W. Wenz

Abdominal Angiography

In collaboration with
G. van Kaick, D. Beduhn
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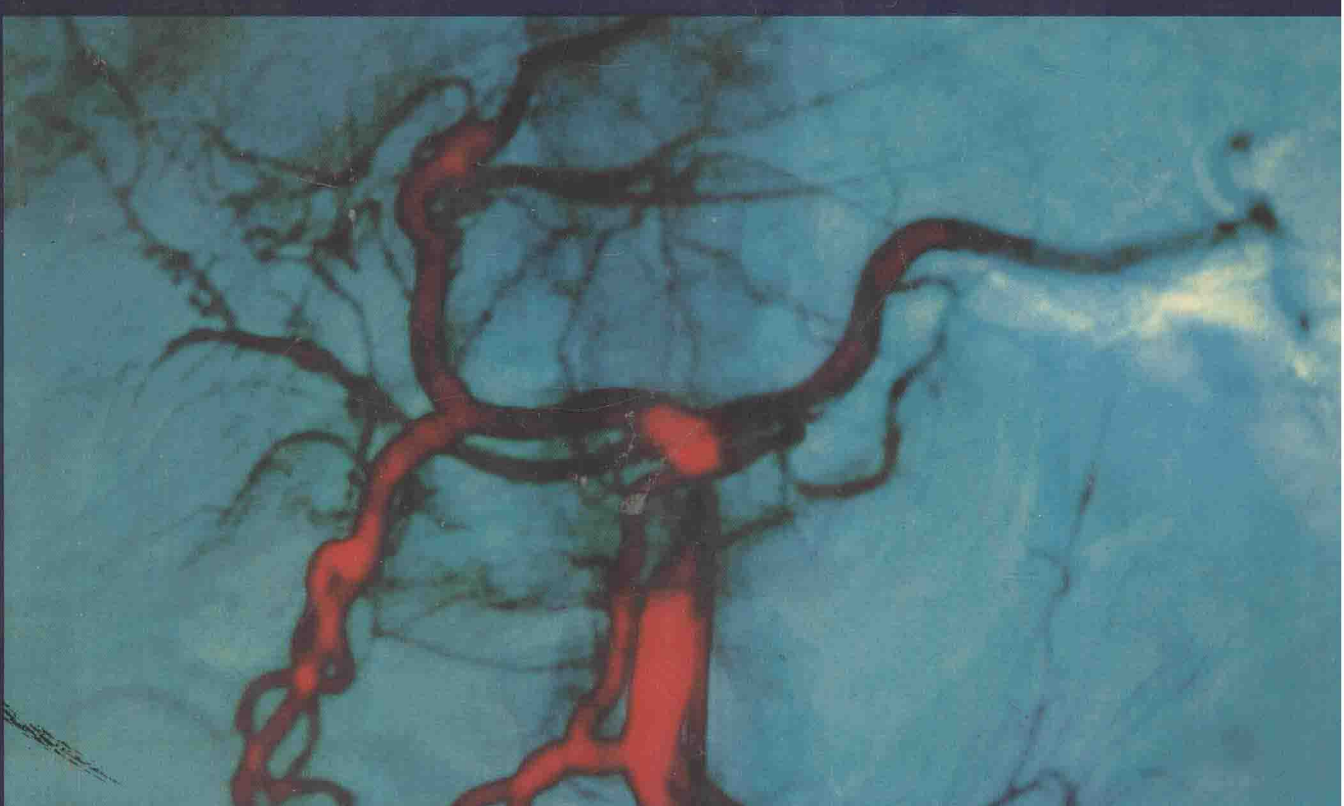

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With 183 figures, some in color,
comprising 351 radiographs and 34 drawings

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Preface

The brilliant yet simple idea of introducing a catheter percutaneously into an artery, without first dissecting it free, using a flexible guide wire, has led to a truly revolutionary breakthrough in abdominal x-ray diagnosis (SELDINGER, 1953).

In the meantime, methods and techniques for injecting contrast media into various vessels have become largely standardized; innumerable publications have appeared which deal with every conceivable aspect of angiographic technique and interpretation.

