VASCULAR ROENTGENOLOGY

Arteriography • Phlebography • Lymphography

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Phlebography,
Lymphography

Preface

DURING THE PAST three decades, angiographic investigations have led to better understanding of and more precise therapy for a variety of morbid conditions, particularly of cardiovascular disease states. The vast field of angiography has been in full motion: new techniques have been developed, better and less toxic contrast media have become available, patients have been selected on a more adequate basis, new areas have been explored, and various types of procedures have been performed under increasingly satisfactory technical conditions by a growing number of qualified individuals.

Each of the three angiographic modalities—arteriography, phlebography, and lymphography—deals, in general, with one portion of the vascular system. Since the numerous segments of the human circulation are linked anatomically to each other, at various levels, some physiologic interdependence automatically ensues. Thus, the hemodynamic events within one system may influence those taking place within another; even more, individual segments of one system may, in the course of normal functional events as well as during pathologic conditions, show considerable hemodynamic variation. The conscientious examiner must take these facts into full consideration, not only where the indications and techniques of intravascular contrast studies are concerned but even more so in the interpretation of angiographic patterns.

Experience has repeatedly demonstrated that artificially created circulatory events in cadavers may be entirely different from the active hemodynamics in the living human subject. Intravascular contrast studies performed on the dissecting table are instructive and frequently necessary in order to settle an anatomic question or to develop a particular technique. Yet, it is only in the subject with a pulsating heart that the static observations collected on cadavers will come to life, reflecting an ofttimes unsuspected anatomic and functional versatility of the human circulation. It is here that the real challenge of angiography resides.

This volume has been designed as an introduction to the general principles of angiography and as a summary of angiographic procedures as executed by several dozen highly experienced workers of international reputation. All 93 contributors are active in the fields with which they are identified herein; indeed, some of them have pioneered certain procedures, whereas others have applied new methods for the first time to the living human subject or have developed important technical refinements. Their experience and judgment can be accepted without documentation; the expressed individual preferences are the inevitable result of extensive experience. Included in the various contributions is a wealth of anatomic, clinical, and technical information, including the answers to such questions as: What has angiography to offer? When are angiographic procedures indicated or contraindicated, and what are their limitations? How are individual procedures best executed in order to obtain diagnostic results, and what information may they yield? What complications, if any, may arise from the various procedures?

The chapters herein are concerned primarily with methods of introducing contrast media directly into the lumen of arteries, veins, and lymphatic channels. However, emphasis is also placed on other methods not based on this principle of direct angiography but on that of introducing radiopaque substances into the vascular system through interposed organs or other structures (percutaneous splenoportography or transosseous phlebography). Although the angiographic techniques practiced at the present time receive the greatest emphasis, some older (and perhaps now obsolete) methods have been included for the sake of comparison, as have several technical variations for one procedure. Thus, the reader will be able to become familiar with a cross section of the more important opinions and angiographic methods and can thereby select the procedure(s) best adapted to his abilities or to the available facilities.

Certain sections will appear to contain too little or too much iconography. This pictorial disequilibrium is the result of necessity and intent. It was inevitable that a proportionately larger number of illustrations be selected for a section such as cerebral angiography, with its multiple details. Conversely, in the section on the heart, the gross anatomy, which should be thoroughly familiar to all, purposely lacks illustrations and description. By the same token, the discussion of the pathologic conditions affecting the heart could hardly be expected to assume the aspect of a separate atlas—hence the minimal number of illustrations in that chapter. On the other hand, a proportionately greater emphasis on illustrative material is placed in chapters dealing with newer angiographic methods, such as coronary arteriography, azygography, vertebral plexus phlebography, and lymphography. Particularly for lymphography, the elaboration upon certain anatomic, technical, and (of no little importance) functional details should allow the reader to gain more profound insight into the behavior and examination of this vascular territory.

Experimental data have been excluded unless of great historical importance or pertinent to a better understanding of the subject or to the development of improved techniques. Statistics have been included only where absolutely essential, since they not only are subject to rapid change but also do not always reflect the true state of affairs (medicine is notorious for its exceptions).

