many angiographers will use only Teflon coated wires.

Deflecting systems have become quite popular in many centers. Many systems are available, each with different attributes and disadvantages (Grollman *et al.*, 1968; Rabinov and Simon, 1969; Reuter, 1969; Rösch and Grollman, 1969; Viamonte and Stevens, 1965; Wholey and Jackman, 1966). Most often they are used with very flexible catheters working on the principle of deflection of the catheter tip by deflection of the wire guide.

Another technique of guided angiography reported by Viamonte and Stevens (1965) involves changing the deflection of a preformed catheter by advancing or withdrawing a straight wire. More recently use of a preformed but flexible catheter in combination with a deflectible guide wire system has been applied (Reuter, 1969; Rösch and Grollman, 1969). A complete, although rather complicated, review of this subject plus preliminary observations on another system may be found in a monograph by Almen (1966).

Miscellaneous Adjuncts

Various assorted clips, syringes, and hemostats are important, but their use is up to the discretion of the angiographer. We recommend the use of heparinized saline for flushing, preferably in a closed system. A pressure pack to allow constant flushing of an arterial catheter is extremely helpful. It is of value to the angiographer to have a pressure monitoring system available for use as occasionally the necessity arises to measure pressures or pressure gradients during performance of selective angiography.

CONTRAST MEDIA

In selective angiography, chemotoxicity is the most important aspect of toxicity with which the angiographer is concerned. This is dependent on the molecular formula, concentration, and osmolarity of the contrast agent. There is probably not much actual difference in toxicity due to minor differences in the molecular configuration between the diatrizoates, iothalamates, and metrizoates (Fischer and Cornell, 1965; Gensini and Di Giorgi, 1964). Therefore, for clinical purposes, there is no reason to pick one over the other for this reason alone.

TABLE I

CLINICAL APPROACH TO CONTRAST MEDIA*

Concentration Group	Agent	I	Na	Viscosity at 37°C.
		mg/ml	*mg/ml*	*cps*
Low	Hypaque Meglumine 60%[3]†	282	0.02	4.1
	Conray‡	282	0.1	4.0
	Reno-M-60§	282	0.9	4.1
	Renografin-60§	293	3.8	4.3
	Hypaque Sodium 50%†	300	17.7	2.3
Medium	Cardiografin 85§	400	0.7	13.7
	Reno-M-76§	358	0.9	8.6
	Renografin-76§	370	4.5	9.3
	Hypaque-M 75%†	385	9.3	8.4
	Vascoray‡	400	9.4	9.7
	Renovist§	372	13.5	6.1
	Conray 400‡	400	24.1	4.4
High	Hypaque-M 90%†	462	10.3	18.7
	Angio-Conray‡	480	29.0	8.4

* Data obtained from manufacturers.

† Formulations of diatrizoate from Winthrop Laboratories, New York, New York.

‡ Formulations of iothalamate from Mallinckrodt Pharmaceuticals, St. Louis, Missouri.

§ Formulations of diatrizoate from E. R. Squibb & Sons, New York, New York.

The major differences between the presently used angiographic contrast media are related then to concentration and osmolarity (Fischer, 1965 and 1968). Osmolarity is influenced by the relative sodium and meglumine salt content of the agents used. The use of meglumine reduces the osmolarity and toxicity significantly, but also increases the viscosity, impairing the delivery rate (Fischer, 1965; Gensini and Di Giorgi, 1964). Stating this in another way, the concentration of sodium ion is directly related to the chemotoxicity of a given contrast agent.

It is convenient to divide the various available angiographic contrast media into three groups: low, medium, and high concentration (table I). In the low concentration group Conray-60, Reno-M-60, and Hypaque Meglumine 60% are essentially entirely meglumine salts whereas Renografin-60 contains a small proportion of sodium salt (roughly 13% (Fischer, 1965)) and Hypaque Sodium 50% is entirely a sodium salt. The iodine content of these agents is similar.

In the medium concentration group are included several agents with iodine contents ranging between 358 and 400 mg. per ml. It should be noted that, whereas Cardiografin-85 and Reno-M-76 contain essentially 100% meglumine diatrizoate, Conray-400 is 100% sodium iothalamate. The remaining three agents are varying mixtures in between with the approximate relative amount of sodium ion being as follows (Fischer, 1965): Renografin-76, 13%; Hypaque-M 75%, 33%; Vascoray, 33%; and Renovist, 50%.

Finally, in the high concentration group there are Hypaque-M 90% and Angio-