This volume is designed to present our experience with abdominal angiography. We deliberately refrained from any systematic discussion of the genitourinary tract, which has been adequately dealt with in the literature, also with respect to angiographic findings. Our interest in the retroperitoneal region is based mainly on its significance in differential diagnosis.

In ten years of angiographic activity, our Department had made successful use of a simple technique which appears suitable also for smaller hospitals. We wish to point out its diagnostic potential and, at the same time, to outline its limitations.

Our experience embraces 2804 abdominal angiograms, which we have classified according to clinical and morphologic anatomical criteria. Their diagnostic interpretation has been compared with the surgical or histopathological results. This may help others to avoid errors of the type which we discovered in our own work.

Angiographic diagnosis requires not only familiarity with normal radiographic anatomy, but also specific knowledge of angiographic pathomorphology. We have tried to identify those features which typify the individual findings and to derive therefrom valid generalizations with the aid of simple sketches.

We consider the introduction of subtraction and color subtraction, which facilitates the visualization of epigastric organs and the differentiation of various vascular systems, another contribution to the field of visceral angiography. A number of our findings were made possible by electronic subtraction techniques and are displayed accordingly.

Some of the more recent indications for human angiography are founded on experience gained in animal experimentation. Results we obtained in the angiographic diagnosis of gastrointestinal bleeding of undetermined origin and during shock are included in the appropriate chapters.

The book unquestionably bears the stamp of a surgical university clinic, notably in the composition of the patient population. We are indebted to the Director of our Clinic, Professor Dr. F. LINDER, for his immediate, unstinting support and his contribution to the advancement of abdominal angiography.

Our thanks extend not only to our colleagues at the Clinic, but to all those who have frequently referred patients to us for angiographic examination from outside. We wish to thank Doctors H. CZEMBIREK, H.-J. ENCKE, and H. LOHÖLTER, former scientific assistants at the Department of Radiology, for their active collaboration in screening the patients, and our secretarial staff and technicians without whose devotion and enthusiasm the performance of the numerous angiographic examinations would not have been possible.

We are indepted to Dr. D. KAUFFMANN for his assistance in the English edition.

Credit for the drawings goes to H. HEINRICH, who showed uncommon skill in giving graphic expression to our ideas. Thanks are also due to Mr. KRAMER, our photography expert, for his untiring cooperation in the preparation of color radiographs.

The publishers, Springer-Verlag, have been extremely cooperative and liberal in their production of the book, and we are sincerely grateful.

Last but not least, we also want to express our appreciation to our patients! We endeavored to arrive at the correct diagnosis with the use of a new radiographic technique and so to open the way for a specific, goal-directed therapy. Without their "passive" cooperation, involving some unavoidable discomfort, this book could never have been written.

Heidelberg, November 1973 W. WENZ

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I Introduction and Historical Review

In contrast to the rapid progress of other methods of radiologic diagnosis, much time elapsed between the first angiographic demonstration of intra-abdominal changes by DOS SANTOS (1931) and the worldwide use being made today of radiologic techniques in the examination of abdominal vasculature.

No doubt the routine performance of abdominal angiography was considerably delayed by the fear of complications due to puncture of the abdominal aorta, as well as by a series of incidents occurring during studies by ICHIKAWA (1936) involving the surgical exposure of arteries for catheterization. It should be recognized, too, that leading scientists failed to grasp or at least misconstrued the clinical implications of the procedure.

PAUL LECENE, for example, has been quoted as follows in the monograph published 1966 by CORMIER and associates: "REYNALDO DOS SANTOS' radiographs are very pretty and most certainly of interest to an anatomist, but I question that they would ever be useful to a surgeon."

This completely erroneous appraisal by a notable contemporary is by no means an isolated instance. Even in Germany, well into the fifties, there were still prominent clinic directors who strictly banned angiography, particularly of abdominal vessels.

What are the factors that ultimately led to a breakthrough in roentgenologic angiography?