This book, timely in concept and purpose, will be of greatest interest to clinicians whose activities bring them in contact with angiography—i.e., radiologists, vascular surgeons, cardiologists, internists, orthopedic surgeons, urologists, and neurosurgeons. However, it should also prove useful to investigators who may already employ angiography or who plan to do so. In this respect, the various sections dealing with future potentialities of certain methods contain many stimulating remarks that may lead the way to a better perception of poorly understood, or as yet unexplained, clinical phenomena. It is only by comparing the past with the present and by anticipating the future that the horizon of this challenging field can be brought into sharper focus.

The editors are profoundly thankful to the various contributors for their willingness, in spite of busy schedules of practice, teaching, research, and writing, to bring their specialized knowledge to this book. Grateful acknowledgment is also made for the secretarial help of Mrs. Ida Rudgerson and Miss Fern Malamet, as well as for bibliographic assistance given by Miss Margaret Kinney and Miss Angela White. Finally, the editors wish to thank their wives, whose patience and understanding have been of inestimable value.

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PART ONE

General Considerations

CHAPTER I

Milestones in Angiography

Robert A. Schobinger, M.D.

THE DISCOVERY of x-rays by Röntgen on November 8, 1895, quickly led to a broad investigation of the potential diagnostic value and clinical significance of this new technical achievement. Indeed, only a few weeks after Röntgen's discovery a report on the first arteriogram was published by the Austrians Haschek and Lindenthal (1896). Their vascular contrast study was obtained by the instillation of a chalk-containing solution into the arterial system of an amputated upper extremity. Though incomplete in detail because of technical limitations, their work must be considered an important milestone in radiographic diagnosis. In the same year, similar experiments were accomplished by McIntyre in England and by Destat and Berard in France, who by confirming the observations of their Austrian colleagues provided further stimulation for continued investigations in this field. Efforts in this latter direction purported primarily to find a contrast substance suitable for injection into the vascular system of living human subjects and to improve roentgenographic techniques.

Although the cornerstone to the building of a special diagnostic field of tremendous importance was laid an extremely short time after Röntgen's discovery, it was only after the development of suitable contrast media early in the second decade of this century that angiography became practicable on a clinical basis. The discovery of the radiologic value of iodized poppyseed oil (Lipiodol) was followed by the injection of this material into the antecubital vein of a living human subject by Sicard and Forestier of France (1923), who fluoroscopically followed the progression of the contrast substance through the right cardiac chambers into the pulmonary arteries. Somewhat later in the same year, the first peripheral angiogram of a living patient was obtained by the Germans Berberich and Hirsch (1923), who injected strontium bromide into the arteries and veins of the arm and hand. An important accomplishment in peripheral arteriography must be credited to the American Brooks, who in 1924 made the first successful femoral arteriogram of a living human subject. The technique of arteriography proposed by Brooks, which consisted of the surgical exposures of the femoral artery near the groin and the injection of a solution of sodium iodide under general anesthesia, remained for many years the standard method.

While clinical angiography of the superficial and peripheral veins was now possible with encouragingly consistent success and relative safety, the deeply situated vessels of the body still escaped radiographic visualization in man. Vascular terri-

tories such as those within the cranium, thoracic cage, and abdominal cavity remained a challenge to the diagnostician.

The door to clinical angiography of these deeper-located vessels was opened by dos Santos, Lamas, and Pereira-Caldas of Portugal, who must be credited with having made the first successful translumbar aortogram of man. Their work, begun in 1925 and reported in 1929, pioneered successful arteriography of the abdominal vessels. The courage and foresight of these workers is merely enhanced by the cool reception of their method, which for many years was the topic of frequently vehement controversy.