Three important events should be cited:

1. The first translumbar aortography by direct puncture, proving the feasibility of radiologic visualization of abdominal vessels (DOS SANTOS et al., 1929).

2. Percutaneous catheterization with the aid of a cannula and a guide wire, without exposure of the artery (SELDINGER, 1953).

3. Efforts by three independent research groups to make it possible for a catheter introduced into the vessel lumen to be passed into any of its branches (OEDMAN; MORINO et al.; TILLANDER, 1956).

In the last analysis, it is to these authors that we owe our knowledge of the course of the celiac and superior mesenteric arteries.

Various methodological way stations still had to be passed before the present-day standardized technique could be developed.

Development of angiography

1928	FORSSMANN	Catheterization of the human vascular system
1928	MONIZ	Carotid angiography
1929	DOS SANTOS	Translumbar aortography
1936	ICHIKAWA	Catheter aortography by way of surgically exposed peripheral artery
1951	ABEATICI and CAMPI	Splenoportography
1951	PEIRCE	Percutaneous catheterization through cannula
1951	BIERMAN	Selective visceral catheter arteriography via surgically exposed carotid or brachial artery with topical injection of chemotherapeutic agents
1952	KINMONTH	Lymphangiography
1953	SELDINGER	Percutaneous catheter aorto-arteriography using cannula and a guide wire
1956	OEDMAN; TILLANDER; MORINO	Selective arteriography with curved plastic catheters
Further advances:		Superselective arteriography Pharmacoangiography Stereoangiography Magnification techniques Electronic optimization of angiograms Color subtraction Therapeutic use of visceral angiography

Still, the breakthrough to clinical application did not occur until after the routine use of visceral angiography by the Radiodiagnostic Department of the University Clinic in Lund, Sweden, by OLLE OLSSON and his associates. The technique elaborated by his department was not only adopted by the other Scandinavian clinics but found acceptance throughout the world; it has also influenced the premises underlying this book.

Nevertheless, the technique would not have developed into a routine radiologic procedure had the equipment technology failed to keep pace. It took serial film changers, TV image-amplifying fluoroscopy, cinematography, and video tape recorders to make this success possible. The same is true of the development of less toxic contrast media which do not provoke adverse reactions except in very rare instances.

Countless authors, building systematically upon the state of the art attained, have proposed further improvements and modifications. These pertain to instrumentation, fluoroscopic and intensification techniques, photography, programming, access routes, and pharmacologic management, and, in no small measure, too, evaluation of angiograms by subtraction and color subtraction.

Abdominal angiography was given a further decisive impetus by radiologic research, which achieved significant advances in pharmacoangiography and in the study of tumors, hemorrhages, states of shock, and traumatic changes.

The following pages will report on the evolution to date and on the procedures followed at a clinic which has liberally fostered visceral angiography from the very start.

II Radiologic Anatomy of Abdominal Blood Vessels

The dominant vessel in the abdominal cavity is the abdominal aorta with its branches. Its diagnostic significance far surpasses that of the veins, including the portal vein. However, under certain circumstances, even these vascular regions may become important diagnostic routes as, for example, in portal hypertension (Fig. 1,2)[1].

1 Abdominal Aorta

In the absence of pathologic changes of the vascular wall, the abdominal aorta is a taut, smooth-walled vessel which drains rapidly and is, therefore, on occasion seen in poor contrast on the angiogram. Its branches arise at an acute angle and collaterals develop sparingly or not at all.

The caliber of the abdominal aorta decreases distally. In the adult, it averages 1.5 cm, but it may be as wide as 4 to 5 cm in the elderly (Fig. 10).

MERCIER and VANNEUVILLE (1968) draw a distinction between a "rectilinear" and a "sinuous" type, which they associate with a variety of vascular diseases in the aged. The numerous curves of the abdominal aorta continue into the pelvic arteries and are referred to as "kinking" in the Anglo-American literature (Figs. 22, 23). In these tortuous segments of the vessel, the flow rate of the blood is reduced, which not infrequently results in aortograms of particularly high contrast. As a rule, the angle of bifurcation is obtuse and numerous collateral vessels can be visualized. These are particularly marked in the presence of stenosis or occlusions.