Some reservations toward translumbar aortography were overcome by Fariñas (1941), who introduced a catheter into the aorta through the exposed femoral artery and thus injected contrast medium into this large vessel. This basic concept was later modified by the percutaneous approach of Peirce (1951), who threaded the catheter into the femoral artery through a needle. This technique, which was greatly refined by Seldinger (1953), forms the basis for many modern angiographic procedures. Recently, intravenous abdominal aortography, developed by Bernstein and co-workers (1958), has been added to our diagnostic armamentarium in the hope of further decreasing the number of contraindications and complications of the translumbar approach.

Thoracic aortography was introduced by Nuvoli (1936), who, applying to the thorax dos Santos' principle of translumbar aortic puncture, advanced a needle into the thoracic aorta or heart via the percutaneous transthoracic approach. To eliminate some drawbacks of this method, Castellanos and Pereiras (1939) introduced retrograde brachial aortography, or counter-current aortography as they called it. A further, yet important, improvement of thoracic aortography must be credited to Radner (1948), who obtained opacification of the thoracic aorta following open retrograde catheterization of the radial artery. This same worker is also credited with having performed the first coronary arteriogram in man (1945). Jönsson (1949) modified Radner's technique by performing thoracic aortography through a cannula inserted percutaneously into the common carotid artery. However, thoracic aortography is now preferably performed by the intravenous method or by applying the previously mentioned principles of Peirce and Seldinger.

Another milestone in angiography must be credited to the Portuguese school which so eminently contributed to the development of this field. In the same period in which dos Santos and his co-workers developed translumbar aortography, the first successful opacification of the cerebral circulation in the living human being was reported by Moniz and associates (1927), who introduced carotid arteriography. Carotid and vertebral arteriography can be adequately performed by catheterization technique or according to one of the methods employing direct percutaneous needle puncture of the subclavian or brachial arteries.

The now well-recognized achievement of cardiovascular catheterization by Forssmann (1929; Nobel Prize, 1956) was greatly responsible not only for the various catheter techniques but also for more selective cardiovascular contrast studies. Indeed, Moniz, Carvalho, and Lima reported in 1931 the first clinically successful demonstration of the pulmonary arteries employing Forssmann's catheter, which procedure they called angiopneumography. Forssmann himself (1931) attempted to opacify the chambers of the right heart and the pulmonary arteries. Some refinements in the technique of pulmonary angiography were introduced by Carlens and co-workers (1951), who temporarily occluded one pulmonary artery while injecting the contralateral vessel, and by Bolt and associates (1957), who introduced contrast medium directly into segmental and even subsegmental pulmonary arteries. Prior to that date, however, Jönsson and co-workers (1949) performed what they termed "selective angiocardiography" by advancing a catheter through a vein at the elbow. This was a refinement of the technique of "direct intracardiac angiocardiography" described by Chavez and co-workers (1947), which consisted of the advancement of a catheter through the external jugular vein into the right side of the heart with injection of contrast substance directly into the cardiac chambers.

Angiocardiography was introduced by Castellanos, Pereiras, and Garcia of Cuba (1937). These workers, by the intravenous injection of opaque medium, accomplished opacification of the heart and pulmonary vessels in children afflicted with congenital heart disease. This method was later extended to adults (Robb and Steinberg, 1938).

Opacification of the arteries leading to the intestine during laparotomy is a more recent angiographic procedure. It was introduced by Schobinger and co-workers (1957), who called it "operative intestinal arteriography."

As stated earlier, it was in 1923 that the first

peripheral arteriogram and phlebogram were obtained by the Germans Berberich and Hirsch. These initial studies were followed by similar examinations of other veins. Dos Santos, who pioneered translumbar aortography, is also credited with making the first successful phlebogram of the lower extremity, pelvis, and inferior vena cava following surgical cannulation of the saphenous vein in the thigh (1935). Castellanos and Pereiras (1946) visualized the inferior vena cava after open cannulation of the saphenous vein at the ankle, hence allowing also opaque studies of the venous system of the entire lower extremity. O'Loughlin (1947) described his method of pelvic and inferior caval phlebography by direct percutaneous puncture of the femoral vein in the groin, a principle which is still employed by many. An original, yet not widely accepted, method of inferior cavography was described by Gansau (1956), who punctured the inferior vena cava through the right translumbar route.