The course of the abdominal aorta in relation to the vertebral column is of very special significance for lumbar aortography. The two French authors just cited found the abdominal aorta located medially in front on the vertebral column in 44% of cases, to the left alongside the column in 50% of cases, and to the right in just 6%. These data, however, are applicable only to a non-scoliotic lumbar column. In the presence of pronounced axial deviations—notably in kyphosis—the abdominal aorta will often extend in tendon fashion across the curvature, as exemplified in Fig. 98.

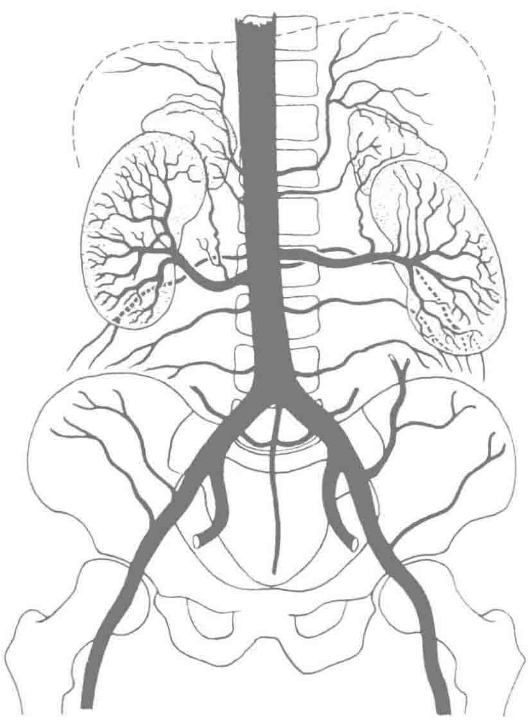
The level of the bifurcation is of special interest with regard to any direct puncture of the aorta, since variations are far from uncommon. According to PATURET (1951), the bifurcation is located at the level of the lower third of the fourth lumbar vertebra in 70% of all cases; less frequently it is at the level of the fifth lumbar vertebra (low bifurcation) or the upper third of the fourth lumbar (high bifurcation). In relation to the promontory, it may be assumed to be located 6 cm cranially. In three of our own patients, we observed an aortic bifurcation at the level of the third lumbar vertebra, so that for lumbar aortography, with the needle in typical position, iliac puncture proved possible at the level of the third or fourth lumbar vertebra.

While the angle of bifurcation is normally about 70 degrees, it may be different if the aorta and the pelvic arteries follow a tortuous course. With the so-called eccentric sinuous type (MERCIER and VANNEUVILLE, 1968) especially, angles between 10 and 20 degrees may be observed or, at the other extreme, nearly rectangular bends. Occasionally, they represent an insurmountable obstacle to passage of the catheter through the femoral artery. Experience has shown that access from the left pelvic artery is generally less difficult than from the right.

1 Figs. 1–183 appear at the end of the text, on p. 115, beginning with the color photographs, in a separate section of illustrations.

1.1 Symmetric Branches of the Abdominal Aorta

The first pair of symmetrical branches to arise from the abdominal aorta, just below the diaphragm, is composed of the right and left phrenic artery, at the level of the twelfth thoracic vertebra, just above the celiac trunk. Both arteries follow a steep craniolateral course. Two to three branches are distributed in the concavity of the diaphragm. Not infrequently, both arteries arise from a common trunk; they invariably give off branches to the adrenal glands (superior adrenal arteries).



Symmetric aortic branches on angiogram

The middle adrenal arteries arise directly from the aorta, whereas the inferior branches to the adrenal glands generally arise from proximal portions of the renal arteries. However, in this area variations are exceedingly common.

The renal arteries themselves arise somewhere between the level of the twelfth thoracic vertebra and the second and third intervertebral disks. In the great majority of cases, they arise between the first and the second lumbar vertebra.