Some deeply situated venous channels such as the azygos, epidural, internal mammary, and portal veins, just to mention a few, escaped visualization by conventional peripheral phlebographic avenues. The scope of venous angiography was widened by the development of transosseous phlebographic techniques by many workers who applied the observations of Benda and co-workers (1940), Tocantins (1940), and Erhardt and Kneip (1943) that the intramedullary route could advantageously be employed for the administration of infusions and contrast substances. Schobinger (1960) described 15 different sites of intra-osseous injections for opacifications of peripheral as well as deep veins.

For many years, clinicians searched for a method allowing the roentgenographic demonstration of the portal venous bed. The first surgical approach to veins of the portal bed consisted of the cannulation of a branch of the portal venous system during laparotomy (Blakemore and Lord, 1945). A more formal technique of operative portal phlebography was introduced a few years later by de Sousa Pereira (1949, 1952). Incidentally, the publication in 1952 by de Sousa contains an illustration of a percutaneous splenoportogram with deposit of contrast medium into a tributary of the splenic vein. After the well-known experimental work of Abeatici and Campi (1951), consisting of the percutaneous puncture of the splenic pulp, it required little time indeed to see their most useful method of percutaneous splenoportography applied for the first time in living man by Leger (1951). Another method allowing the radiographic opacification of the portal vein was proposed by Bierman and coworkers (1952), who introduced percutaneous transhepatic portal phlebography.

While some of the intrahepatic vascular patterns become apparent in the course of portal phlebography, it remained for Tori (1953) to pioneer the opacification of the hepatic veins proper by the retrograde catheterization method.

The third and angiographically least-known portion of the vascular system is the network of lymphatic pathways. The presence of lymphatic vessels was already known to Hippocrates, who called them conduits for "white blood." The term "ductus lactei" was employed by the disciples of the famous Alexandrine school to identify these structures in humans and animals. Yet, their existence was forgotten, not an unusual occurrence in medical history, until they were rediscovered in the seventeenth century A.D. by Asellius (1627). The great anatomist Vesalius (1543), who contributed so much to the knowledge of the vascular system, is credited with having first adequately described the thoracic duct. Further anatomic details concerning the lymphatic channels can be found in the writings of Pecquet (1651) and Rudbeck (1651).

Although certain lymphatic channels were already outlined by Nuck (1692), who used mercury for injection purposes, clinical studies on the human lymphatic system had to await the advent of the twentieth century and dealt primarily with the flow rate of lymph. In this regard, the techniques employed were the intracutaneous methods of Dalmady (1911), who injected epinephrine, and of McMaster (1937), who employed dye. The subcutaneous lymphatics were apparently for the first time opacified by Teneff and Stoppani (1934), who radiographically studied these structures in dogs following the subcutaneous injection of thorium dioxide (Thorotrast). However, it remained for Kinmonth (1952) to devise a clinically practical method for contrast studies of the lymphatics in the living human being. His technique remains up to the present the basic method for clinical lymphography.

An alternate method to visualize lymphatic structures consists of instilling contrast medium into a lymph node. This approach was apparently first described by Monteiro (1938).

Hence, the groundwork for the discipline called angiology, which comprises angiography as an essential modality, was laid centuries ago in regards to anatomy and decades ago where technical pro-

cedures are concerned. The intensive use of angiography witnessed today has only been rendered possible by an unceasing effort to refine technical aspects, to broaden the indications for vascular contrast studies, and by taking into full consideration the curiosity and the experience of a great number of workers, some well known, some unjustly forgotten. Furthermore, angiographic progress has and still is greatly conditioned by the development of effective therapeutic measures requiring precise diagnostic information for their successful execution. On the other hand, increased diagnostic precision fostered by advanced angiographic knowledge not only has led to the detection of many morbid conditions but has also placed certain congenital and acquired disease states within the scope of successful therapeusis. There can be no doubt that the role played by angiography in our diagnostic armamentarium will continue to grow.

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