MERKLIN and MICHELS (1958) examined more than 11 000 kidneys and found one renal artery on each side in 72% of the cases, while in the remaining 28% of the kidneys there were multiple renal arteries, usually bilaterally. The symmetrically disposed metameric lumbar arteries arise mostly from the posterior or lateroposterior aspect of the abdominal aorta at the level of each lumbar vertebra; they usually extend no further than $^1/_2$ to 1 cm lateral to the margin of the psoas muscle, but they first give off branches to the spinal canal.

The spinal cord below C4 or C5 is supplied via the branches of the intercostal, lumbar, and sacral arteries, as well as by numerous anterior radicular arteries of varied configuration. The lowest radicular artery is nearly always the one with the largest caliber and is, therefore, also called the greater radicular artery (or Adamkiewicz artery). Its origin varies irregularly between D8 and L3, but more commonly between D9 and D11. Injury to this artery usually leads to severe neurologic disturbances, and for this reason special attention should be paid to this region in lumbar aortography as well as in selective explorations.

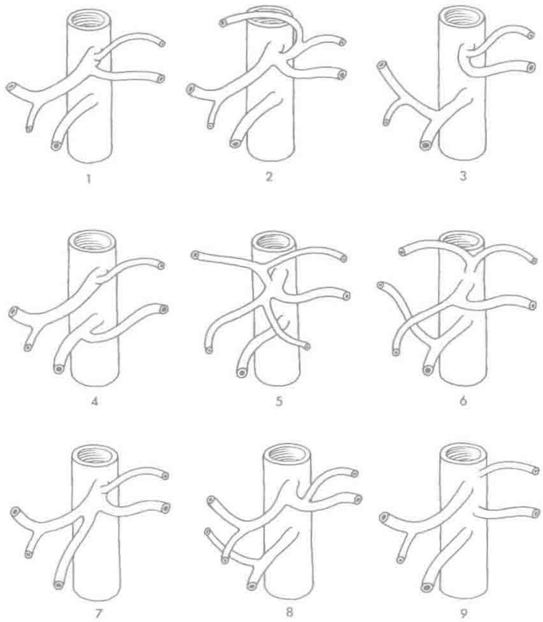
1.2 Visceral Branches of the Abdominal Aorta

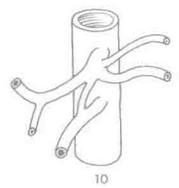
1.2.1 Celiac Trunk

The first visceral branch of the abdominal aorta is the celiac trunk, arising just below the diaphragm, mostly at the level of the twelfth thoracic to first lumbar intervertebral disk. It arises ventrally and typically divides into three large branches: the hepatic, the splenic, and the left gastric artery (Fig. 24). Of all the visceral arteries, these show the most common anatomic variations and the most numerous anastomoses with other visceral and systemic arteries.

In 1965, BOIJSEN and associates catalogued the major variants involving the celiac trunk which in 2% of the cases (PATURET, 1951) shares a common origin with the superior mesenteric artery, forming the celiac-mesenteric trunk.

Generally, the trunk measures no more than a few cm in length, arises from the aorta at an acute angle of about 20°, initially keeps close to the anterior aspect of this vessel and





Normal variations of the celiac trunk, the superior mesenteric artery and its branches (according to BOIJSEN, 1965).

1. Normal branching of celiac trunk to the left into the left gastric artery (top) and the splenic artery (bottom). To the right is the common hepatic artery, which continues upward and laterally into proper hepatic artery and downward into the gastroduodenal artery. Caudal to the celiac trunk lies the superior mesenteric artery.
2. The left hepatic artery arising from the left gastric artery.
3. The common hepatic artery arising from the superior mesenteric artery.
4. Splenic artery arising from the superior mesenteric artery.
5. Middle colic artery arising from the celiac trunk.
6. Isolated origin of left gastric artery and left hepatic artery from the aorta. Right hepatic artery arising from superior mesenteric artery.
7. Celiac-mesenteric trunk.
8. Right hepatic artery arising from superior mesenteric.
9. Isolated origin of all celiac branches from aorta. No trunk.
10. Shunt between celiac trunk and trunk of superior mesenteric artery via dorsal pancreatic artery.

courses in a caudal direction, mostly somewhat to the right. In the adult, its caliber varies between 5 and 8 mm.

Instead of all three of these major branches sharing a common origin, the splenic and hepatic arteries alone may arise from a common trunk, while the left gastric artery arises separately from the aorta (as in 10% of cases examined by PATURET, 1951).

Angiographic differentiation of the trunk in an anteroposterior projection is extremely difficult because it appears punctiform if it follows a precise dorsoventral course and is largely concealed by the aorta when slightly inclined unless the examination is carried out in a selective manner. This explains why it is virtually impossible to visualize a stenosis of the celiac trunk except in lateral projection.

The branches arising from the trunk will be discussed when reference is made to the specific organs. They supply the major epigastric organs as well as the stomach and the duodenum.

1.2.2 Superior Mesenteric Artery

This artery, called "grande mésenterique" by the French, supplies by far the largest portion of the intestine (Figs. 2, 25), and is derived from the omphalomesenteric artery of the fetus.

It originates on the anterior aspect of the abdominal aorta, just below the celiac trunk —approximately at the level of the isthmus of the pancreas—is generally situated within the range of the upper third of the first lumbar vertebra, and has a caliber of 8–10 mm in the adult. It runs for a distance of 3 cm in a vertically caudal direction, then deviates from the aorta toward the uncinate process of the pancreas and along the ascending portion of the duodenum, and upon reaching the mesentery divides into numerous branches.

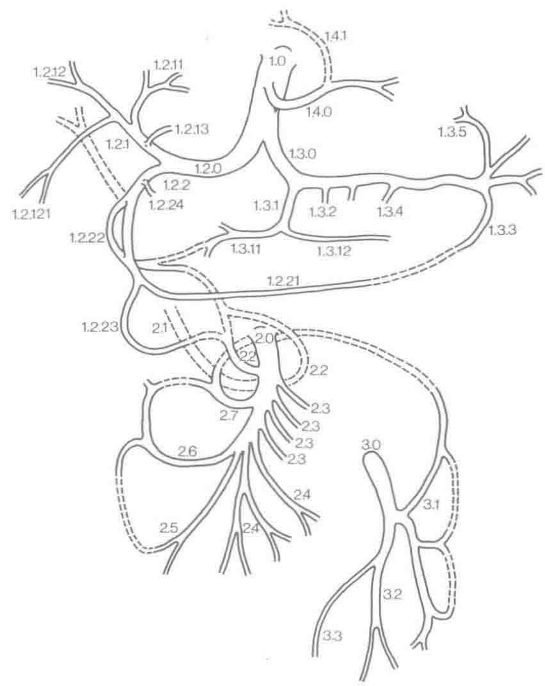
The anatomic location of the superior mesenteric artery also depends on the position of the spinal column. As a rule, the vessel runs left or right of the aorta, usually curving slightly to the right. Among the individual branches arising from the superior mesenteric artery, the retropancreatic segment lying close to the aorta is almost never identifiable in the angiogram. Collateral vessels in this area are inconsequential. The first ramifications ventral to the pancreas include the two pancreatico-duodenal arteries, the most important connecting passages to the celiac trunk, and the first two jejunal arteries. The right colic artery—the only one branching off to the right—is the first one to originate within the mesentery. On the left, another four to five jejunal and ileal branches extend to the small intestine. Between them and the ileocolic artery lies an area of peculiarly low vascularization.

Viewed laterally, there is an angle of 30–50° between the trunk of the superior mesenteric artery and the aorta, which plays an important role in arteriomesenteric compression of the duodenum.

Particular mention should be made here of the anastomosis between the right and left colic arteries which runs on a virtually horizontal plane from the right to the left side and assumes vital significance when one of the two mesenteric arteries is occluded; when this happens, its caliber increases considerably, and a so-called Riolan anastomosis is produced.

1.2.3 Inferior Mesenteric Artery

This artery, which supplies the left colon only, likewise arises from the ventral aspect of the abdominal aorta, 7 to 8 cm below the superior mesenteric and 4 to 5 cm above its bifurcation (Figs. 2, 26). Projected in relation to the lumbar column, its point of origin lies at the level of the lowest segment of the third lumbar vertebra, corresponding to the inferior (horizontal) part of the duodenum. In the aortogram, its origin may be found anywhere between the second and the fourth lumbar vertebrae. Its course nearly always slants downward to the left, so that in anteroposterior aortography its origin is even more difficult to discern than it is in the case of the superior mesenteric artery. The trunk of the vessel has an average length of 3.5 cm and a caliber averaging 5 mm. However, both the length and the caliber are subject to considerable variation. Its major branches are the left colic artery communicating with the right colic artery via RIOLAN's anastomosis; more distally, the sigmoid artery; and lastly, the superior hemorrhoidal artery, a particularly long vessel branching off at the level of the fifth lumbar vertebra and descending to the rectum. This branch forms anastomoses with the middle sacral artery, which arises directly from the bifurcation of the aorta, as well as with the inferior hemorrhoidal artery, hence the internal iliac artery.



1.3 Nomenclature of Arterial Branches of Celiac Trunk and Mesenteric Arteries

(as proposed by RÜTTIMANN and BEELER, 1970)

1.0	*Celiac trunk*
1.2.0	Common hepatic artery
1.2.1	Proper hepatic artery
1.2.11	Left branch of proper hepatic artery
1.2.12	Right branch of proper hepatic artery
1.2.121	Cystic artery (in 75% of cases) Variant of 1.2.2 or 2.1
1.2.13	Right gastric artery
1.2.2	Gastroduodenal artery
1.2.21	Right gastroepiploic artery (anastomosing with 1.33)
1.2.22	Posterosuperior pancreaticoduodenal artery (forming an arcade with 2.2)
1.2.23	Anterosuperior pancreaticoduodenal artery (forming an arcade with 2.2)
1.2.24	Supraduodenal branches
1.3.0	Splenic artery
1.3.1	Dorsal pancreatic artery (anastomosing in 5% of cases with 1.0 and 2.0)

1.3.11	Right branch of dorsal pancreatic artery (forming KIRK's arcade with 1.2.23)
1.3.12	Transverse pancreatic artery (variant of 2.0, 1.2, 1.2.2)
1.3.2	Pancreatic branches
1.3.3	Left gastroepiploic artery (anastomosing with 1.2.21)
1.3.4	Arteria pancreatica magna
1.3.5	Short gastric artery
1.4.0	Left gastric artery
1.4.1	Left hepatic artery
2.0	*Superior mesenteric artery*
2.1	Right hepatic artery (variant in 25% of cases)
2.2	Inferior pancreaticoduodenal artery
2.3	Jejunal arteries
2.4	Ileal arteries
2.5	Ileocolic artery
2.6	Right colic artery
2.7	Middle colic artery
3.0	*Inferior mesenteric artery*
3.1	Left colic artery
3.2	Sigmoid artery
3.3	Superior rectal (hemorrhoidal) artery

2 Inferior Vena Cava

The inferior vena cava is formed by the confluence of the right and left common iliac veins at the level of the lower margin of the fourth lumbar vertebra. The confluence is situated caudad and to the right of the aortic bifurcation. In cranial direction, the inferior vena cava follows the aorta on the right side up to the level of the second lumbar vertebra, where it deviates ventrally and to the right leading into the foramen of the vena cava within the diaphragm (Fig. 31).

Along its path, the vena cava is in close contact with the right side of the lumbar column, the root of mesentery, the sympathetic trunk, the head of the pancreas and adjoining duodenum, as well as the right kidney and adrenal gland.

Inasmuch as the portal vein carries the blood of the entire gastrointestinal tract and the spleen into the liver, only the hepatic veins, being unpaired, open into the inferior vena cava within or just below the diaphragm. The paired roots of these hepatic veins match the configuration of the aortic branches to the gastrointestinal tract.

A lengthwise anastomosis connecting the four lumbar veins is known as the ascending lumbar vein. It derives from the common iliac vein and ascends in the iliopsoas muscle to the side of the lumbar column in a craniad course. From the abdomen, each ascending lumbar vein runs through a cleft in the medial crus of the diaphragm into its thoracic continuation as the azygos and hemiazygos vein.

3 Portal Vein

The portal vein arises behind the head of the pancreas by the union of its three roots: the superior and inferior mesenteric veins and the splenic vein (Fig. 32). Behind it lies the inferior vena cava in the retroperitoneal cavity. Craniad, the portal vein is crossed ventrally by the superior portion of the duodenum and so reaches the hepatoduodenal ligament; close to the porta hepatis it divides into the right and the left branch.

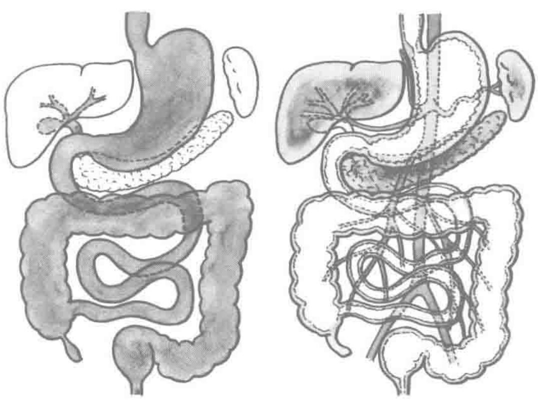
The tributaries of the portal vein in this region are small veins, such as the gastric veins, and, in the immediate vicinity of its bifurcation, the cystic vein. In addition, minute paraumbilical veins coursing alongside the obliterated umbilical vein in the ligamentum teres hepatis drain into the portal venous system of the liver.

III Angiographic Technique

1 Basic Considerations

For the patient, angiography is invariably a stressful procedure owing to both the manipulation of the vascular system and the injection of a contrast medium. Discriminating use of the technique is, therefore, imperative. It is indicated only in situations in wich less drastic measures prove diagnostically or therapeutically unsatisfactory.

The conventional examination of the gastrointestinal tract with a barium meal permits visualization of the interior surface of the lumen but provides no information about the bowel wall or the interior of parenchymatous organs. Angiography, on the other hand, makes it possible to visualize the intestinal wall itself, to collect information about the major abdominal organs and, last but not least, to visualize the vascular network down to its smallest ramifications.



Therefore, the first prerequisites for angiography are consultation with the referring physician, familiarity with clinical and laboratory test data previously obtained, and a critical review of available x-ray studies (plain films, upper GI series, barium enema, cholecystography, and excretory urography).

As a rule, these examinations provide little, if any, information about the abdominal vascular system, with the exception of readily defined, dense soft-tissue "tumors" in the presence of a circumscribed aneurysm of the abdominal aorta, or widening of the aortal segment extending from the thorax into the abdomen in dissecting aneurysm, which may sometimes be visualized even more readily by tomography.

Calcium deposits in Mönckeberg's medial sclerosis, arteriosclerosis, aneurysms, and angiomas at times produce impressive findings.

We should mention, in particular, the recurrent finding of calcified deposits within the splenic artery, recognizable by its typically tortuous course, which are revealed by the contrast medium. Not infrequently, there is a marked disproportion between the spherically disposed calcific shells of the outer strata of an aneurysm—ranging up to a child's head in size—and the often extremely narrow, open internal lumen which is evaluable only by contrast radiography.

2 Patient Preparation and Contraindications

Just as the anesthetist makes his rounds on the eve of the operation, the radiologist, too, should examine the candidate for angiography beforehand and plan his strategy in advance.

In the final analysis, it is the condition of the peripheral vessels which determines the best possible access route. The same applies to the pelvic veins or to a projected splenoportography (determination of size and position of spleen).

A calm and factual explanation to the patient is of considerable importance for the success of the angiographic examination. Even children that are shown how to follow the procedure on the TV screen become cooperative partners in angiography. We try in every case